Assessment of Antioxidant Potential of Four Selected Leafy Vegetables and Development of Herbal Drinks for Intestinal Health

A
Thesis Submitted
in Partial Fulfillment of Requirements
for the Degree of

DOCTOR OF PHILOSOPHY

BY

ESHA BALA

School of Agro and Rural Technology
Indian Institute of Technology Guwahati
Guwahati - 781039, India

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CERTIFICATE

This is to certify that the thesis entitled "**Assessment of Antioxidant Potential of Four Selected Leafy Vegetables and Development of Herbal Drinks for Intestinal Health**" submitted by Miss Esha Bala, a research scholar in the *School of Agro and Rural Technology, Indian Institute of Technology, Guwahati*, for the award of the degree of Doctor of Philosophy, is a record of an original research work carried out by her under the supervision and guidance of Dr. Siddhartha Singha and Prof. Sanjukta Patra. The thesis has fulfilled all the requirements as per institute regulations. The research embodied in the thesis has not been submitted anywhere for the award of any degree.

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DECLARATION

This is to certify that the thesis entitled "**Assessment of Antioxidant Potential of Four Selected Leafy Vegetables and Development of Herbal Drinks for Intestinal Health**" submitted by me to the *Indian Institute of Technology, Guwahati*, for the award of the degree of Doctor of Philosophy, is a bonafide work carried out by me under the supervision of Dr. Siddhartha Singha and Prof. Sanjukta Patra. The content of this thesis has not been submitted to any other University or Institute. I also wish to state that experimentation, characterization, validations and data presented in my thesis were performed by me with due verification.

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Guwahati **Ms. Esha Bala**

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Abstract

In order to find out dietary interventions against growing lifestyle diseases especially linked to gastrointestinal tract, a product development strategy from leafy vegetables was attempted that will deliver physiologically relevant antioxidant and prebiotic activity. In the present study, three hundred ten leafy vegetables have been documented, covering their nutrients and bioactive components, culinary usage, and health benefits recorded in ethnobotanical surveys. It was noticed that the perceptive health benefits recorded in ethnobotanical surveys are often vague and need to be converted to a universally accepted code (like the International Classification of Primary Care Code of WHO) to claim a specific leafy vegetable/plant as a curative/preventive agent for a particular disorder/disease. Though many leafy vegetables have been reported for oxidative stress-related diseases localized in the gastrointestinal tract, such claims require further validation. A theoretical study of thirty-four leafy vegetables enlisted in Indian Food Composition Tables (NIN) implied that the concentration of polyphenols in such plants is in mM range. Hence, they may not cause enough concentration of the polyphenols in the blood plasma to impart health benefits, especially when consumed in whole form or composite meal. However, they may have significant local effects on the small and large intestine. An *in-silico* study identified that many microbial enzymes could transform undigested polyphenols and may play an important role in intestinal homeostasis.

Moreover, a detailed review of leaf-polysaccharides and oligosaccharides has shown cell wall-derived polysaccharides and a few other poly-/oligo-saccharides from leafy vegetables have promising prebiotic, immunostimulatory, and antioxidant activity. The theoretical analysis indicated that the herbal decoction or infusion kind product (beverages, soups, curries, kadha, etc.) is a good dietary mode for delivering bioactive compounds with several health benefits. In this study, to develop beverages from leafy vegetables with antioxidant potential, on one side, an effective cell level antioxidant assay was developed, and on the other side, beverages were developed from four selected herbs; *Centella asiatica, Eryngium foetidum, Enhydra fluctuans* and *Marsilea minuta* and validated for their sensory and antioxidant property.

Stationary phase wild (EG103) and SOD double mutant (EG133) strains of *Saccharomyces cerevisiae* were confirmed to be a suitable cell model for studying oxidative stress and antioxidant activity of a target antioxidant molecule/extract by checking seven cellular parameters; CFU, spot assay, the enzymatic activity of CAT, SOD, GPx, and GR and concentration of total GSH and reduction capacities or free radical scavenging capacities viz., IRP, ARSA, and LPOX. 5 mM H_2O_2 was the appropriate level of stress in case of resting cell of the yeast strains to study antioxidant assay. Also, cell viability (CFU) was also found to be a simple and reliable marker for such assay, and other cellular parameters supported the CFU trend. To retain the bioactive molecules of selected leafy vegetables, their processing conditions are to be standardized with a suitable drying and extraction process. The study also revealed that microwave drying was equivalent to 105°C oven drying for moisture content determination. Microwave drying was found to be an effective drying process for converting leafy vegetables into herbal beverages with high antioxidant activity.

Since the sensory appeal is an essential criterion to prefer a beverage, sensory evaluation was done for the decoction and infusion products from all four selected herbs. Infused and decoction beverages of *Centella asiatica* were found to be more promising than the other three products. This study revealed 10% Khasi mandarin (*Citrus reticulata*) peel blended with *Centella asiatica* powder could improve the taste and flavour of the resultant infused beverages. Owing to the hygroscopic nature, the physicochemical and sensory properties of *Centella asiatica* powder tends to change during storage condition. One month of accelerated storage study revealed that the water activity and moisture content of the powder was in allowable limits (respectively 0.28 and 0.63% in db). A combination of high relative humidity (82%), temperature (45ºC), and UV could influence the antioxidant activity of the herbal beverages. The LPOX activity value was particularly sensitive, exhibiting at least half degradation time ($t_{1/2}$). The *in vitro* antioxidant activity change during the accelerated storage study of *Centella* blended beverages suggested appropriate packaging is required for storing them and open storage may decrease the antioxidative potential significantly.

Finally, the potential antioxidant and prebiotic properties of two ready-to-serve beverages from *Centella asiatica* (CABs; decoction and infusion) were further studied. In this study, partial chemical characterization of the small molecule (ethanol soluble) and polymeric (ethanol precipitated and TCA precipitated) fractions of CABs were investigated. Fifty-two compounds with known records of antioxidant or anti-inflammation effects were identified in both beverages. All three fractions of the two beverages had reducing capacity and free radical scavenging ability. The *in vitro* antioxidant capacity of both the beverages and their individual fractions were further confirmed in H_2O_2-stressed *Saccharomyces cerevisiae* models. However, the lipid peroxidation lessening ability was only observed in the small molecule fractions. The results suggested different types of molecules in the beverages can work via multiple mechanisms to reverse the oxidative stress in cells. In a separate experiment, both beverages could significantly retard the growth of the gastrointestinal pathogen *Bacillus cereus*.

On the other hand, the CABs could promote the growth of a well-known probiotic strain *Lacticaseibacillus rhamnosus* ATCC 53103, when tested individually and when grown together with *B. cereus*. These findings suggest that the beverages balance antioxidant status and maintain the quantity and diversity of microbiota to protect intestinal health. Additionally, a theoretical framework has been put forward to highlight the possible sites of the intestine where an herbal beverage can prevent and cure some intestinal diseases.

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List of Abbreviations

Abbreviations	Definitions
LV	Leafy Vegetables
CF	Crude Fibre
SDF	Soluble Dietary Fibre
ISDF	Insoluble Dietary Fibre
BDM	Bone dry mass
IBD	Inflammatory Bowel Diseases
SIBO	Small Intestinal Bacterial Overgrowth
LD	Lifestyle Diseases
CAGR	Compound Annual Growth Rate
IBS	Irritable Bowel Syndrome
CRC	Colorectal Cancer
GI	Gastrointestinal
ICPC	International Classification of Primary Care
NIN	National Institute of Nutrition
IFCT	Indian Food Composition Tables
ROS	Reactive Oxygen Species
CuZnSOD (SOD1)	Copper, zinc superoxide dismutase (cytosolic and mitochondrial intermembrane space-localized isoform of superoxide dismutase)
MnSOD (SOD2)	Manganese superoxide dismutase (located in mitochondrial matrix)
EG103	Wild type *Saccharomyces cerevisiae*
EG133	Sod mutant strain *Saccharomyces cerevisiae*
YPD	Yeast Extract–Peptone–Dextrose
EDTA	Ethylenediaminetetraacetic acid
DTNB	5,5'-dithiobis(2-nitrobenzoic acid)
PBS	Phosphate Buffer Saline
S.E.	Standard Error

BCA	Bicinchoninic acid
GR	Glutathione reductase
CAT	Catalase
GPx	Glutathione peroxidase
SOD	Superoxide dismutase
ABTS	2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)
FRAP	Ferric Reducing Antioxidant Power
FRP	Folin's reducing power
IRP	Fe^{3+} Reducing power
ARSA	ABTS radical scavenging activity
LPOX	Lipid peroxidation
TPC	Total Phenolic Content
TFC	Total Flavonoid Content
GSH	Glutathione
GAE	Gallic acid
AA	Ascorbic Acid
TE	Trolox
MDA	Malondialdehyde
CA	*Centella asiatica* (Asiatic pennywort or Gotu Kola)
ENF	*Enhydra fluctuans* (Buffalo Spinach or Marsh herb)
EGF	*Eryngium foetidum* (Culantro or Mexican coriander)
MN	*Marsilea minuta* (Water Clover)
LOD	Loss on Drying
MC	Moisture content
EMC	Equilibrium Moisture Content
FSSAI	Food Safety and Standards Authority of India
FAO	Food and Agricultural Organization
OECD	Organisation for Economic Co-operation and Development
AOAC	Association of Official Analytical Collaboration
ISO	International Organization for Standardization
AOCS	American Oil Chemists' Society
OD	Oven (105°C) dried
TD	Tray (50°C) dried

MW	Microwave (720W) dried
FD	Freeze (-40°C) dried
a_w	Water activity
CW	Continuous wave
LDPE	Low Density Polyethylene
RH	Relative Humidity
PC	Pearson Correlation
ED	Euclidean Distance
CABs	*Centella asiatica* beverages
WB	Whole Beverage
EF	Ethanolic soluble fraction
EPPF	Ethanolic precipitated polysaccharide fraction
TPPF	TCA precipitated protein fraction
TCC	Total Carbohydrate Content
RS	Total Reducing Sugar
TSP	Total Soluble Protein
BSA	Bovine Serum albumin
RAAI	Relative antioxidant activity index
GAAI	Global antioxidant activity index
LR	*Lacticaseibacillus rhamnosus*
BC	*Bacillus cereus*

List of Notation

Notation	Definitions	Units
μ	Specific Growth Rate	per hour
t	Time	Hour or minutes
CFU	Colony Forming Unit	cells/mL
f.w.	Fresh weight	g/g; kg/kg
d.b.	Dry basis	mg/g or mg/100g
d.c.w.	Dry Cell Weight	mg/mL
d.w.	Dry Weight of Leaves Powder	mg/g
U	Enzymatic Activity	U/mg of protein
D_{eff}	Effective Diffusivity	m^2/s
PPO	Polyphenol Oxidase	U/mg of protein
r	Pearson Correlation	dimensionless
	Spearman	
d	Euclidean Distance	dimensionless
ΔE^*	Color Difference	dimensionless
t_{lag}	Lag time	hour
t_{mid}	Mid exponential phase at time t	hour
t_{max}	Stationary phase at time t	hour
$t_{1/2}$	Half degradation time	days

Chapter 1

Introduction, Background and Objectives

Chapter 1

1. Introduction

Many developing nations are suffering from health issues related to improper lifestyles. The situation is complex when such diseases spread among the population living in rural and remote areas. The lack of basic healthcare facilities is a hallmark of most rural places. Chronic disorder is a concern to rural healthcare structures and residents due to its impact on productivity, mortality, and local economies. Around 10% of people in rural areas have no access to fundamental medical facilities. This increasing LD burden needs dietary strategies to prevent and treat such diseases. Chronic disease occurrence and outcomes vary between urban and rural populations. The rural population is more susceptible to higher degrees of risk due to chronic ailment compared to city dwellers with greater productivity loss and mortality rates. Lifestyle diseases (LD) such as digestive diseases, cardiovascular diseases, cancer, persistent lung diseases, and diabetes are increasing alarmingly. They are the primary cause of human loss in India and globally (Jana & Chattopadhyay, 2022; WHO, 2018). Multiple clinical trials have established a strong connection between sufficient intake of fruits and vegetables (FVs) and reduced hazard of hypertension, coronary heart disease, and stroke (WHO, 2022).

Unfortunately, most people in many developing and underdeveloped countries do not get the recommended supply of FVs of 400 g per capita per day. On top of that, the cost of commercially promoted FVs is out of reach of a significant number of people. The emergence of high-yield fruits (bananas, apples, citrus fruits, grapes, etc.) and vegetables (tomatoes, chilies, lettuce, cucumbers, potato, onions, etc.) have decreased the food diversity available to ordinary people. In rural India, the reported per-head consumption of fruits and vegetables was 145 and 15 g, whereas the same in urban India was 155 and 29 g (Minocha et al., 2018). The same study highlighted that the major fruit consumed was banana, and the major vegetable consumed was potato in the country. More research is needed on nutrient/bioactive composition, production, processing, and assimilation of indigenous and underutilized fruits and vegetables to supply adequate quantity and quality of nutrition to the ailing global population. In this context, leafy vegetables (LVs) are often an ignored class of vegetables instead of being a rich source of micronutrients and bioactive compounds.

1.1. Literature Review

1.1.1. Nutritional potential of different leafy vegetable varieties

Ethnic populations use about 3,900 plant species as food; out of these, 145 species comprise root and tubers and 521 leafy vegetables (Neugart et al., 2017). They are rich sources of provitamin A, vitamin C, and minerals like calcium, iron, phosphorus, and dietary fibre (Ajayi et al., 2020; Dhakar et al., 2011; Nazmul et al., 2013). Nutrients of twelve LVs have been collected from different research work and listed in Table 1.1. It has been found that *Amaranthus viridis > Marsilea minuta > Chenopodium album > Urtica dioica > Diplazium esculentum > Murraya koenigii > Moringa oleifera* can be considered carbohydrate-rich leaves due to their relatively high carbohydrate content. The diverse range of carbohydrate present in the leaf matrix upon hydrolysis, either mechanically (chewing) or enzymatically (e.g., amylase), release nutrients such as carbohydrates, proteins, fat, and minerals (Fig. 1.1).

The protein content of the leaves varied between 8-33.8%. LVs like *Nasturtium officinale* (33.8%), *Diplazium esculentum* (31.2%), *Urtica dioica* (28.5%), *Marsilea minuta* (24.9%), *Moringa oleifera* (24.4%), *Chenopodium album* (23%) cannot be ignored as a dietary protein source. LVs can accumulate high amounts of minerals which are reflected in their ash content (10-24%) (Table 1.1). The values of the crude fat for the leaves ranged from 0.81% (*Nasturtium officinale*) to 8.3% (*Diplazium esculentum*). The crude fibre content is highest in *Moringa oleifera* (27.1%) and lowest in *Nasturtium officinale* (1.05%) compared to other leaves. Vegetable with high fibre is essential in the diet to control obesity, diabetes, and cancer (Meckling, 2006).

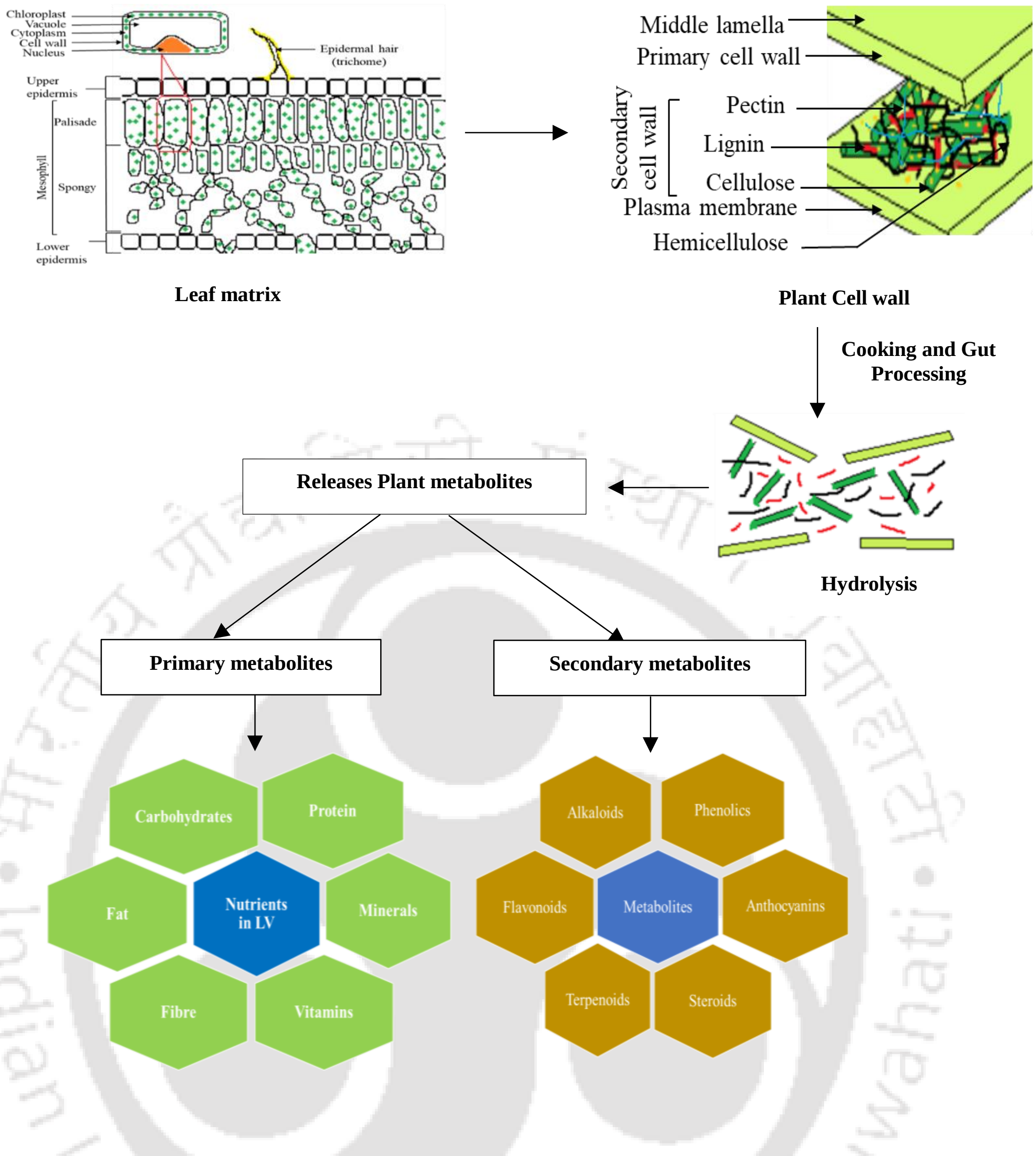

Fig. 1.1 Nutrients and phytochemical classification in plant cell

1.1.2. Effects of processing or cooking on leafy vegetables

During domestic cooking, leafy vegetables are generally processed through thermal treatment such as boiling, steaming, frying, and microwaving (Fig. 1.2). Vegetable cooking significantly changes the chemical composition and the bioavailability of the bioactive compounds (Table 1.2). Cooking affects membrane disruption, loss of turgor, and reduction of cell adhesion strength, which will lead to loss of firmness or softening. However, such changes are varied and have both positive and negative effects. The changes brought by cooking treatment mainly depend on the cooking method, length of heating time, and the type of vegetable.

Morales and Babbel, (2002) suggested four possible reasons for the increase in the antioxidant activity of vegetables after cooking:

1) the liberation of high amounts of antioxidant components due to the thermal destruction of cell walls and sub-cellular compartments,
2) the production of more potent radical-scavenging antioxidants by thermal chemical reaction,
3) thermal inactivation of oxidative enzymes,
4) producing new non-nutrient antioxidants or forming novel compounds such as maillard reaction products with antioxidant activity.

Fig. 1.2 Types of cooking process

1.1.2.1. Boiling

Leafy vegetables are cooked mainly through boiling to make them tender and palatable. This process predominantly modifies the physical and chemical properties of the food matrix. The boiling time and its processing condition depend on the type of vegetables and preferably on the consumption pattern. During boiling, leaching changes the quantity and quality of bioactive molecules in vegetables which affects their antioxidant potential (Podsędek et al., 2008). For example, in spinach, boiling increases the phenolics, β-carotene and lutein content (Mazzeo et al., 2011; Rani & Fernando, 2016). Some studies reported that boiling increases the water-soluble polyphenol compounds by 81% higher than raw spinach (Ng et al., 2011). Similarly, reports were found in the Brassica family, water spinach, and moringa (Thi & Hwang, 2015; Subramaniam et al., 2017; Subudhi et al., 2014), but an increase in β-carotene was observed in basil, pak choi, sweet potato leaves, and coriander leaves. Gehse et al. (2018) observed that in vegetables bioavailability of carotenoids increases in short boiling time <10 min. The bioavailability increases due to the release of absorbable phenolics like aglycones from flavonoid conjugates, inactivated oxidizing enzymes of carotenoids, and disruption of the carotenoid-protein complexes (Moyo et al., 2020; Thi & Hwang, 2015; Kao et al., 2012; Sultana et al., 2008).

1.1.2.2. Steaming

This method is a safer method for water-soluble polyphenolic compounds because during steaming the food materials are not in direct contact with boiling water. It softens the food matrix to extract bioavailable compounds and enhance the digestibility of fundamental nutrients without leaching of soluble nutrients and bioactive compounds. In the case of *Centella asiatica,* the concentration of polyphenols and flavonoid increased but that of carotenoids decreased during 5 minutes of steaming (Prasanna et al., 2018). The phenolic contents of spinach enhanced during steaming (Mazzeo et al., 2011; Turkmen et al., 2005). The study on spinach by Mazzeo et al. (2011) and Eriksen et al. (2016) discussed that β-carotene decreases; however, polyphenolic and flavonoid increased by 34 and 25%, respectively, during steaming.

1.1.2.3. Frying

Frying is one of the oldest processing techniques in the food industry and house kitchens (Zeb, 2019). The organoleptic properties change during frying. Numerous techniques of frying are available; pan, shallow, and deep-fat frying. Food is exposed to boiling oil during frying at 160-180 °C, which leads to drying and other physical and chemical changes (Banerjee & Saha, 2017). During the frying of leafy vegetables, the lipid-soluble phenolic compounds inhibit the formation of thermal-oxidative compounds like acrylamide and heterocyclic amines in frying oil (Cheng et al., 2010). It has a two-way relationship; this process increases the stability of the frying oil as well as enhances the antioxidant potential of the leafy vegetables. For example, Zeb and Habib, (2018) confirmed an increase in phenolic acids in fried LVs, such as chlorogenic acid, coumaric acid derivatives, caffeic acids, and caffeoyl hexose of *Nasturtium officinale*. However, compounds such as quinic acids (caffeoyl feruloyl quinic acid, 5-caffeoylquinic acid, 4-feruloyl quinic acid, 3,4-di-caffeoylquinic acid, 4-caffeoylquinic acid) and hydroxycinnamic acid (sinapic acid derivative) decreased during the frying process. Phenolic compounds can be affected by frying positively or negatively depending on the LV variety and the frying condition. (Prasanna et al., 2018).

1.1.2.4. Microwave drying

Microwave drying is a promising processing method due to its ease and faster rate (Salazar-González et al., 2012; Zhang et al., 2006). Furthermore, microwave drying would possibly have much less impact on food flavour and nutritional qualities in contrast to different traditional cooking techniques including drying (Vadivambal et al., 2010; Turkmen et al., 2005). Some reports have confirmed that glucosinolate and other nutritional content of Brassica leaves remained unchanged in microwave drying (Song & Thornalley, 2007). Ötles & Çagindi, (2007) reported that carotenoid content was reduced but its bioavailability increased during microwaving.

1.1.3. Bioactive components of leafy vegetables and their possible health benefits

Bioactive components and the possible health benefits of twelve leafy vegetables were collected from several published literature and tabulated for review (Table 1.3). It was obvious that these bioactive were part of secondary metabolism and varied in diversity and quantity from one species to another (Ankanna et al., 2012). The antioxidant property or ROS reduction capacity of such polyphenols might be vital for many plant products' anti-inflammatory, antiaging, and anti-proliferative properties (Pandey & Rizvi, 2009). Polyphenols can be categorized based on their structure, like phenolic acids (e.g., hydroxybenzoic and hydroxycinnamic acids), flavonoids, coumarins, tannins, lignans, and stilbenes. The specific type and quantity of these polyphenols vary from species to species as well as in different tissues of the same plants.

For example, *Moringa oleifera* possessed area of secondary metabolites; Flavonoids (myrecytin, quercetin and kaempferol, iso-quercetin, apigenin, naringenin, catechin, luteolin, myricitrin, genistin), phenolic acids (chlorogenic acid, caffeic acid, p-coumaric acid, ferulic acid, quinic acid, dicaffeoyl quinic acid, gallic acid), anthocyanins (pelargonidin, pinotin A, delphinidin-3-O-sambubioside, cyanidin-3-O-xyloside), lignans (secoisolariciresinol-sesquilignan, 7-oxomatairesinol, 7-hydroxysecoisolariciresinol, 7-oxomatairesinol, isolariciresinol glucoside), alkylphenols (5-heptadecylresorcinol, 5-pentacosylresorcinol, 4-vinylphenol), hydroxycoumarins (umbelliferone, 4-hydroxycoumarin, coumarin, mellein), hydroxyphenylpropenes (estragole, [6]-gingerol, acetyl eugenol). Many reports have identified bioactive in LVs but have not quantified them. The amount of a particular bioactive in a particular species varied between different workers. Authors have often not reported variety, environmental conditions (of growth), and postharvest handling. Apart from that the extraction and analytical methods reported by different workers differed.

Table 1.1 Proximate composition of leafy vegetables

Sl. No.	LV name	Proximate composition (g/100g d.b.)						Micro nutrients (mg/100g d.b.)								Vitamins (mg/100g d.b.)								DF (mg/100g d.b.)		References
		Moisture	Carbohydrates	Protein	Fat	Ash	CF	Fe	K	P	Ca	Mg	Zn	Cu	Mn	A	B1	B2	B3	B6	C	E	SDF	ISDF	
1.	*Centella asiatica*	8.0	4.8	19.4	2.9	12	2.77	6	3182	290	1283	345	7	1	1.7	0.39	ND	ND	ND	0.78	0.76	ND	0.8	26.3	Ajayi et al., 2020
2.	*Moringa oleifera*	7.6	38.2	24.4	7.1	11.2	27.1	7.3	1583	354	2560	600	3.1	1.9	2.1	18.9	2.64	20.5	8.2	ND	17.3	ND	4.5	27.5	Dhakar et al., 2011
3.	*Murraya koenigii*	6.8	39.44	11.8	5.1	12.5	6.3	5	2150	364	2089	314	2	1	1	6.04	0.89	0.09	2.73	ND	0.04	0.03	2.5	38.8	Igara et al., 2016
4.	*Hibiscus sabdariffa*	7.8	8.7	17.3	3.1	6.5	24.5	5	1227	216	1365	205	3	1	4.4	1.23	0.2	0.4	1.4	ND	2.3	35.11	8.5	34.7	Singh et al., 2017
5.	*Amaranthus viridis*	13.3	64.6	19.8	3.4	12.2	8.2	10.8	382	52	24.7	0.48	9.73	1.11	8	65.70	ND	0.52	0.05	0.07	179	ND	12.5	36.5	Nazmul et al., 2013; Ray & Ray, 2022; Jayasinghe et al., 2019
6.	*Chenopodium album*	15.2	53.3	23	4.2	19.5	24.45	5.4	848.32	1.55	155.75	0.31	8.44	1.22	118	1.74	0.01	0.14	ND	ND	35	ND	4.29	20.15	Poonia & Upadhayay, 2015; Koca et al., 2015
7.	*Enhydra fluctuans*	13.66	9.64	8.00	1.10	15.15	15.37	123	487	48.3	622	3.8	4.38	0.3	11.5	0.98	0.40	1.04	0.60	1.85	4	ND	ND	ND	Datta et al., 2019
8.	*Eryngium foetidum*	13.43	5.34	5.25	1.95	10.21	9.72	111.21	58.4	43	312.3	98.5	4.5	441.4	10.5	7.33	0.05	0.02	1.02	0.1	3.60	0.36	0.22	10.3	Chyne et al., 2019
9.	*Marsilea minuta*	16.6	57.50	24.9	5.53	10.43	7.33	0.46	6.13	10.13	80.35	38.33	0.13	0.42	0.17	0.491	ND	ND	ND	ND	69.06	ND	ND	ND	Bhati et al., 2016; Sinha, 2018; Gupta et al., 2017
10.	*Diplazium esculentum*	7.6	44.3	31.2	8.3	16.2	4.6	11.2	914.4	49	192.7	0.36	2.73	0.32	0.51	0.83	0.02	0.21	0.1	4.76	32.03	ND	ND	ND	Pradeepkumar et al., 2015; Sarwar et al., 2020; Komarayanti et al., 2020
11.	*Nasturtium officinale*	9.4	31.7	33.8	9.6	24.9	21.31	7	465.2	52.5	65.6	0.41	2.04	0.58	0.62	0.42	1.63	ND	ND	0.23	62.5	1.46	2.09	19.22	Al-Snafi et al., 2020
12.	*Urtica dioica*	15.5	47.4	28.5	5.2	18.9	26.85	8.1	917.2	ND	113.2	0.22	2.32	0.67	ND	32.25	0.06	1.48	4	0.44	1535	92.9	3.25	23.6	Said et al., 2015; Pradhan et al., 2015

Note: LV: Leafy vegetables; CF: Crude fibre; SDF: Soluble dietary fibre, ISDF: Insoluble dietary fibre; Fe: Iron; K: Potassium; P: Phosphorus; Ca: Calcium; Mg: Magnesium; Zn: Zinc; Cu: Copper; Mn: Manganese.

Table 1.2 Consumption pattern and absorption of phytochemicals

Sl. No.	Available Phytochemical constituents (mg/g d.b.)						Consumption pattern	References
	LV Name	Total Phenols	Total Flavonoids	Total Alkaloids	Total Tannins	Total saponins		
1.	*Centella asiatica*	2.14	23.03	17.75	11.6	2.6	Leaves and stems are edible raw, Dried leaves can be ground down into a fine powder for culinary use e.g. in smoothies, nut milks, raw cakes, raw crackers, etc and also cooked as curry and pasted and eaten with rice	Kunjumon et al., 2022; Long et al., 2012; Quyen et al., 2020
2.	*Moringa oleifera*	105.04	31.28	70	93.6	64	Leaves of moringa are fried and mixed with tuna chips, onions and dried chillies. This is equivalent to sambal and eaten along with rice and curry. Leaves of moringa can also use in the preparation of soup and eaten especially for breakfast	Hassan et al., 2021; Kashyap et al., 2022, Madukwe et al., 2013; Leone et al., 2015
3.	*Murraya koenigii*	0.043	0.07	0.02	0.01	0.03	Dried curry leaf powder (CLP) at 5 or 10% level to common dishes to increase the intake of greens as a source of micronutrients. Leaves are widely used in Indian cookery for flavouring foodstuffs.	Igara et al., 2016; Jain et al., 2017
4.	*Hibiscus sabdariffa*	1.20	5.28	3.27	0.04	2.19	Tender leaves and stalks are eaten as salad and as a pot-herb and are used for seasoning curries	Da-Costa-Rocha et al, 2014; Famurewa et al., 2015
5.	*Amaranthus viridis*	14	27.8	131.4	60.7	530	Amaranth leaves, stems and entire plants may be eaten raw or cooked as spinach or greens	Ahmed et al, 2013; Khanam et al., 2013; Sarker & Oba, 2018a,2018b
6.	*Chenopodium album*	2.94	17.64	2.80	22.34	3.22	The tender shoots are eaten raw in salad or with curd. They are also cooked as vegetable or the cooked shoots are mixed with curd and eaten.	Choudhary et al., 2021
7.	*Enhydra fluctuans*	1.11	2.25	0.2	6.6	4.1	Fried or boiled with rice and eaten with boiled rice with boiled potato, salt and mastered oil.	Ramproshad et al., 2018; Choudhury et al., 2017; Barua et al., 2021
8.	*Eryngium foetidum*	50.23	77.24	7.8	14.5	2.3	The leaves can be eaten as a soup or raw or cooked as vegetables	Choudhury et al., 2017; Malik et al., 2016
9.	*Marsilea minuta*	72.6	54.9	ND	ND	ND	Bright green leaves are tender and are eaten as a potherb or fried as vegetables	Arokiyaraj et al, 2018; Iqbal et al., 2021; Chakraborthy et al., 2012
10.	*Diplazium esculentum*	0.24	0.09	0.05	ND	0.32	Tender leaves are cooked with fruit of *Dillenia indica* and fish and taken as vegetable; Hairs are removed, boiled with salt and water until water is evaporated then fried and eaten as vegetable, Cooked and eaten as a vegetable and in soups to maintain good health	Khatoniar et al., 2018; Semwal et al., 2021
11.	*Nasturtium officinale*	9.35	42.65	ND	43.05	ND	Fresh leaves are cooked as vegetables	Amiri, 2012; Rawal et al., 2021
12.	*Urtica dioica*	4.52	20.29	14	10.54	81.4	consumed primarily as a fresh vegetable whereby it is added to soups, cooked as a pot herb, or used as a vegetable complement in dishes	Repaji´c et al., 2021; Kukrić et al., 2012; Stanković et al., 2012; Dhouibi et al., 2020; Rutto et al., 2013

Note: LV: Leafy vegetables; d.b.: dry basis

Table 1.3 Relation between botanical classification and bioactive compounds

Sl. No.	Botanical/Taxonomic specification					Bioactive compounds	Functional Properties	References
	LV Name	Class	Superorder	Order	Family			
1.	*Centella asiatica*	Magnoliopsida	Asteranae	Apiales	Apiaceae	**Triterpenoid** (pent acyclic triterpenic acids and their respective glycosides, belonging to ursane or oleanane-type including asiatic acid, asiaticoside, madecassic acid, madecassoside, brahm oside, brahmic acid, brahminoside, thankuniside, isothankuniside, centelloside, madasiatic acid, centic acid, cenellic acid, betulinic acid) **Volatile oil** (p-cymol, b-caryophyllene and farnesene), **Flavonoids** (quercetin and kaempferol, catechin, rutin and naringin, castillicetin, castilliferol), **Polyacetylenes** (polyacetylene I, II, III, IV, V, centellicin, centellin, cadiyenol, **Phenolic acid** (Irbic acid, 1-Caffeoylquinic acid, 1,4-Dicaffeoylquinic acid, 3,4-Dicaffeoylquinic acid, Cryptochlorogenic acid, Chlorogenic acid)	Sedative, Anti-depressant, Anti-inflammatory activity, used in dysentery, fever, Anticancer activity, Brain stimulating effects, medicinal uses including treatment for tuberculosis and leprosy, the pain of arthritis and rheumatism, as a blood purifier, Treatment of venous hypertension and microangiopathy, effectively applied for anti-bilharzial, antifertility, anti-herpes simplex virus, radioprotection, cosmetics, immunomodulatory and antagonizing liver fibrosis	Kunjumon et al., 2022; Long et al., 2012; Quyen et al., 2020
2.	*Moringa oleifera*	Magnoliopsida	Rosanae	Brassicales	Moringaceae	**Flavonoids** (myrecytin, quercetin and kaempferol, iso-quercetin, apigenin, Naringenin, Catechin, Luteolin, Myricitrin, Genistin) **Phenolic acids** (Chlorogenic acid, Caffeic acid, p-coumaric acid, Ferulic acid, Quinic acid, dicaffeoyl quinic acid, Gallic acid) **Anthocyanins** (Pelargonidin, Pinotin A, Delphinidin-3-O-sambubioside, Cyanidin-3-O-xyloside) **Lignans** (Secoisolariciresinol-sesquilignan, 7-oxomatairesinol, 7-hydroxysecoisolariciresinol, 7-oxomatairesinol, Isolariciresinol glucoside) **Alkylphenols** (5-heptadecylresorcinol, 5-pentacosylresorcinol, 4-vinylphenol) **Hydroxycoumarins** (Umbelliferone, 4-hydroxycoumarin, Coumarin, Mellein) **Hydroxyphenylpropenes** (Estragole, [6]-Gingerol, Acetyl eugenol) **Tyrosols** (Hydroxytyrosol, Hydroxytyrosol- 4-O-glucoside, 3,4-DHPEA-AC)	antiproliferation, hepatoprotective, anti-inflammatory, antinociceptive, antiatherosclerotic, oxidative DNA damage protective, antiperoxidative, cardioprotective, Antibacterial, Antineoplastic and other Pharmaceutical function, anticarcinogenic, immunomodulatory, reduce gastric ulcers, hypotensive, antidiabetic, anti-cancer, antiatherosclerotic, antiatherogenic, and hepatoprotective functions	Hassan et al., 2021; Kashyap et al., 2022; Madukwe et al., 2013; Leone et al., 2015

						Phenolic terpenes (Rosmanol), **Stilbenoids**(Resveratrol, resveratrol-3-O- glucoside)		
3.	*Murraya koenigii*	Magnoliopsida	Rosanae	Sapindales	Rutaceae	**Sesquiterpenoid** (α-Copaene, α-Humulene, Aromadendrene, β- Elemene, β-Bisabolene, β-Caryophyllene, β-Selinene) **Turpentine**(α-Pinene) **Monoterpenoid** (α-Selinene, Carbazole) **Alkaloid** (Bismurrayafoline E, Bispyrafoline, Bicyclomahanimbine) **Olefinic Natural Organic Hydrocarbon** (β-Myrcene **Terpene** (Bornyl Acetate, β-Pinene) **Terpenoid Alkaloids** (Bicyclomahanimbicine **Alcohols** (β-Costol, β-Eduesmol, Tocopherol) **Cyclic Monoterpenes**(β-Phellandrene) **Indole Alkaloid** (Formlycarbozole, Girinimbine, Isomahanimbine, Koenimbine, Koenine, Koenigine	antiemetics, antidiarrheal, febrifuge, blood purifier, antifungal, depressant, anti-inflammatory, body aches, for kidney pain and vomiting	Igara et al., 2016; Jain et al., 2017
4.	*Hibiscus sabdariffa*	Magnoliopsida	Rosanae	Malvales	Malvaceae	**Organic acid** (Hydroxycitric acid, Hibiscus acid, Hibiscus acid glucoside, Hibiscus acid 6-methyl ester) **Anthocyanins** (Delphinidin-3-sambubioside, Cyanidin-3-sambubioside) **Phenolic acid**(Gallic acid, Chlorogenic acid isomer I, Chlorogenic acid, Chlorogenic acid isomer II, 5-Hydroxymethylfurfural, Methyl gallate, 2-O-trans-Caffeoyl-hydroxicitric acid, 5-Caffeoylquinic acid, 3-Caffeoylquinic acid, Protocatechuic acid, Protocatechuic acid glucoside, Coumaroylquinic acid, 5-O-Caffeoylshikimic acid, Feruloyl derivative 2 Methyl(AS in Methylepigallocatechin), N-Feruloyltyramide, 4-Caffeoylquinic acid, Caffeoylquinic acid isomer, Caffeic acid 2 Galloyl ester, Feruloyl quinic acid derivative) **Flavonoids** (Quercetin-3-sambioside, Quercetin-3-rutinoside, Leucoside(kaempferol-3-O-sambubioside), Quercetin-3-glucoside, Kaempferol-3-O-rutinoside, Myricetin, Kaempferol-3-p-coumarylglucoside, Quercetin, Kaempferol-3-glucoside, Quercetin derivative)	treatment of abscesses, bilious conditions, cancer, cough, debility, dyspepsia, fever, hangover, heart ailments, hypertension, and neurosis, antiscorbutic, emollient; diuretic, refrigerant, and sedative, cardioprotective, hypocholesterolemic; antioxidative and heaptoprotective	Da-Costa-Rocha et al., 2014; Famurewa et al., 2015
5.	*Amaranthus viridis*	Magnoliopsida	Caryophyllanae	Caryophyllales	Amaranthaceae	**Hydroxybenzoic acid** (Gallic acid, Vanilic acid, Syringic acid, p-hydroxybenzoic acid, Salicylic acid, Ellagic acid)	used to stop dysentery and inflammations, and also to purify the blood, to treat inflammation	Ahmed et al., 2013; Khanam et al., 2013; Sarker & Oba, 2018b

						Hydroxycinnamic acid (Caffeic acid, Chlorogenic acid, p-Coumaric acid, m-Coumaric acid, Ferulic acid, Sinapic acid, Trans-cinnamic acid) **Flavonoid** (Isoquercetin, Hyperoside, Rutin)	during urination, to treat constipation, dysentery, diuretic, febrifuge and purgative, to act as a vermifuge, being effective against filaria, as an emmenagogue and to relieve heart troubles, used to treat inflammations, boils and abscesses, gonorrhoea, orchitis and haemorrhoids, used as an eye wash to treat eye infections	
6.	*Chenopodium album*	Magnoliopsida	Caryophyllanae	Caryophyllales	Amaranthaceae	**Flavonoid**(kaempferol-3-O-(4-β-D-xylopyranosyl)-α-Lrhamnopyranoside-7-O-α-L-rhamno-pyranoside, 3-O-(4-β-Dapiofuranosyl)-α-L-rhamnopyranoside-7-O-α-L-rhamnopyranoside, 3,7-di-O-α-L-rhamnopyranoside, 3-O-glucopyranoside and quercetin 3,7-di-O-β-D-glucopyranoside, 3-O-glucosylglucuronide, 3-O-α-L-rhamnopyranosyl-(1→ 6)-β-D-glucopyranoside, 3-O-β-D-glucopyranoside)	Laxative and anthelmintic, reduces skin problems, anti-inflammatory, anorexia, cough, dysentery, diarrhoea, oedema, piles, small worms, properties like antiphlogistic, antirheumatic, contraceptive, laxative, odontalgic, rheumatism, bug bites, sunstroke, urinary problems, have sedative and refrigerant properties, used the poultice leaves to soothe burns, Constipation, intestinal worms; Jaundice, urinary disorder	Choudhary et al., 2021
7.	*Enhydra fluctuans*	Magnoliopsida	Asteridae	Asterales	Asteraceae	**Germacranolide** (Enhydrin), **Sesquiterpene lactone** (Fluctuadin, Fluctuanin), **Flavonoid**(Baicalein 7-O-glucoside, Baicalein 7-O-diglucoside), **Essential oil** (alpha-Pinene, 1-Octen-3-ol, Myrcene, Limonene, (E)-beta-Ocimene, Linalool, Camphor, cis-1,2-Dihydroperillaldehyde, Perillaldehyde, (E)-Caryophyllene, alpha-Humulene, Longiverbenone), **Steroid** (Stigmasterol, Stigmasta-5,22,25-trien-3beta-ol), **Diterpenoid** (Myricyl alcohol, (-)-Kauran-16-ol, (-)-Kaur-16-en-19-oic acid), **Gibberellin A9, Gibberellin A13**,	good blood purifier and appetizer, Hepatoprotective activity, CNS Depressant Activity, Antidiarrheal activity, Leaves are laxative and antibilious; cure inflammation, leucoderma, bronchitis and biliousness; useful in skin and nervous affections;	Ramproshad et al., 2018; Choudhury et al., 2017; Barua et al., 2021

						Melampolide(8-Deepoxyangeloyl-8-[2-hydroxy-3-chloro-isobutyroyl]- enhydrin, 8-Deepoxyangeloyl-8-[chloro-2-hydroxy-2-methylbutyroyl]-enhydrin), **Sesquiterpene lactone** (8-Desacyl enhydrin tiglate, 8-Desacyl enhydrin-[4-hydroxymethacrylate], 8-Desacyl enhydrin-[4-hydroxytiglate], 8-Desacyl enhydrin-[2,3-epoxyisobutyrate]), **Isoflavone glycoside** (4',5,6,7-Tetrahydroxy-8-methoxyisoflavone-7-O-beta-Dgalactopyranosyl-(1→3)-O-beta-D-xylopyranosyl-(1→4)- O-alpha-L-rhamnopyranoside)		
8.	*Eryngium foetidum*	Magnoliopsida	Asteranae	Apiales	Apiaceae	**Triterpenoid Saponins (**3-O-[-D-glucopyranosyl-(1->2)-[β-D-fucopyranosyl-(1->3)]-α-Lrhamnopyranosyl-(1->4)-β-D-glucopyranosyl]-olean-12-en-23,28-diol**),** **Steroids** (β-sitosterol, stigmasterol, campesterol, brassicasterol, 3α-cholesterol, (-)-clerosterol, avenosterol, avenasterol, stigmastadienol), **Essential oil** (α– pinene, p-cymene, 2,3,6 Trimethyl benzaldehyde, E(2) Dodecenal, Dodecenoic acid, E(2) Tridedecenal, Duraldehyde, Formyl1,1,5trimethyl cyclohexa 2,4 den 6-ol, Eryngiol, Dimethyl acetophenine, Lauric acid, Capric acid)	anti-inflammatory and antinociceptive activity, treatment for burns, earache, fever, hypertension, constipation, fits, asthma, stomach ache, worms, infertility complications, snake bites, diarrhoea and malaria	Choudhury et al., 2017; Wang et al., 2012; Malik et al., 2016
9.	*Marsilea minuta*	Polypodiopsida	Polypodiidae	Salviniales	Marsileaceae	**Phenolic acid** (Caffeic acid, ferulic acid, gallic acid) **Flavonoids** (quercetin-3-o-glucoside, quercetin-3-o-galactoside, kaempferol-3-o-glucoside, chalconeo-glucoside, quercetin-3-rutinoside (rutin), naringenin7-o-glucoside) **Steroid**(beta-sitosterol) **Ketonic compound** (marsiline), **Phenol** (Phenol, 2,4-bis (1,1-dimethylethyl)), **Oxygenated sesquiterpene** (1,6,10-dodecatrien-3-ol,3,7,11-trimethyl, Trans-Farnesol), **Sesquiterpene** (2,6,10-Dodecatrien-1-ol,3,7,11-trimethyl-acetate, Farnesol, acetate), **Unsaturated fatty acid** (Octadec-9-enoic acid, Oleic acid)	used as aphrodisiac and for increased fertility, to stop nose bleeding, applied to swollen gums in order to reduce the swelling, reduced cholesterol and triglyceride levels in blood and liver substantially; hypocholesterolemic, anxiolytic, antidepressant, antiamnestic, antistress, antiaggressive and antifertility	Arokiyaraj et al., 2018; Iqbal et al., 2021; Chakraborthy et al., 2012
10.	*Diplazium esculentum*	Polypodiopsida	Polypodiidae	Polypodiales	Woodsiaceae	**Volatile oil** (β-pinene, α-pinene, caryophyllene oxide, sabinene, and 1,8-cineole) **Phenolic compounds** ((2R)-3-(4′ -hydroxyphenyl) lactic acid, trans-cinnamic acid, protocatechuic acid),	Good appetizer and effective against constipation and leprosy, coronary heart disease, neurodegenerative disorders,	Khatoniar et al., 2018; Semwal et al., 2021

						Ecdysteroids (amarasterone A1, makisterone C, and ponasterone A), **Flavonoids** (quercetin, rutin)	diabetes, arthritis, inflammatory diseases, lung damage, aging, and cancer, antimalarial effects, treat jaundice, constipation, earache, to treat fever, measles and dermatitis, treatment of skin infections such as dermatitis and measles	
11.	*Nasturtium officinale*	Magnoliopsida	Rosanae	Brassicales	Brassicaceae	**Essential oil** (limonene, -terpinolene, p-cymene-8-ol, caryophyllene oxide, myristicin, -terpinolene) **Phenolic compound** (gallic acid derivative, gallic acid derivative, ferrullic acid derivative, proanthocynidin B1, p-coumaric acid derivative, phydroxybenzoic acid, sinapic acid, p-coumaric acid, caftaric acid, caffeoylmalic acid, and coumaric acid derivative), **Flavonoids** (apigenin, quercetin-3- (cafferoyldiglucoside)-7- glucoside, kaempferol-3-(caffeoyl diglucoside)- 7-rhamnoside)	depurative, diuretic, expectorant, hypoglycaemic, hypolipidemic, odontalgic, stimulant, for the treatment of pulmonary diseases, hypertension and cardiovascular diseases, abdominal pain, as anti-ulcerogenic, in the treatment of scurvy, tuberculosis, bronchitis, influenza and asthmadepurative, diuretic, expectorant, hypoglycemic and odontalgic, lung cancer	Amiri, 2012; Rawal et al., 2021
12.	*Urtica dioica*	Magnoliopsida	Rosanae	Rosales	Urticaceae	**Phenolic acids** (Protocatechuic acid, Gentisic acid, Syringic acid, Caffeic acid, Chlorogenic acid, p-coumaric acid, Cinnamic acid, Ferulic acid, Sinapic acid, Quinic acid), **Flavonoids** (Isorhamnetin derivatives, Kaempferol derivatives, Quercetin derivatives, Myricetin, catechin, Epigallocatechin gallate, Epicatechin, Luteolin, Apigenin, Genistein, Naringenin), **Coumarins** (Umbelliferone, Esculetin, Scopoletin)	Cure jaundice, inflammatory diseases, rheumatoid arthritis, Cardiovascular diseases, Diabetes, Respiratory diseases, Cancer, Neural disease, Skin disease	Repajić et al., 2021; Kukrić et al., 2012; Stanković et al., 2019; Dhouibi et al., 2020; Rutto et al., 2013

Note: LV: Leafy vegetables

1.1.4. Location of phytochemicals in leafy vegetables and their absorption in gut

Secondary metabolites such as polyphenols are conjugated with monosaccharides, polysaccharides and proteins and located in vacuoles and the apoplast of plant cells. However, carotenoids are located both in the chloroplast and chromoplast membrane. For example, plant chromoplast of tomato (crystal), papaya (lipid dissolved) and mango (liquid crystalline) have unique varieties of carotenoids that effectively influence the liberation from the food matrix and are typically involved in the defense system. Dietary fibre-bound polyphenols are hydrolyzed via enzymes in the upper intestine; otherwise, these compounds will now not be bioaccessible and will possibly be degraded through the colonic microflora in the large intestine (Pérez-Jiménez et al., 2009). Dietary fibre acts as an entrapping matrix and restricts the diffusion of the enzymes with their substrates. Therefore, appropriate processing and consumption patterns are the essential factors to be viewed for the bioavailability of the bioactive compounds.

Bioactives from different LVs vary significantly in terms of the bioaccessibility, bioavailability, and concentration of these active metabolites in the tissues. Food fragmentation occurs predominantly in the mouth and stomach. At the same time, enzymatic digestion and absorption of nutrients, including vitamins and other bioactive and water, happens primarily in the small and large intestines.

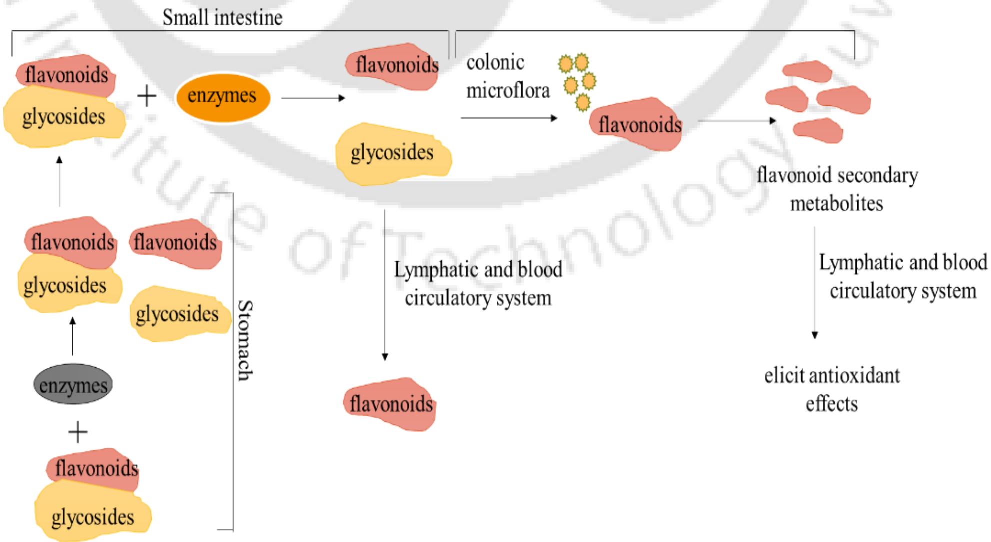

Fig. 1.3 Absorption pattern of water soluble phytoconstituents (Bohn et al., 2015)

Water-soluble bioactive can partly absorb via the intestinal wall (Fig. 1.3). Whereas some lipophilic compounds, such as carotenoids or triterpenes, require micellization, as may certain polyphenol aglycones. Carotenoid absorption depends upon efficient release from the food matrix and subsequent solubilization by bile acids and digestive enzymes, culminating in their incorporation into micelles (Fig. 1.4). Carotenoids are disassociated from their native environment in the plant tissue during food processing and digestion (acidic conditions and enzymatic hydrolysis) in the stomach (Khachik et al., 2002). The carotenoids are not actively absorbed by the gut but are passively absorbed along with lipids. The absorption efficiency of carotenoids depends on dissolving lipophilic molecules into dietary lipids (van het Hof et al., 2000).

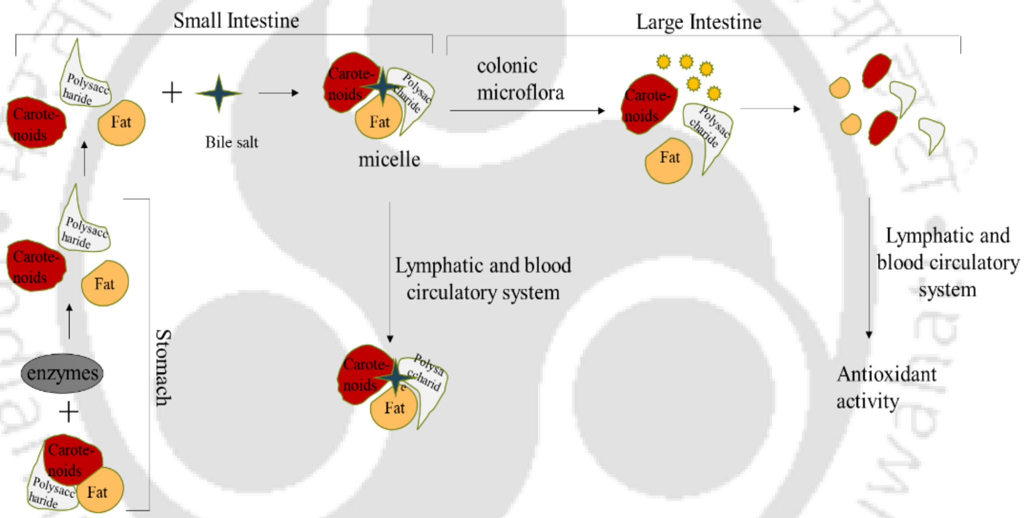

Fig. 1.4 Absorption pattern of water insoluble phytoconstituents (Bohn et al., 2015)

1.2. Lacunae and Scope of work

- There are many reports on medicinal aspects of the plant used as leafy vegetables or herbs but they are mostly targeted towards a particular (group) of compound(s) or towards non-aqueous extracts containing secondary metabolites of such plants. Such reports do not highlight their health benefit in food form.
- There is no comprehensive database available on these plants covering their classification, geographical distribution, bio-active secondary metabolites, proximate composition, possible health benefits, and the way they are consumed. No focus review on relation between their dietary use and their possible health benefits especially in gastrointestinal diseases.
- Though many authors have pointed out a positive correlation between polyphenol content and antioxidant activity of some of the plants used as leafy vegetables but in their dietary form how great the amount of polyphenols these leafy vegetables can deliver and in an aqueous system how they play a physiologically important role has rarely been investigated.
- Though *in vitro* antioxidant properties of these vegetables have been reported, the results are incomparable and not validated at further cellular or *in vivo* level. Considering the complexity involved in the *in vivo* action of antioxidants, different *in vitro* methods usually followed to estimate the antioxidant properties of leafy vegetables show misleading results. Alternatively, animal models and human studies are more appropriate, but it is expensive, time-consuming and have ethical/regulatory issues. Therefore, it is important to proceed to cellular assays for meaningful screening of antioxidant-rich natural sources.
- There are very few literatures that shows a scientific product development approach from any leafy vegetables with a specific health benefit.

1.3. Objectives of work

- Creating database of leafy vegetables and theoretical analysis of polyphenols in leafy vegetables for their antioxidant activity relevant for intestinal health.

- Development of protocol for assessment of antioxidant properties of a target solution in yeast model.
- To study the effect of different drying conditions on antioxidant activity of four selected leafy vegetables from North East India.
- To develop herbal beverages from dried *Centella asiatica* powder with potential antioxidant and prebiotic activity.

1.4. Thesis organization

This thesis comprises of eight chapters:

- **Chapter 1** introduces the motivation, extensive literature review on consumption pattern, nutritional value including their antioxidant potential, and health benefit. The chapter also includes the research gaps and scopes of work and objectives of the present work.
- **Chapter 2** presents an extensive database of leafy vegetables and analyzes how polyphenols and other antioxidant vitamins may play a role in antioxidant homeostasis in gut.
- **Chapter 3** explores the polysaccharides of leafy vegetables since polysaccharides (the major source of dietary fibers) in leafy vegetables have not been documented before.
- **Chapter 4** describes a process that was developed to assess antioxidant activity by utilizing H_2O_2 stressed yeast cells.
- **Chapter 5** evaluates the impact of different drying processes on four selected leafy vegetables w.r.t their antioxidant potential.
- **Chapter 6** described the assessment of four selected leafy vegetables for preparation of herbal drink.
- **Chapter 7** discusses potential antioxidant and prebiotic activity of *Centella asiatica* beverages for maintaining intestinal health.
- **Chapter 8** summarizes the key research findings and scope of future work.

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Chapter 2

Creating database of leafy vegetables and theoretical analysis of polyphenols in leafy vegetables for their antioxidant activity

Chapter 2

2. Introduction

Gastrointestinal disorders are one of the major reasons for visiting doctors in developing countries. Different types of infections are predominant among GI disorders and cause significant economic loss, mortality, and morbidity. The burden of such disorders is further snowballing in many developing countries with the changing socioeconomic status. The so-called Western diseases associated with functional abnormality and structural deformity like IBS, IBD and Colorectal cancer are spreading in developing nations. Especially young population (14-40 yrs) in both rural and urban areas are being susceptible to these diseases and that requires immediate attention to prevent the future generations from losing the quality of life or premature death. There are evidences that an improper diet can cause inflammation on the other hand inflammatory changes can be mitigated also by dietary interventions. Nutritionists and clinicians are investigating the relation between food products (or their ingredients) and occurrence or inhibition of inflammation. Further inflammation can lead to several metabolic disorders and diseases like diabetes, cardiac disease, inflammatory bowel diseases, cancer and so on. Although some trials have proven that dietary intervention can reduce the serum level of inflammatory factors, the mechanistic relation between the dietary intervention and the serum level of inflammatory factors is yet to be understood. However, inflammation and its resolution in the GI tract are linked with oxidative stress (and exogenous antioxidant) balance plus gut microbiome homeostasis.

Different epidemiological studies suggested phytochemicals from plant-based foods are capable of fighting inflammation and reducing the risk of health disorders caused by lifestyle factors, pollution, aging, drug abuse (e.g., antibiotic overuse), infection, etc. WHO and the member countries recommend at least five servings or 80 g each of fruits and vegetables together or two servings of fruits and three servings of vegetables per day for protection from chronic diseases (Kalmpourtzidou et al., 2020). However, per capita consumption of fruits and vegetables in the world has been estimated to be far lower, with values of 167 g/day (Caprile & Rossi, 2021). Country-specific figures can be further dismal and will consist of a very narrow diversity. Hall et al. (2009) estimated over two-third population of fifty-two low and middle-income countries consumed less than the minimum recommended servings of fruits and vegetables. In an emerging economy like India in spite of adequate production of fruits and vegetable their consumption rates are low and leafy vegetables are the most ignored food group (Mukherjee et al., 2017). Indigenous leafy vegetables have been used by mankind for centuries to harvest nutrition and to fight with ailments. Different socioeconomic causes have reduced their consumption. In this communication value of this underutilized group of vegetables are to be investigated w.r.t their antioxidant activity and prebiotic potential.

2.1. Methodology

2.1.1. Creation of a database of leafy vegetables and analysis of their health benefit

2.1.1.1. Search strategy

The search strategy was based on scientific literature published on the ethnobotanical survey and reports retrieved from databases like google scholar, PubMed, NCBI, Scopus, and Ayurvedic literature from Ayush repository till January 2023. The searches were guided by Booolean operator to target most relevant literatures. The keywords used were “Ethnobotanical survey + edible leaves”, “Edible Herbs + traditional medicine”, “Ethnobotanical survey + consumption pattern”, “Ethnobotanical survey + traditional healers + edible plants”, “Ethnopharmacological + leafy vegetables”. The symbol (-) was put after the word "ethno" while searching to ensure not to miss any research articles which contain hyphenated terms like ethno-medicinal, ethno-botanical, ethno-medical etc. in their title.

2.1.1.2. Inclusion and exclusion criteria

Three inclusion criteria were used; (i) articles should be in the English language, (ii) articles should be primary data from field studies, (iii) all related articles with no year limit until 2022 were included. As for our exclusion criteria, (i) articles without any specification of study areas or scientific plant names, (ii) partially accessed articles with abstract only, and (iii) articles in languages other than English were not included (Aumeeruddy & Mahomoodally, 2021).

2.1.2. *In silico* determination of the effect of the polyphenols of the leafy vegetables in the GI tract

2.1.2.1. SwissADME

SwissADME tool (access at http://www.swissadme.ch) allows the user to navigate within the different SwissDrugDesign tools. The methodology to evaluate molecule properties is described in Fig. 2.1. In the webpage, molecules can be loaded in the SMILES list by clicking "Enter a list of SMILES here". By clicking "Run" button output panels are loaded on the same webpage. The panel compiles all values for the selected molecule. It is filled immediately after calculation completion, one molecule after the other. This way, it is possible to inspect the results for the first compounds without waiting for the whole list to be treated. This one-panel-per-molecule (Fig. 2.2) is headed by the molecule name and divided into different sections i.e., Chemical Structure and Bioavailability Radar, Physicochemical Properties, Lipophilicity, Water Solubility., Pharmacokinetics, Drug-likeness and Medicinal Chemistry. In this study, the pharmacokinetics of the molecules are evaluated to estimate the relevant metabolic functions in the GI tract (Fig. 2.2).

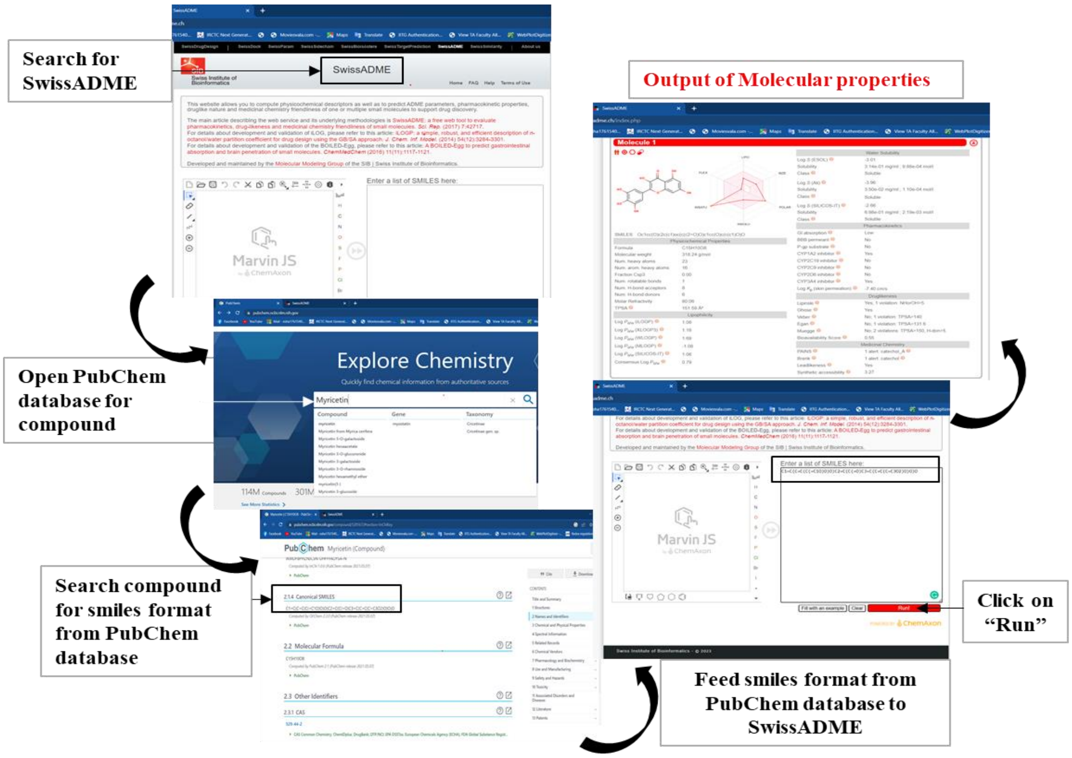

Fig. 2.1 Methodology of SwissADME tool to evaluate molecule properties

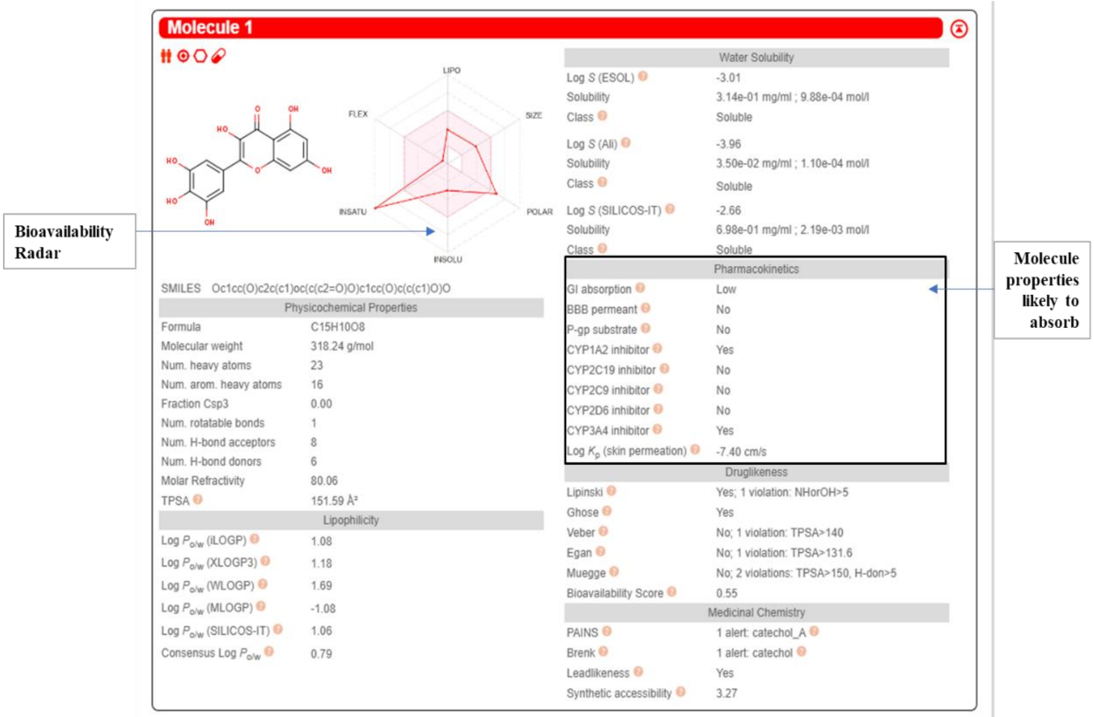

Fig. 2.2 Computed parameter values are grouped in the different sections of the one-panel-par-molecule output

2.1.2.2. Biotransformer 3.0

BioTransformer is a metabolism prediction and identification tool (BMPT and BMIT). It is a database of experimentally confirmed metabolite reactions. BioTransformer webpage contains a metabolism prediction tab, which accepts molecules either in SMILES (single molecule), InChI (single molecule), MOL (single molecule), or SDF (single or multiple compounds) format as input. The data can be curated for any molecule as described in Fig. 2.3. In the webpage, the option "select on metabolite transformation" is used to specify the transformation module. After submitting the metabolite prediction, the information from the predicted biotransformation builds a metabolic profile by associating each metabolite with its parent molecule. The results include three chemical identifiers (metabolite ID, InChI, InChI Key), molecular formula, monoisotopic mass, the reaction type, type of enzymes, the biosystem that generated the molecule, the parent compound identifiers (BioTransformer ID, InChIKey), the parent monoisotopic mass, the metabolite's and parent's AlogP, as well as metabolite's and parent's synonyms (Fig. 2.4).

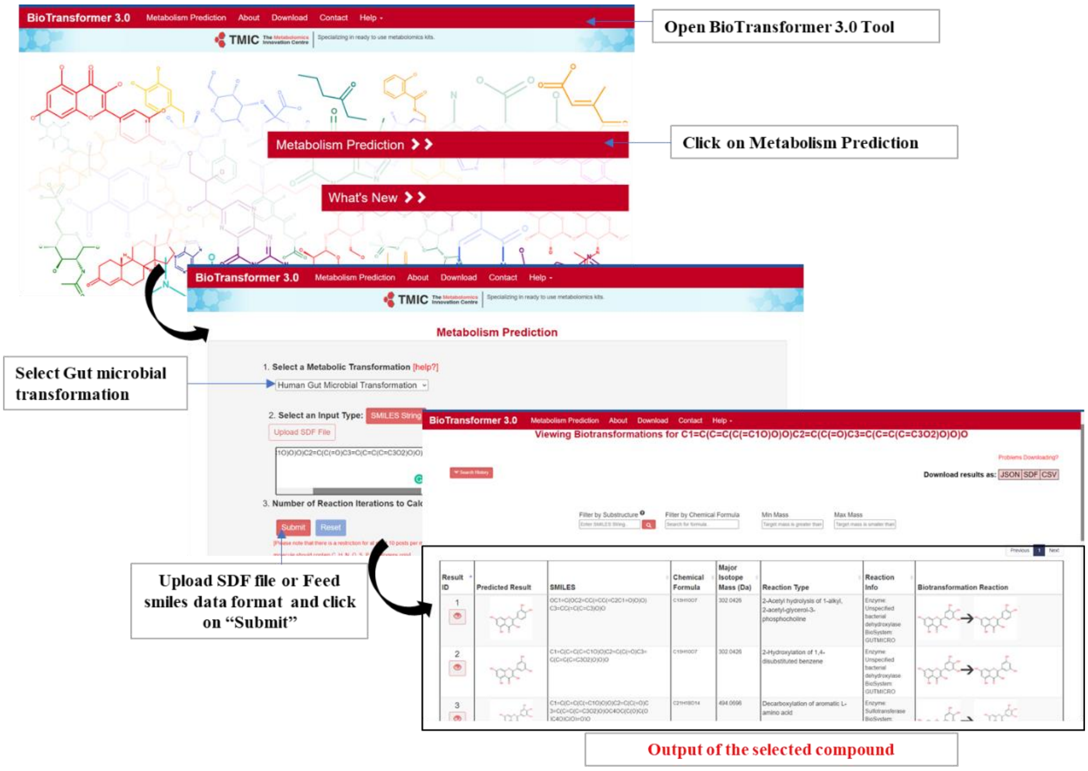

Fig. 2.3 Methodology of Biotransformer tool to predict metabolism in human tissues and microbial transformation in the human gut

BTMR_ID	BTMR0528
Metabolite_ID	BT00001
Synonyms	quercetin; 117-39-5; Meletin; Sophoretin; Quercetine; Xanthaurine; Quercetol; Quertine; 3,3',4',5,7-Pentahydroxyflavone; Quercitin
PUBCHEM_CID	5280343
InChI	InChI=1S/C15H10O7/c16-7-4-10(19)12-11(5-7)22-15(14(21)13(12)20)6-1-2-8(17)9(18)3-6/h1-5,16-19,21H
InChIKey	InChIKey=REFJWTPEDVJJIY-UHFFFAOYSA-N
SMILES	OC1=C(OC2=CC(=CC(=C2C1=O)O)O)C3=CC(=C(C=C3)O)O
Molecular_formula	C15H10O7
Major_Isotope_Mass	302.0426
ALogP	2.4922
Biosystem	Gut microbial environment
Enzyme(s)	Unspecified bacterial dehydroxylase
Reaction	2-Acetyl hydrolysis of 1-alkyl, 2-acetyl-glycerol-3-phosphocholine
Precursor_ID	myricetin
Precursor_InChI	InChI=1S/C15H10O8/c16-6-3-7(17)11-10(4-6)23-15(14(22)13(11)21)5-1-8(18)12(20)9(19)2-5/h1-4,16-20,22H
Precursor_InChIKey	InChIKey=IKMDFBPHZNJCSN-UHFFFAOYSA-N
Precursor_SMILES	C1=C(C=C(C(=C1O)O)O)C2=C(C(=O)C3=C(C=C(C=C3O2)O)O)O
Precursor_ALogP	2.2248

Fig. 2.4 Biotransformer output result of myricetin

2.2. Results and Discussion

2.2.1. Creation of a database of leafy vegetables and analysis of their health benefit from published ethnobotanical surveys

Globally there is an increasing interest in edible plants as protective foods. In so-called model healthy diets like the Mediterranean diet and the East Asian diet use of herbs and leafy vegetables are generous. There are so many epidemiological studies that attempted to correlate these diet intakes with low incidence of non-infectious diseases like cardiovascular diseases and diabetes. Review of such studies have revealed it is not just an isolated food or one specific component that is responsible for their beneficial effect. The physical form of these food plants and overall diet plays the most important role (Trichopoulou et al., 2014) in their protective properties. In this study, an extensive survey of literature has been done to make a database of 310 leafy vegetables covering their synonyms, taxonomic classification, nutritional composition (both macro and micro nutrients), bioactive secondary metabolites, culinary usage and perceived health benefits (Appendix A.1). The documented leafy vegetables belong to 3 division of taxonomy where 268 numbers belong to Tracheophyta, 16 belongs to Magnoliophyta, 4 belongs to Pteridophyta, 3 belongs to Angiosperms, 2 belongs to Spermatophyta and 1 belongs to Eudicota and rest are undefined.

The database could identify the several ways of consumption (different compositions and physical forms) of leafy vegetables (LVs) in various communities. They are either consumed in composite form in salads, omelettes, pastries or with rice/bread or as individual food like clarified juices, soups, beverages (e.g., herbal tea), pastes, etc. For example, spinach (*Spinacia oleracea*) and lettuce (*Lactuca sativa*) are usually consumed in cooked mixed vegetable, whereas lettuce is also consumed raw in salad and as dried leaves in winter by some communities. Fresh Indian pennywort (*Centella asiatica*) leaves and stems are eaten as salad or paste or its dried leaves powder can be mixed in smoothies, nut milk, raw cakes, raw crackers, etc. Some of the LVs are exclusively consumed by ethnic communities and in a very specific fashion. For example, *Bodo* community of Assam consumes *Lippia javanica* (vernacular name *Ontaibajab*), a LV as an ingredient for fish or meat curries. The way of consumption dictates their nutritional and extra-nutritional benefits or even their contraindications or toxicity. The subsequent section of this article discusses the fate of different micro- and macro-nutrient and other components in the case of different cooking of LVs.

The antioxidant molecules can be distributed in either of the three phases in a leafy vegetable product; soluble phase, insoluble phase and lipid phase. As per our database of leafy vegetables, the different forms of leafy vegetable consumption can be classified into three cases w.r.t their matrix features (Fig. 2.5). Case I where the LVs are in solid form with near intact tissues having trapped water and lipid phase that can be observed in steamed or deep-fried LVs. Hence, the bioactive components (like polyphenols, vitamins etc.) requires to be liberated in the stomach and later in the other compartments of the intestine. The solid matrix of such food poses a possibility of delay in transit from the stomach due to their large solid particle size (Kong & Singh, 2008). In another case (II), when the LVs are crushed into thin pulp or curries the solid matrix part would reduce except for a dispersed phase with a smaller particle size. For clarified leaf juices and infused beverages, the insoluble phase can be negligible and only a solution phase will exist with mostly water-soluble components (Case III). In Case II & III, evidently, the gastric transit time will be lesser than Case I food system with less than 2 mm particle size where the digesta from stomach can have $t_{1/2}$ as short as few tens of minutes (Mudie et al., 2014). In this context, the dietary fibre (soluble and insoluble) content of LVs can influence the GI transit time and, therefore, the free polyphenol content in the lumen. For soup or beverage kinds of product, a selective extraction of water-soluble fractions during processing may give rise to two-compartments; a small molecule fraction and a polymeric fraction. Since the polymeric fraction will be mostly polysaccharides a separate segment has been devoted to LV polysaccharides in this thesis.

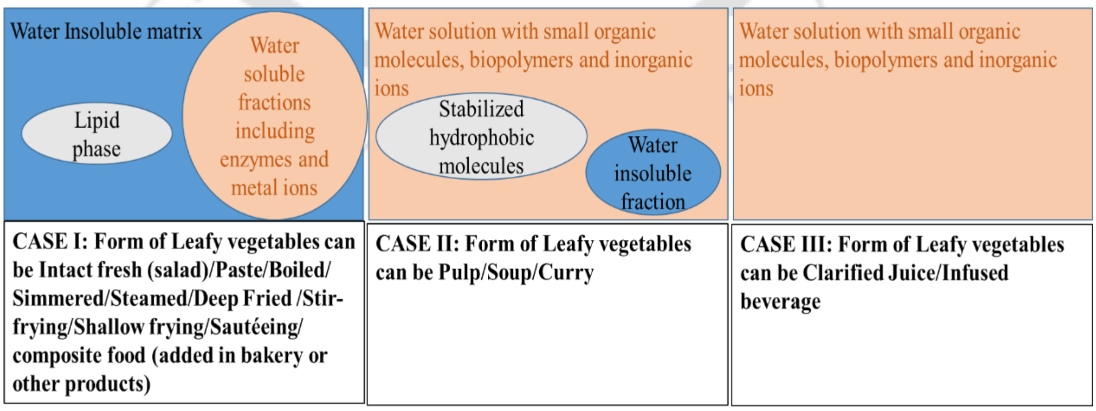

Fig. 2.5 Classification of matrix features of leafy vegetables based on different forms of its consumption

Survey based perceptive health benefit data is often based on ethnic understanding of a health disorder/disease and the use of plant-based medicines (with other ingredients plus rituals) for its remedy. Often standard disease classifications are the prerequisite to use such data from different surveys (of different communities) espescially for the purpose of bioprospecting (Staub et al., 2015). In this study, we found that the health benefits of different LVs expressed in surveys are often ill-defined. As an example, Muyana (*Vangueria spinosa*), a LV is believed to cure cough, skin infection, peptic ulcer, headache, diabetes, hepatic disorder, dysentery, indigestion, intestinal worm, and painful urination, and scorpion-sting. It is difficult to find from these ethnobotanical reports whether such curative properties are universal. Moreover, for a given disease like skin infection it is imperative to know whether the plant is effective against a particular infection (like bacterial or fungul) or against a broad range of infection. We have adopted ICPC framework to identify the disease data and interpret them for any future reference. In particular, the digestive disease-related symptoms identified in the surveys were compared with the ICPC-prescribed symptoms (Table 2.1). It was found in many ethnobotanical/ethnomedicinal survey reports the symptoms of digestive diseases are beyond the list of ICPC code (28 symptoms with D28 coding Verbeke et al., 2006). We have tabulated some of the descriptors that are meaningful or disease in itself (e.g., piles, ringworm infection, etc.) but not included in the ICPC codes. Another vital observation from the database was many of the diseases share common symptoms and to diagnose a particular disease requires a series of clinical investigations. Like diarrhoea, abdominal pain, vomiting is common in many GI tract related diseases. To confirm an enteric pathogen behind such symptoms, require culture and antibiotic susceptibility testing, microscopic observation and/or immunoassays. Similarly, for identifying a functional disease like irritable bowel syndrome apart from biomedical tests the psychosocial factors need to be included. Diagnostic procedures like colonoscopy and biopsy are essential to confirm and assess the degree of structural diseases like ulcerative colitis or colon cancer. So, when a disease is perceived to be cured by a particular plant product the response of traditional healers or individual consumer/community members are to be documented as per ICPC code of symptoms with the additional clinical comments. Many ethnomedicinal surveys express their perception/experience in very broad terms like some plants are suitable for digestion, good for the liver, strengthen the digestive system etc. that can be a possible indicator of the plants preventive role in GI tract-related disorders. For further confirmation of the extra-nutritional bioactivity of such LVs need to be done through *in silico, in vitro* and *in vivo* systems. In the subsequent segment, we verified the hypothesis that polyphenols from LVs may have a role as antimicrobial (against the pathogen) and in gut-related disorders due to their antioxidant potential.

2.2.2. Relation between processing and gut processing

2.2.2.1. Theoretical evaluation of distribution of antioxidant molecules including polyphenols among popular leafy vegetables

Leafy vegetables are known to be a natural reservoir of antioxidant molecules like polyphenols, ascorbic acids, carotenoids, and other pigments like chlorophyll A, chlorophyll B etc. (Sarker & Oba, 2018a, 2018b; Oboh, 2005). The entire pool of chemical components of any plant tissue can vary from femtomolar concentration (for some minerals and vitamins) to millimolar concentration for macronutrients like sugars, amino acids etc. (Wishart, 2008).

Often to discuss the health effect of a specific food product, the individual micronutrients/bioactive components are considered in isolation. For example, quercetin, a common flavonoid molecule with high antioxidant capacity, is believed to have a preventive effect on diseases like cancer, cardiovascular diseases, inflammation, and other degenerative diseases (Jan et al., 2010; Wach et al., 2007). However, the effect of a particular class of compound or an exclusive compound on human body coming from a dietary source will depend on the entire pool of molecules capable of doing same function (say a group of flavonoids), the matrix as well as other constituents of the food. Specifically, for antioxidant activity, the collective effect (both synergistic and antagonistic) of the constituents are to be known. Hence, we attempted to categorize the commonly estimated proximate and micro constituents in leafy vegetables in terms of their chemical groups (Appendix A.2). The composition data for thirty-four leafy vegetables was used from the NIN database (IFCT 2017) for analysis of the different constituents and their possible antioxidant activity. The compositions from different workers often shows as high as one order of magnitude variation in the composition data of LVs are comparable.

One challenge in predicting the reactivity of a milieu of compounds requires their molar concentration, but the food components are expressed in w/w of fresh edible part form in IFCT. Table 2.2 shows theoretically calculated molar concentration (μM) of major antioxidant molecules, i.e., Twenty-four polyphenols *viz*., 3,4-dihydroxy benzoic acid, protocatechuic acid, vanillic acid, gallic acid, o-coumaric acid, p-coumaric acid, caffeic acid, syringic acid, sinapinic acid, ellagic acid, chlorogenic acid, ferulic acid, apigenin, apigenin-6-c-glucoside apigenin-7-o-noehesperidoside, luteolin, kaempferol, quercetin, quercetin-3-β-d-glucoside, quercetin-3-o-rutinoside, quercetin-3-β-galactoside, isorhamnetin, myricetin, resveratrol, three carotenoids zeaxanthin, beta-carotene, lutein and antioxidant vitamins (or provitamins) i.e., total ascorbic acid, α-tocopherol eq, and phyloquinones (K1) in their fresh edible portion. Total polyphenol concentration varied from non-detectable levels (*Brassica rapa* var. chinensis) to 3.7 mM (Rumex leaves). Most of the LVs has total polyphenol of around 0.46 mM (Table 2.3). Native concentration of ascorbic acid was estimated between 1-10 mM concentration whereas individual polyphenol molecules showed concentration mostly in the 0.01-0.25 mM range in most LVs (Table 2.2). Except in the case of Radish leaves and Rumex leaves which showed a high concentration of quercetin (>2.5 mM). Another set of fat-soluble antioxidant molecule viz., tocopherols, tocotrienols, carotenoids and phyloquinones showed wide variations among the thirty-four selected LVs. Concertation of the carotenoids was higher than the concentration of polyphenols among the targeted leafy vegetables. We calculated the total polyphenol to ascorbic acid ratio and total polyphenol to oil soluble vitamins (and their analogues) ratio which showed each plant/LVs had both ratios unique and there was no correlation between the two ratios (Fig. 2.6). This reflects while evaluating the antioxidant activity of such plant extracts or the whole LV products, not just the polyphenols but the native antioxidants like vitamin A, E, K, C are also important. Especially during chewing and further digestion in the GI tract, liberation and antioxidant activity of these molecules may show unique characteristics in individual plants/LVs. The mentioned molecules will have a different cellular locations, aqueous solubility, inherent redox property, and reactivity/ association with other small and polymeric molecules at different GI pH.

Table 2.1 Selected diseases of the GI tract associated with infection, motility and functional disorder and/or structural damage of the GI tract

			Infectious disease																		CNS–enteric nervous system dysregulation related disorders	Structural diseases of GI tract				
Descriptors absent in ICPC code related to digestive diseases	ICPC Code	Symptoms	*Escherichia coli*	*Salmonella*	*Shigella*	*Vibrio cholerae*	*Vibrio parahaemolyticus*	*Campylobacter*	*Clostridium perfringens*	*C. botulinum*	*Bacillus cereus* diarrheal emetic	*Yersinia enterocolitica*	Rotavirus, Adenovirus, Astrovirus, Noroviruses and Norwalk virus	*Giardia lamblia*	*Entamoeba histolytica*	*Cryptosporidium parvum*	*Enterobius vermicularis* (pinworm or threadworm)	*Ascaris lumbricoides* (large roundworm) and *Trichuris trichiura* (whipworm)	*Ancylostoma duodenale* and *Necator americanus* (hook-worms) and *Strongyloides stercoralis*	Motility and Functional GI disorder	Fissure	Hemorrhoids (piles)	Fistula	Chron's disease	Ulcerative colitis	Colorectal cancer
Prominent symptoms and disease: loss of appetite, ulcer, piles, colitis, laxative, dysentery, anthelmintic, colic, Biliary tract infections, worm infection, stomach ache and gastric ulcers, ring worm infection	D1	Abdominal pain/cramps general																								
	D2	Abdominal pain epigastric																								
	D3	Heartburn																								
	D4	Rectal/anal pain																								
	D5	Perianal itching																								
	D6	Abdominal pain localized other																								
	D7	Dyspepsia/indigestion																								
	D8	Flatulence/gas/belchin																								
	D9	Nausea																								
	D10	Vomiting									May be															
	D11	Diarrhoea				Abrupt watery							Watery	mild to foul-smelling, watery												
	D12	Constipation																								
	D13	Jaundice																								
	D14	Haematemesis/vomiting blood																								
Ill defined terms: Digestive problems, Good for digestion, Good for the liver, food poisoning, taken for stomach upsets, Improves digestion, strengthens liver, stomach ache, removes bowel troubles, Stomach disorder	D15	Melaena																								
	D16	Rectal bleeding																								
	D17	Incontinence of bowel																								
	D18	Change faeces/bowel movements																								
	D19	Teeth/gum symptom/complaint																								
	D20	Mouth/tongue/lip symptom/complt																								
	D21	Swallowing problem																								
	D22	Hepatomegaly																								
	D23	Abdominal mass NOS																								
	D24	Abdominal distension																								
	D25	Fear of cancer of digestive system																								
	D26	Fear of digestive disease other																								
	D27	Limited function/disability (d)																								
	D28	Digestive symptom/complaint other																								

Note: Yellow colour: Infections; Pink beige colour: Injuries

Table 2.2 Calculated molar concentration (μM) of major antioxidant molecules in fresh leafy vegetables

Compounds	3,4-Dihydroxy benzoic acid	Protocatechuic acid	Vannilic Acid	Gallic Acid	O-Coumaric Acid	P-Coumaric Acid	Caffeic Acid	Syringic Acid	Sinapinic Acid	Chlorogenic acid	Ferulic acid	Apigenin	Apigenin-6-C-glucoside	Apigenin-7-O-noehesperidoside	Luteolin	Kaempferol	Quercetin	Quercetin-3-β-D-glucoside	Quercetin-3-O-rutinoside	Quercetin-3-β-galactoside	Isorhamnetin	Myricetin	Resveratrol	Total Ascorbic Acid	α-Tocopherol Eq	Phyloquinones (K1)
Sesbania grandiflora	145	0	0	78	29	34	15	0	0	413	24	42	0	0	12	20	23	0	0	0	51	43	0	9230.36	55.21	8.02
Amaranthus gangeticus	59	0	74	0	0	34	35	0	0	59	94	0	0	0	0	0	0	197	0	0	0	0	0	5461.43	11.76	7.15
Amaranthus gangeticus	70	0	86	0	0	101	37	0	0	41	145	0	0	0	0	0	0	199	0	0	0	0	0	5720.29	12.48	8.09
Amaranthus gangeticus	48	0	96	0	0	47	37	0	0	68	101	0	0	0	0	0	0	208	0	0	0	0	0	5077.63	12.10	7.30
Amaranthus spinosus	0	0	0	0	0	43	261	0	0	64	0	0	0	0	0	30	56	0	0	0	0	0	0	5427.35	7.53	11.38
Amaranthus spinosus	0	0	0	0	0	51	283	0	0	87	0	0	0	0	0	36	65	0	0	0	0	0	0	5065.74	7.50	11.47
Basella alba	2	5	0	0	0	0	4	0	0	34	23	106	0	0	0	0	0	0	0	0	0	136	0	3880.99	4.01	5.65
Chenopodium album	29	0	6	0	0	0	14	0	0	10	1	0	0	0	0	0	0	0	42	0	0	0	0	2624.32	6.54	5.60
Beta vulgaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	16	0	0	0	0	0	0	2346.98	5.63	1.78
Piper betle	0	9	0	0	0	0	5	0	0	226	39	0	0	0	0	0	0	0	0	0	0	0	0	1230.09	1.37	5.41
Piper betle	0	21	0	0	0	0	16	0	0	30	10	0	0	0	0	0	0	0	0	0	0	0	0	1619.68	0.81	5.27
Brassica oleracea var. gemmifera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	52	42	32	0	0	0	0	0	0	6018.26	5.78	0.62
Brassica rupa	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1177.12	6.23	2.64
Brassica oleracea var. viridis	2	0	0	0	0	0	179	0	0	83	0	65	0	0	61	26	52	0	0	0	0	0	0	2584.92	5.19	3.10
Brassica oleracea var. capitata f. alba	1	0	0	0	0	0	239	0	0	77	0	60	0	0	68	101	13	0	0	0	0	0	0	2055.39	1.26	2.73
Brassica oleracea var. capitata f. rubra	4	0	0	0	0	0	241	0	0	86	0	67	0	0	65	104	14	0	0	0	0	0	0	2685.75	0.76	2.82
Brassica oleracea var. botrytis	0	65	0	5	0	48	151	5	9	0	100	0	0	0	10	24	23	0	0	0	0	0	25	3423.28	2.12	3.65
Colocasia esculenta	0	0	0	0	0	34	0	0	0	0	4	0	0	0	1	1	2	0	0	0	0	1	0	2764.55	1.94	8.44
Moringa Oleifera	0	24	0	0	0	75	4	0	0	22	5	0	0	0	0	0	0	0	0	0	0	0	0	8105.81	9.51	14.05
Trigonella foenum graecum	0	50	0	179	0	41	55	0	0	51	34	25	3	0	0	73	0	36	37	0	1	0	0	3813.36	9.64	10.95
Lepidium sativum	0	0	0	0	0	4	3	0	0	15	1	0	0	0	0	25	0	0	0	0	460	0	0	2888.92	20.45	12.09
Hibiscus cannabinus	0	0	0	0	0	28	32	0	0	6	160	0	0	0	0	0	14	39	9	0	0	0	0	1925.73	13.28	10.99
Hibiscus cannabinus	0	0	0	0	0	35	38	0	0	6	211	0	0	0	0	0	12	42	8	0	0	0	0	2286.49	13.20	11.05
Brassica oleracea var. gongylodes	5	0	0	0	0	39	0	0	0	3	0	17	0	0	0	0	0	0	0	0	0	15	0	4683.87	14.28	7.59
Lactuca sativa	0	0	0	0	0	0	0	0	0	110	0	48	0	0	105	5	3	5	1	72	0	2	0	732.88	0.25	2.19
Brassica juncea	0	0	0	0	0	169	105	0	0	10	157	0	0	0	0	69	54	0	0	0	1	0	0	3884.38	15.01	4.83
Brassica rapa var. chinensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3374.16	0.74	0.95
Petroselinum crispum	0	0	90	0	32	2	19	0	0	55	22	768	0	0	0	0	0	0	0	0	0	0	0	9711.29	10.45	9.19
Alternanthera sessilis	33	128	0	0	0	0	2	0	0	153	0	14	0	0	219	33	23	0	0	0	0	0	0	7362.65	15.78	16.03
Cucurbita maxima	0	0	0	0	0	18	26	0	0	6	17	0	0	0	0	0	21	0	0	0	0	0	0	815.75	45.72	6.28
Raphanus sativus	0	100	0	3	0	17	25	160	9	0	33	0	0	0	125	315	2522	0	65	0	0	0	0	4094.45	2.04	4.50
Rumex patientia	0	0	0	0	0	7	46	0	0	116	23	0	0	0	0	402	3066	0	0	0	0	0	0	3275.80	12.71	3.00
Spinacia oleracea	0	162	0	0	0	290	0	0	0	97	0	104	0	52	14	3	18	0	0	0	0	47	0	1903.71	33.16	7.98
Tamarindus indica	0	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2235.01	26.23	7.71

Note: Green colour: Low concentration; Yellow colour: Medium concentration; Red colour: Higher concentration

Table 2.3 Distribution of total polyphenol among thirty-four leafy vegetables consumed in India

Descriptive Statistics	Total polyphenols
Mean (µM)	563.3
Standard Error	136.8
Median (µM)	460.1
Mode	NA
Standard Deviation (µM)	797.5
Sample Variance	636010.6
Kurtosis	10.6
Skewness	3.2
Range	3658.9
Minimum (µM)	0.0
Maximum (µM)	3658.9
Sum	19152.5
Count	34.0
Largest (1)	3658.9
Smallest (1)	0.0
Confidence Level (95.0%)	278.3

Note: NA: Not applicable

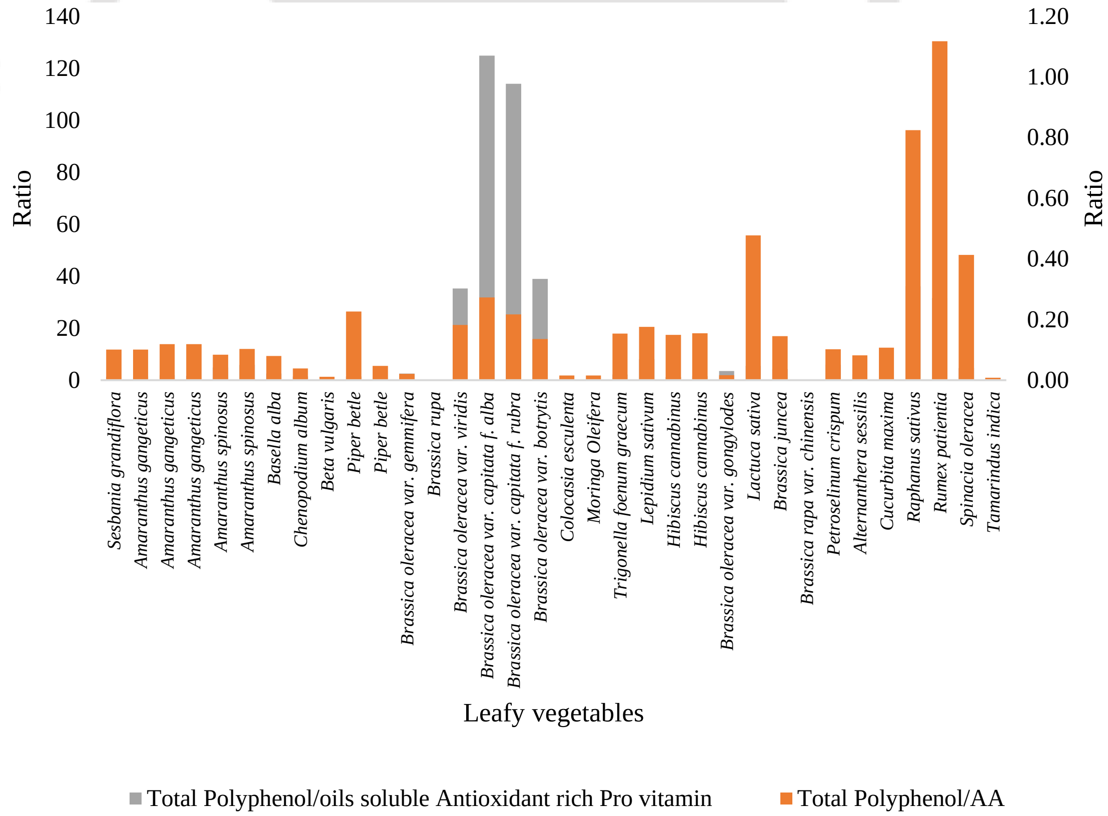

Fig. 2.6 Total polyphenol content and vitamins and their analogues ratio

The maximum possible concentration of various polyphenols in stomach was calculated assuming 50 g of (fresh or unaltered) intake of the leafy vegetable and at 100% liberation (Appendix A.3). These values are theoretical values and only roughly indicates the concentration possible when the orally processed food arrives in the stomach. The concentration of any bioactive in the stomach depends on gastric volume, gastric emptying rate, liberation rate and any reaction taking place in the gastric environment and on the liberation rate. For the sake of simplification, we have taken the gastric juice volume 28 mL (Steingoetter et al., 2006) for calculation of the polyphenol concentration. It is to be noted this concentration is sort of over estimation and in actual scenario the liberation of individual components will be incomplete. In case of compositional analysis, maximum extraction of a component is considered using best possible solvent (ethanol, hydroethanol etc.) and condition (solid particle size, temperature, use of aid like ultrasound etc.) unlike the aqueous extraction in stomach.

Table 2.4 Effect of different solvent on extraction of different conventional solvents like ethanol, hydroalcohol, water on different polyphenol from *Moringa oleifera* leaves

Compounds	Water	20% EtOH	50% EtOH	80% EtOH	EtOH
Neochlorogenic acid	57%	95%	100%	53%	17%
Chlorogenic acid	58%	96%	100%	52%	20%
Rutin	26%	82%	100%	94%	69%
Apigenin	ND	24%	100%	ND	ND
Quercetin 3-glucoside	23%	53%	99%	100%	53%
Quercetin	ND	ND	ND	44%	100%
Kaempferol 3-glucoside	18%	51%	93%	100%	50%
Kaempferol	5%	43%	100%	24%	12%
Vitexin	26%	57%	100%	74%	35%
Isovitexin	21%	58%	100%	61%	14%

Note: ND: Not detected; EtOH: Ethanolic extract.

In Table 2.4, we have analysed the effect of different solvent on extraction of different conventional solvents like ethanol, hydroalcohol, water on different polyphenol from *Moringa oleifera* leaves reported by Kashaninejad et al. (2021). In most cases, the aqueous phase composition will be half of the best extraction condition, but the actual value depends on the structure of the polyphenol. In the said report, the minimum (42% reduction) and maximum (95%) deviation were reported for, respectively chlorogenic acid and kaempferol in aqueous extraction. The other source of overestimation was gastric juice volume which can be a few hundreds of mL (~250 mL) during solid food digestion, and competitive reaction to utilize the polyphenols can take place. With the said limitation the maximum possible concentrations estimated for most polyphenols from the selected LVs in stomach or GI tract was less than 45 nM. One exception is chlorogenic acid which showed the highest concentration of 549 nM in *Sesbania grandiflora* leaves. Comparison of any two LVs reveals just because of the difference in the metabolome, the mixture of polyphenols available in the stomach will be quite different (Fig. 2.7) as can be seen by the distribution of the 36 polyphenols analysed. Also, the concentration of the antioxidant molecules other than the polyphenols were also quite varied. From the compositional data of LVs a multiphase environment can be modelled in GI Tract (in stomach and intestine) (Fig. 2.8). Hence out of the three cases of leafy vegetable-based foods (Fig. 2.5) for Case III (and Case II with lesser quantity of solid particulates) the matrix effect will be minimum and perhaps the role of oil phase can be minimized.

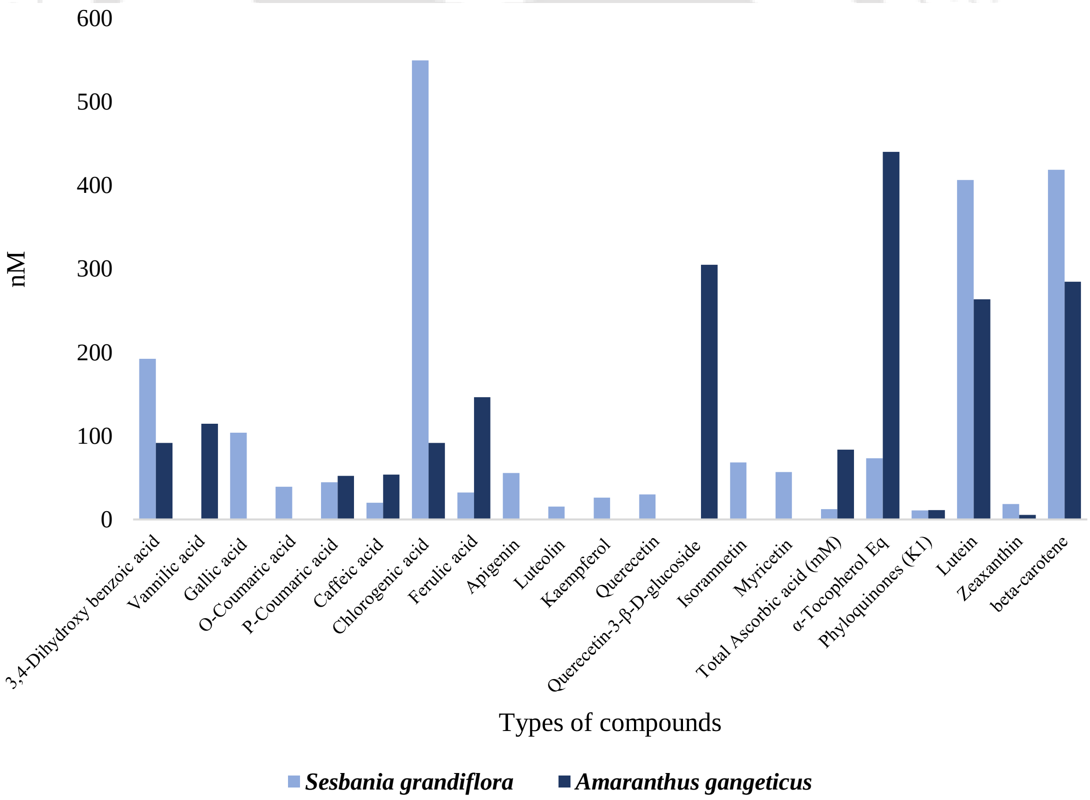

Fig. 2.7 Difference in the metabolome in mixture of polyphenol of two different LV in available in the stomach

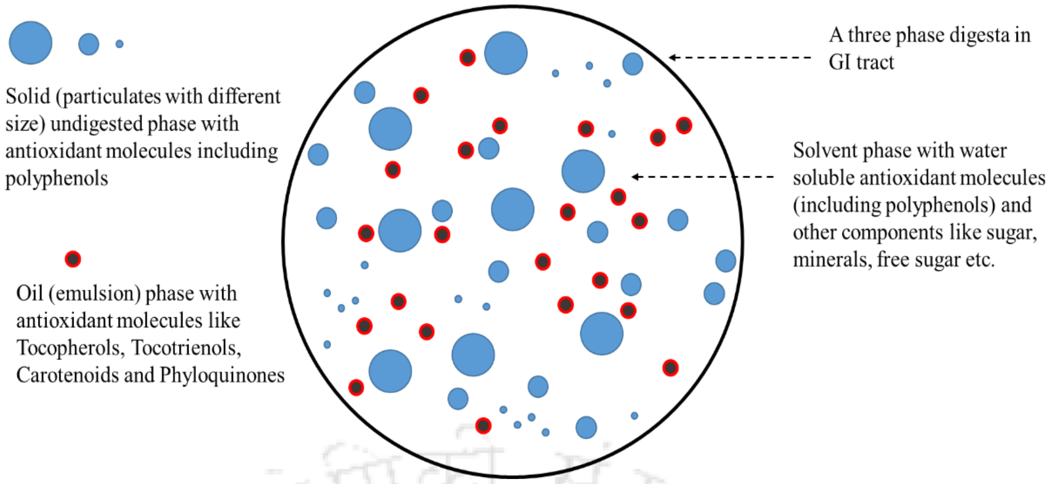

Fig.2.8 Compositional data of LVs a multiphase environment can be modelled in GI Tract (in stomach and intestine)

2.2.3. *In silico* determination of the effect of the polyphenols of the leafy vegetables in the upper GI tract

Once the LVs are ingested alone or as part of a composite meal (depicted in Case I of the Fig. 2.5) the chewing and agitation of the tongue cause its physical disintegration and mixing with the saliva. The resultant mass formed in the mouth (bolus) passes through the oesophagus to stomach. In the stomach, the bolus is mixed with gastric secretions consisting of HCl, pepsin, gastric lipase enzymes, electrolytes, mucus and some intrinsic factors. In stomach further physical and chemical degradation of the LV matrix occurs rendering partial liberation of polyphenols and other antioxidant molecules in soluble (water) phase. From stomach the digesta (with a particle size <1 mm) passes to intestine where remaining carbohydrate and protein plus the fat gets digested and absorb. However, *in vitro* studies have suggested that the during the 2 h of gastric digestion followed by another 2 h of intestinal digestion causes 10-100% residual undigested polyphenols from LVs depending on the structure of the molecules (Spínola et al., 2018). The digestibility of (Case I form) LVs and bioaccessibility of each polyphenol may vary between species to species. For example, Gunathilake et al. (2018) showed that 14.4%, 28.3%, 77.4%, 31.3%, 17.0% and 26.0% of the total polyphenol content (in terms of gallic acid equivalent) was recovered after gastro-intestinal digestion of *Cassia auriculata, Olax zeylanica, Centella asiatica, Gymnema lactiferum, Sesbania grandiflora* and *Passiflora edulis* leaves. The same study showed the concentration of β-carotene and lutein during simulated gastric digestion reduced to respectively 13.8%, 23.0%, 51.1%, 27.1%, 49.2%, and 41.8% and 16.3%, 34.6%, 120.4%, 38.7%, 54.3% and 83.7% for the six plants *Cassia auriculata, Olax zeylanica, Centella asiatica, Gymnema lactiferum, Sesbania grandiflora* and *Passiflora edulis*. Morreover, β-carotene was 100% bioaccessible in the intestinal phase the other carotenoid lutein was not at all bioaccessible. Polyphenols and other water and oil soluble (antioxidant) components can form a three phase dispersion (undigested solid, lipid and aqueous solution as shown in Fig. 2.8) which most likely contributes in three ways; interacting with the gut wall (epithelial tissue including all kinds of secretive cells like Goblet, Paneth, and enteroendocrine cells, the enteric nerves, and immune cells like lymphocytes and macrophages), interacting directly with the microbial cells (both transient and colonizers) and reacting with the other digesta components in the GI lumen. From the discussion above it is quite obvious for whole leafy vegetable foods a significant amount of the polyphenols and other antioxidant molecules (e.g., carotenoids) reach the colon. Especially for Case I type of products the amount will be dependent on the motility of the GI tract.

In this section, we did an *in-silico* analysis to understand whether the polyphenols and some other antioxidants can undergo xenobiotic metabolism alike drug molecules. The intestinal wall contains xenobiotic metabolizing enzymes and export proteins, of which the most important are Cytochromes P450 enzymes (CYPs) and Permeability glycoprotein (Pgp). Pgp and the family of CYPs work together to metabolize the molecules in the gut and then in the liver to excrete from the system (Andersen & Sonne, 2000). Pgp is an ABC-transporter responsible for influx or efflux of different organic molecules via the cell membrane. If a molecule is a substrate to the transporter, it can excrete a xenobiotic molecule into the gastro intestinal lumen. Using the online tool SwissADME relevant metabolic functions were evaluated. The polyphenols like chlorogenic acid, apigenin-6-c-glucoside, apigenin-7-o-noehesperidoside, luteolin, quercetin-3-β-d-glucoside, quercetin-3-o-rutinoside, quercetin-3-β-galactoside, myricetin, resveratrol and all the oils soluble tocopherols and tocotrienols, carotenoids and vitamin K had a lesser probability of GI absorption whereas other polyphenols and ascorbic acid among all the 38 antioxidant molecules had ability to absorb through the gut wall (Table 2.5). Similarly, except apigenin-7-o-noehesperidoside, quercetin-3-o-rutinoside and the oil soluble molecules none of the other 22 polyphenols were Pgp substrate - like feature.

Table 2.5 Antioxidant molecules to absorb through gut wall

Antioxidant Compounds	GI absorption	BBB permeant	Pgp substrate	CYP1A2 inhibitor	CYP2C19 inhibitor	CYP2C9 inhibitor	CYP2D6 inhibitor	CYP3A4 inhibitor	log Kp (cm/s)
3,4-Dihydroxy benzoic acid	High	No	No	No	No	No	No	Yes	-6.42
Protocatechuic acid	High	No	No	No	No	No	No	Yes	-6.42
Vannilic Acid	High	No	No	No	No	No	No	No	-6.31
Gallic Acid	High	No	No	No	No	No	No	Yes	-6.84
Cinamic Acid	High	Yes	No	No	No	No	No	No	-5.69
O-Coumaric Acid	High	Yes	No	No	No	No	No	No	-5.86
P-Coumaric Acid	High	Yes	No	No	No	No	No	No	-6.26
Caffeic Acid	High	No	No	No	No	No	No	No	-6.58
Syringic Acid	High	No	No	No	No	No	No	No	-6.77
Sinapinic Acid	High	No	No	No	No	No	No	No	-6.63
Chlorogenic acid	Low	No	No	No	No	No	No	No	-8.76
Ferulic acid	High	Yes	No	No	No	No	No	No	-6.41
Apigenin	High	No	No	Yes	No	No	Yes	Yes	-5.8
Apigenin-6-C-glucoside	Low	No	No	No	No	No	No	No	-8.79
Apigenin-7-O-noehesperidoside	Low	No	Yes	No	No	No	No	No	-9.94
Luteolin	Low	No	No	No	No	No	No	No	-8.79
Kaempferol	High	No	No	Yes	No	No	Yes	Yes	-6.7
Quercetin	High	No	No	Yes	No	No	Yes	Yes	-7.05
Quercetin-3-β-D-glucoside	Low	No	No	No	No	No	No	No	-8.87
Quercetin-3-O-rutinoside	Low	No	Yes	No	No	No	No	No	-13.06
Quercetin-3-β-galactoside	Low	No	No	No	No	No	No	No	-8.88
Isorhamnetin	High	No	No	Yes	No	No	Yes	Yes	-6.9
Myricetin	Low	No	No	Yes	No	No	No	Yes	-7.4
Resveratrol	High	Yes	No	Yes	No	Yes	No	Yes	-5.47
Total Ascorbic Acid	High	No	No	No	No	No	No	No	-8.54
Alpha Tocopherols	Low	No	Yes	No	No	No	No	No	-1.33
Beta Tocopherols	Low	No	Yes	No	No	No	No	No	-1.51
Gama Tocopherols	Low	No	Yes	No	No	No	No	No	-1.51
Delta Tocopherols	Low	No	Yes	No	No	No	No	No	-1.68
Alpha Tocotrienols	Low	No	Yes	No	No	No	No	No	-2.28
Beta Tocotrienols	Low	No	Yes	No	No	No	No	No	-2.46
Gama Tocotrienols	Low	No	Yes	No	No	No	No	No	-2.46
Delta Tocotrienols	Low	No	Yes	No	No	No	No	Yes	-2.63
Phyloquinones (K1)	Low	No	Yes	Yes	No	No	No	No	-1.3
Lutein	Low	No	Yes	No	No	No	No	No	-1.95
Zeaxanthin	Low	No	Yes	No	No	No	No	No	-2.02
Alpha-carotene	Low	No	Yes	No	No	No	No	No	0.12
Beta-carotene	Low	No	Yes	No	No	No	No	No	0.04

Most of the selected 38 antioxidant molecules from LVs showed no inhibition towards the five CYPs except in case of CYP3A4, one of the most potent xenobiotic monooxygenase. 3,4-dihydroxy benzoic acid, protocatechuic acid, gallic acid, apigenin, kaempferol, quercetin, isorhamnetin, myricetin, resveratrol, delta tocotrienols showed inhibition towards CYP3A4. This reflect in a mixture of polyphenols (or antioxidant) the xenobiotic metabolism may be inhibited by one or more molecules, to cause local accumulation of some of the polyphenols. This fact further asserts that the beneficial effect of polyphenols (and other antioxidant molecules) from leafy vegetables cannot be just because its action in the upper GI tract metabolism and via systematic circulation. The role of intestinal accumulation cannot be ignored.

2.2.4. *In silico* determination of the effect of the polyphenols of the leafy vegetables in the lower GI tract and colonic gut microbiota

Proof of health benefits of dietary polyphenol - rich foods like tea, fruit, and vegetables are epidemiological studies based. Many animal and human-level studies have established that native forms of complex dietary polyphenols have limited bioavailability, with low circulating levels in plasma (van Duynhoven et al., 2011). So, a significant part of dietary polyphenols goes to the colon, where they can be metabolized by the diverse range of resident microbiota. The 10^{12} microorganisms per gram of digesta in the colon can produce metabolites from the polyphenols that can exert some benefit in the gut level or undergo absorption and subsequent metabolism in the body. To be absorbed in the intestine, polyphenolic compounds must be deconjugated using glycosidases or carboxylesterases. We have used Biotransformer 3.0, a freely available web server that supports accurate, rapid and comprehensive *in-silico* metabolism prediction in human tissues and microbial transformation in the human gut. The polyphenols quantified in the thirty-four leafy vegetables were checked for being substrate for different gut microbiome enzyme. Appendix A.4 indicates the enzymatic reactions identified for the targeted polyphenols except for apigenin-7-o-noehesperidoside, quercetin-3-β-d-glucoside, quercetin-3-o-rutinoside and quercetin-3-β-galactoside for which Biotransformer analysis was returning zero results. Twenty-six types of enzymatic transformations (Table 2.6) were identified, which is possible for the polyphenols of LVs. Till date, gut microbial metabolism of polyphenols is less known. The current analysis indicates the kind of transformation that can take place for a class of polyphenols in gut. Also, it indicates why the polyphenols from LVs may lead to selective growth of specific classes of microorganisms.

Table 2.6 Biotransformer enzymatic transformations

Sl. No	Enzyme(s)	Reaction
1.	Unspecified bacterial decarboxylase	N-Glucuronidation of azole
2.	Unspecified bacterial dehydroxylase	Carnitine conjugation
3.	Unspecified bacterial dehydroxylase	2-Acetyl hydrolysis of 1-alkyl, 2-acetyl-glycerol-3-phosphocholine
4.	Sulfotransferase	Decarboxylation of aromatic L-amino acid
5.	Sulfotransferase	Epoxidation of arene
6.	Unspecified bacterial dehydroxylase	2-Hydroxylation of 1,4-disubstituted benzene
7.	EC 1.6.99.1	Reduction of alpha, beta-unsaturated carbon-carbon double bond adjacent to electron withdrawing group
8.	Bacterial UDP-glucuronosyltransferase	Aromatic OH-glucuronidation
9.	Bacterial UDP-glucuronosyltransferase	O-Glucuronidation of aliphatic acid
10.	EC 1.6.99.1	Phosphatidylcholine sitosterol O-acylation
11.	Bacterial phenolic acid decarboxylase (EC 4.1.1.-)	NitrosoReduction from CyProduct
12.	Bacterial UDP-glucuronosyltransferase	alpha-amino acid to aldoxime
13.	Unspecified bacterial dehydroxylase	Carnitine conjugation
14.	Sulfotransferase	alpha-Amino acid to aldoxime
15.	Bacterial phenolic acid decarboxylase (EC 4.1.1.-)	Decarboxylation of phenolic acid
16.	Bacterial UDP-glucuronosyltransferase	Aromatic OH-glucuronidation
17.	EC 3.1.1.1	Hydrolysis of carboxylic acid ester
18.	Bacterial UDP-glucuronosyltransferase	Alkyl-OH-glucuronidation
19.	EC 2.1.1.6	Catechol O-methylation
20.	Unspecified gut bacterial enzyme	Flavonoid C-ring reduction
21.	Unspecified bacterial dehydroxylase	4'-Dehydroxylation of substituted benzene
22.	Sulfotransferase	Sulfation of primary alcohol
23.	Sulfotransferase	Sulfation of secondary alcohol
24.	Unspecified_microbial_bile_acid_amino_acid_n_acyltransferase	3-OH-Sulfonation of phenolic compound
25.	Unspecified_microbial_bile_acid_amino_acid_n_acyltransferase	Eawag_rule_bt0173
26.	Unspecified bacterial dehydroxylase	N-Methylation of phosphatidyl-N-monomethylethanolamine

2.3. Summary

A database of 310 leafy vegetables were made particularly covering their consumption pattern, perceptive health benefit and bioactive compounds. It was noticed that the perceptive health benefits need to be mapped with a universally accepted code like the

International Classification of Primary Care of WHO; otherwise, preventive/curative action of a specific LV for a disease cannot be identified. Though many of the leafy vegetables have been reported to be used in digestive disorders, it requires further investigation to assign any scientific evidence to such perception. To link polyphenols of leafy vegetables with antioxidant properties and some therapeutic value, simulation of gut concentration of thirty-four leafy vegetables enlisted in the NINs database was done. The diversity of polyphenols was relatively high but individual concentrations of these polyphenols were in the mM range. Moreover, they can undergo significant loss during digestion. Therefore, the individual polyphenol molecules might not reach the blood in such high concentration that can impart any beneficial effect in a distant organ from the gut like the heart, brain, etc. However, they may have a significant effect inside the gut. The theoretical study suggested the polyphenols may work in tandem with other antioxidant molecules like ascorbic acid, vitamin A, E and carotenoids since they also exist in much higher concentrations compared to individual polyphenol molecule. In a separate *in-silico* study twenty-six enzymatic reactions were identified that supports the undigested polyphenols may have a role in the microbial metabolism in the intestine and may impact the progress of gut infection and other disorders. From the perspective of gut digestion, the LV products can be categorized into three types; Case I-solid or near intact LV products (e.g., salad, steamed leaves, etc.), Case II-slurry kind of product (e.g., paste, curry, etc.) and Case III water extracts without insoluble phase (e.g., clarified juice or beverages). In this thesis Case III type of products was selected for further investigation which has better possibility of local effect in the gut-related ailments. Also, we have selected four LVs from the 310 plants in the database with known ethnomedicinal documentation for digestive disorder. *Centella asiatica*, *Enhydra fluctuans*, *Eryngium foetidum*, and *Marsilea minuta* were to be evaluated in subsequent section for their use of herbal beverage and whether they have any antioxidant and prebiotic properties.

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Chapter 3

Polysaccharides of leafy vegetables: a narrative review

Chapter 3

3. Introduction

Leafy vegetables are important part of human diet and well recognized for its nutritional and often medicinal values. Botanically the term leafy vegetable is not well defined. The term should strictly refer to leaves which is eaten with meals in cooked form. However, in common practice across cultures, a great variety of leaves or plant parts with leaves are consumed in different processed forms and not necessarily only with meals. Sometimes they overlap with herbs, medicinal leaves and weeds as famine food. Hence in this chapter, all such plants are included where leaves are the major part consumed in ether raw or processed form. Typically, basic nutritional properties of such leaves are known but their extended functions like their therapeutic values, drug-food interactions or other broader physiological impacts are yet to be studied. Though a leaf contains myriad of molecules and most of them are having some or the other effect on human health. This chapter deals with one such group of compounds called polysaccharides and their beneficial as well as detrimental effect on human health.

Though polysaccharides/glycans are defined as chains consisted of more than 10 units of monosaccharides some shorter chains or oligosaccharides (i.e., chains containing 3-10 monomer units) are also included in the scope of the chapter for the sake of complicity. Based on structure, polysaccharides are classified as homopolysaccharide i.e., those consisted of only one type of sugar unit (e.g. glucans, fructans, mannans, etc.) and heteropolysaccharides i.e. those composed of two or more types of sugar units (e.g. like arabinoxylans and glucomannans). In terms of functions, they can be further classified as dietary fibre, prebiotics, immunostimulant and antioxidant polysaccharides (Xu, 2017).

So far, many polysaccharides from different plant sources have been studied and utilized and serves as an important component of food products, nutraceuticals, pharmaceuticals and other industrial products like packaging film, adhesive etc.

However, very few leafy vegetables are known for their polysaccharides with significant nutritional or medicinal properties. In this communication the aim is to facilitate applications of leafy vegetable polysaccharides through understanding of their chemical, nutritional and medicinal properties in isolated or in native form.

3.1. Polysaccharide localization in leaves

In order to exploit the wealth of leaf-polysaccharides for various functional and medicinal properties, knowledge about their localization and metabolic role in leaves is important. Primarily three cellular substructures of leaves are pertinent with respect to polysaccharides and oligosaccharides; cell wall, vacuoles, and plastid. Cell walls of plants including leaves are made up of a principle structure and an auxiliary structure. The principle structure is consisted of cellulose microfibrils and hemicellulose which is further entrenched by pectic polysaccharides (Carpita et al., 1993; McCann et al., 1991) (Fig 3.1). This hemicellulose and the pectic polysaccharides are the major source of polysaccharides in leaves. Another special source of polysaccharides and oligosaccharides (e.g., fructans) are the vacuoles of plant cells. Vacuoles are very important for plants due to their multiplicity of roles as storage compartment and lytic organelle (Eisenach et al., 2015). In a plant cell, plastid is a complex organelle for synthesis and storage of many physiologically important molecules including starch. However, the starch in leaves are usually transitory in nature. It typically gets synthesized in day time subsequent to photosynthesis and degrades during the night time to meet metabolic demand of energy and C-precursor. Starch chains in leaves are quite different than their seed counterpart. Such as, degree of phosphorylation is more in seed/tuber cells than that in leaves (Pfister et al., 2016). In addition to these cell organelles some small amount of polysaccharides including complexes like glycoproteins can be identified in various other subcellular compartments.

3.2. Structural illustration of some relevant polysaccharides from leaves

Polysaccharides are highly diverse in structure and biological functions. A wide variety of linear or branched polysaccharide structures can be seen in various leaves. Sometimes the polysaccharide chains are cross-linked to give rise to a complex substance like pectin. Often these heteropolysaccharides are quite challenging to characterise. With the advancement of extraction techniques and sophisticated analytical methods some of these structures have been established. The ubiquitous plant polysaccharides like starch and cellulose are excluded here because there are numerous reviews available on them. Instead other polysaccharides typical but not always exclusive to leaves are listed below (Fig. 3.2). Many of them has shown beneficial effect in human body. This section explores structural and other important physicochemical aspects of the such polysaccharides present in leaves viz., fructans, hemicelluloses and pectins.

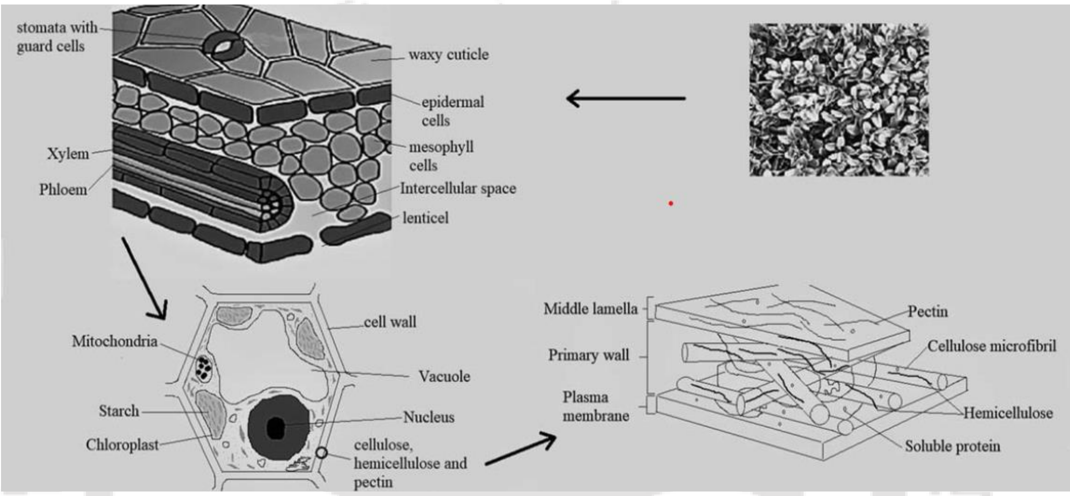

Fig. 3.1 Localization of major polysaccharides in plant leaves

Hemicellulose is the most common component of the cell wall in all plant tissues including leaves and represent a heterogeneous group of polysaccharides. They contain a backbone structure with either of the sugars like xylose, mannose, glucose, galactose. Apart from the main chain it might have side chains with other sugars or sugar derivatives like arabinose, fucose and methyl glucuronic acid etc. as side chains. It is the alkali soluble fraction of the cell wall polysaccharides. Hemicellulose branches with smaller chains that are degraded easily and has much smaller degree polymerization (i.e., 50-200) compared to that of cellulose (i.e., 300–15000). The hemicellulose content in dried leafy vegetables are in the range of 15-34 g/100g on dry basis (Islam et al., 2004). With the availability of the sophisticated separation (e.g., chromatographic, electrophoresis) and analytical techniques (spectroscopy, nuclear magnetic resonance, mass spectrometry, electron microscopy etc.) knowledge of these hemicellulose structures is evolving very rapidly. Depending on the primary chain forming monomer and side chains hemicellulose can be categorized further.

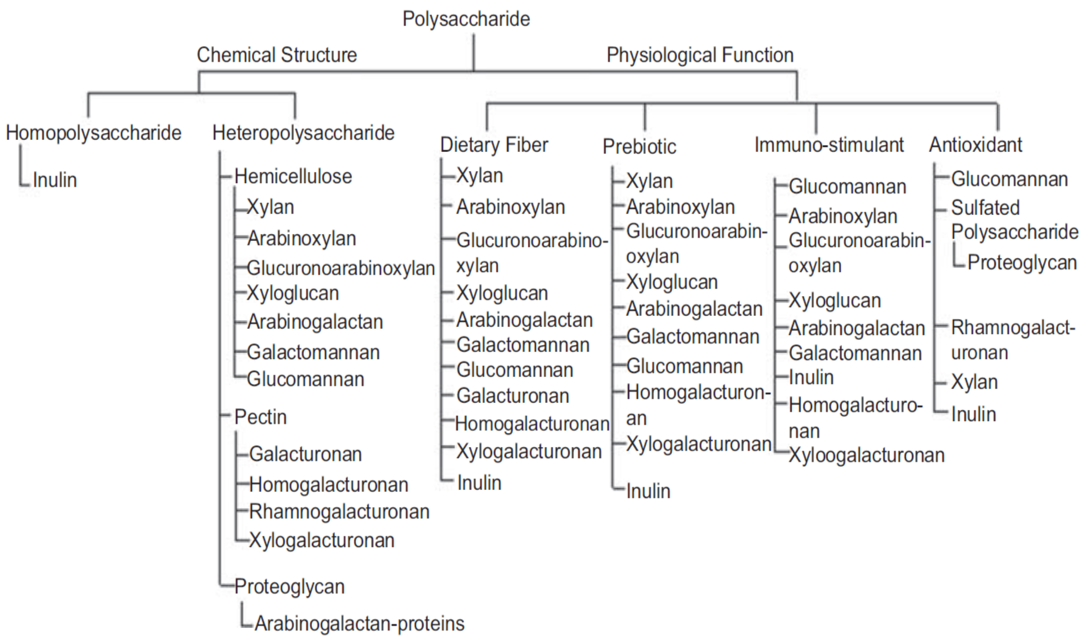

Fig. 3.2 Structure and biological function of polysaccharide

3.2.1. Fructans

Some plants do not store C-source as starch instead they store in the form of polymer of fructose called fructans. Fructans help the plant in resisting drought and cold conditions. On the basis of monomer-monomer bonding fructans can be of three types; inulins with β 2-1 bonds (Fig. 3.3a), levans with β 2-1 bonds and gramminans with both types of bond. Out of the three fructans inulins are found to be prebiotic in nature. Apart from that, in many species inulin provides protection in membrane during dehydration. Membrane lipid interact more with inulin-fructans than levan-fructans (Kays & Nottingham, 2008). However, this polysaccharide is dynamic in nature. In leaves at night, inulin is transformed to sugar (i.e., fructose) and get transferred within the plant tissues. Fructose chain of different chain occurs during this transition. That are the reason leaves contain the inulins with variety of structure starting from just two monomers length to sixty monomer length. The stems and stalk also contain inulin along with fructooligosaccharides or oligofructose (degree of polymerization below 10) and fructose. Low molecular weight structural polysaccharide and fructans are more in stems compared to leaves. Inulin in the stems increases from arial part to root. Long chain inulins are found more towards the middle of the stem in lignin-containing tissues, while shorter chain inulin molecules are more prevalent towards the stem base. Chicory (*Cichorium intybus* L.) is one example of leafy vegetables that contains high amount of inulin which can be as high as 15% of the fresh weight (f.w.) and 75% of the dry weight (d.w.).

3.2.2. Xylans

Xylans are a class of polymer consists of β-1, 4 xylopyranose linkages and acts as a crosslinking polymer among cellulose microfibrills and lignin component of plant cell wall (Fig. 3.3b) (Anand et al., 2009). Structure, composition and their metabolism of xylans differs widely in different plant species and even in the same species grown in dissimilar conditions. In leaves hardly pure xylan chain is available. The xylan may have different types of branches consisting of acetyl, arabinosyl, and glucuronosyl residues which mainly depends on origin of compound and way of extraction but most common residue (Ochoa-Villarreal et al., 2012). The xylan chain containing α-D-glucopyranosyl uronate residue or more specifically 4-O-methyl-α-D-glucopyranosyl uronate residues are called Glucuronoxylan. Glucuronoxylan is mostly part of secondary cell wall. As in mulberry leaves the polysaccharide content increases with decreases in protein and water activity.

3.2.2.1. Arabinoxylan

Arabinoxylans are composed of branched side-chain of arabinose with the backbone of xylose chain (Rivière et al., 2014). The branching pattern is diverse in different species. Usually, the skeleton contains β- anomer of xylose and α-anomers of arabinose residues. Often the arabinose residue is bonded with glucuronic acid, ferulic acid and acetyl groups. In a recent study an unusual arabinoxylan has been reported.The green leaves of *Litsea glutinosa* contains arabinoxylan consists of →4)--d-Xylp-(1→ structure, interchanged at C-2 position by -l-Araf-(1→3)--l-Araf-(1→3)--l-Araf-(1→. This molecule showed strong phagocytotic and immune activation along with the activation of T- and B-lymphocyte. The isolated arabinoxylans posess arabinose residues with both α- and β- anomers (Das et al., 2013).

3.2.2.2. Glucuronoarabinoxylan

Glucuronoarabinoxylan are a type of xylan with arabinosyl and/or glucuronyl residues. possesses the β-4-linked xylopyranosyl structure give a detailed account for similar polysaccharides in dicot and also in the primary and secondary monocot cell walls.

They form hydrogen-bond to cellulose and therefore, strengthen the cell wall (Darvill et al., 1980). Only 5% of the cell wall content is glucuronoarabinoxylan in the dicotyledons whereas cell walls in monocotyledons contain 25% glucuronoarabinoxylans. The neutral arabinoxyl- and/or xylosyl-containing sidechains, a common structural feature of the primary and secondary walls of monocots. Unlike glucuronoxylan in glucuronoarabinoxylan there are no uronosyl residues in the middle of the chain but all the residues are located at the end. In stronger leaves like Aechmea the presence of glucuronoarabinoxylan is more.

3.2.2.3. Xyloglucan

Xyloglucan possesses 1,4-β-glucan structure with 1,6-a-xylosyl residues (Hayashi et al., 2011). Chemically, the structure of xyloglucan is rigid and identical with cellulose i.e., straight-chain polymer of β-(1-→4)-linked D-glucopyranose residues. The distribution of side-chains with the structure there are some homogeneity (Fry, 1989). In dicotyledons, xyloglucan is present in middle lamella of primary wall and its content in the dry matter is around 20%. It is also present in non graminaceous monocots and in gelatinous plants. In different plant species, the substitution of side chain xylosyl residues with different monosaccharides, disaccharides or trisaccharides produces broad array of xyloglucan structures (Zabotina, 2012).

3.2.3. Mannans

Mannans are plant polysaccharise with linear or branched chains primarily made up of D-mannose. The basic mannose chain branches with D-galactose, and D-glucose and gets the nomenclature as galactomannan and glucomannan respectively. Though the total mannan content and branching of mannan chains depends on the plant species. It is one of the principle component of plant hemicellulose and sometimes acts as C-source storage molecule. During metabolism both *endo* and *exo* type hydrolases hydrolyses the mannan backbone to produce variety of oligosaccharides and fermentable sugars.

3.2.3.1. Glucomannan

Glucomannan is abundantly available in plant species (e.g., *Plantago major*). However, glucomannan matrix depends on the source or origin which can change the ratio of mannose/glucose monomer. The shape of the glucomannan polymer is similar to cellulose (Alonso-Sande et al., 2009). In the photosynthetically active leaves, the outer green cortex contains glucommanan but in the parenchyma cells it exists in acetylated form (called as acemannan). Glucommanan helps in maintaining cell moisture content. It gets synthesized in Golgi apparatus and travels out of the cell to form part of the cell wall (Salinas et al., 2018).

3.2.3.2. Galactomannan

It is a group of polysaccharides with rigid hydrophilic backbone (polymannose, or mannan), and grafted galactose units. In terms of its distribution in the plant world, this biopolymer represents the second largest group of storage polysaccharides. It has been identified that some of the leafy vegetables like fenugreek leaves, butterfly pea leaves contain galactomannan with antioxidant, immunostimulant activity (Paulovicˇová et al., 2017).

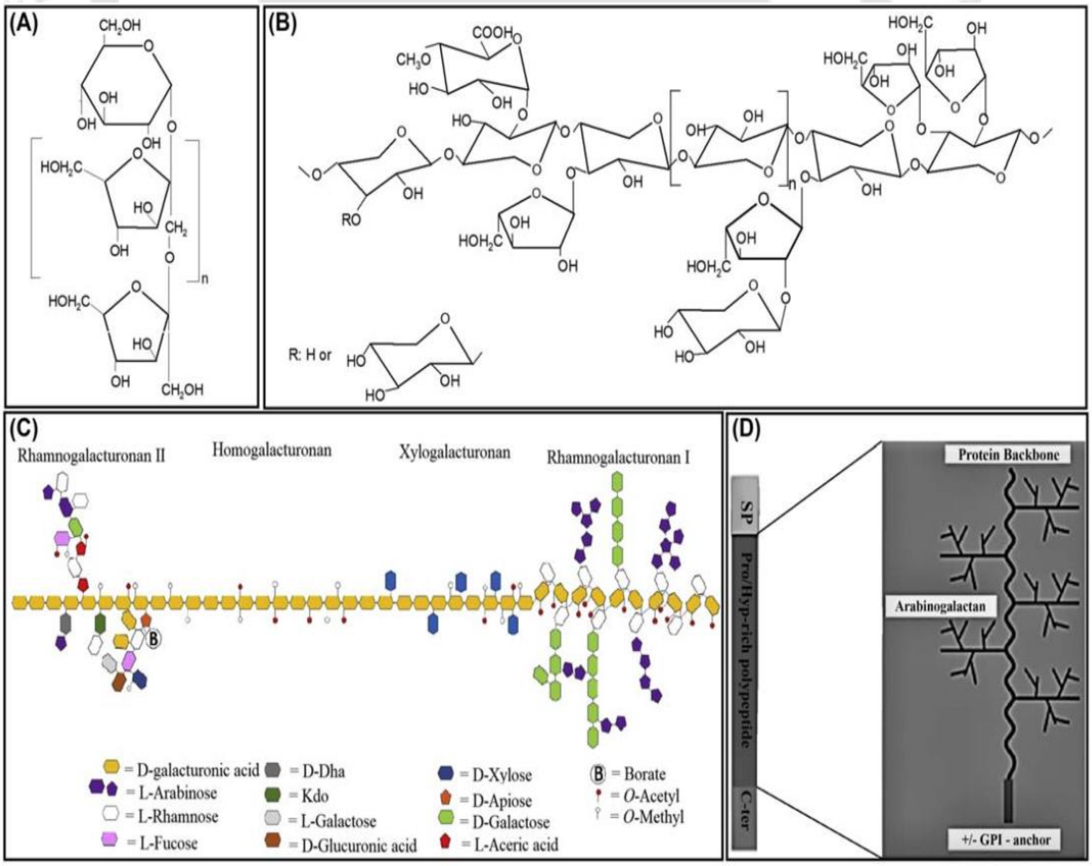

Fig. 3.3 a) Chemical structure of Inulin (Nwafor et al., 2017); b) Chemical structure of Xylan (Ebringerova, 2000); c) Chemical structure of Pectin substances (Harholt et al., 2010); d) Proteoglycan (example; Arabinogalaction – proteins) (Coimbra and Pereira, 2012).

3.2.4. Pectin

Pectin represents a complex group of cell wall polysaccharides in plants that plays role in cell wall growth, intercellular communication and cellular defence (Jarvis, 1984). It is synthesized in Golgi Apparatus and get transported to the middle lamella or space between two adjacent cells in a tissue (Jensen et al., 2008). Pectin content and its structure and chemical composition varies in different plants. Structurally they are hetero-polymers with galacturonic acid as the major component. The composition of these polysaccharides is often so complex that establishing their structure accurately is a daunting task. Pectic polysaccharides are classified are homogalacturonan, rhamnogalacturonan I, rhamnogalacturonan II and xylogalacturonan (Fig. 3.3c) (Hamman, 2010). Though pectin is mostly extracted from fruits (e.g., apple, apricots, oranges etc.) but it is also found in leafy vegetables especially in brassica species.

3.2.4.1. Homogalacturonan

Homogalacturonan (HG) is a straight chain polymer of α-1,4-linked D-galacturonic acid with a mean chain length of 100 units. It represents almost 65% of the total pectic substances. The galacturonan chain may contain monomers with esterified (C-6) carboxylic group and/or hydroxyl group (at O-2/O-3 position). The degree and type of esterification varies in different plant species (Wolf et al., 2009). The negatively charged unmethylated HG may form complex with Ca^{2+}. If proper atmosphere is provided to produce the network through such complexation of unmethyl-esterified GalA residues a stable gel result the process is called gelation (Darvill et al., 1985).

3.2.4.2. Rhamnogalacturonan

These pectic polysaccharides are composed of disaccharide subunits of GalA (galacturonic acid) and Rha (rhamnose). Rhamnogalacturonans-I & II (RG I & RG II)) are two different types of this heteropolymer. Rhamnogalacturonan I is the major one which represents 20-35% of pectin. In RG I, the galacturonic acid residue is bonded with one neutral glucosyl residue and α-L rhamnose residues are bonded with different polymeric side chains like α-(1,5)-L arabinans, β-(1,4)-D galactans, arabinogalactans-I and II and galacto-arabinans (Wolf et al., 2009). RG-I interconnected covalently with side chain of other pectic components such as HG and RG-II (Darvill et al., 1985).

Rhamnogalacturonans-II is a minor pectin component with 0.5 to 8% presence in dicotyledons and > 0.1% in monocotyledons. Usually in plant cell wall, rhamnogalacturonans-II exists as dimers interlinked via apiosyl residues (Mohnen, 2008). The pectic polymers (HG, RG-I and RG-II) covalently combines to give strength as well as flexibility to cell wall (Ochoa-Villarreal et al., 2012). There are many leaves and leafy vegetables contains rhamnogalacturonans such as *Arabidopsis thaliana*, *Panax ginseng*, *Salvia officinalis*, *Impatiens parviflora*, *Artemisia princeps*, *Mesembryanthenum crystallinum*, *Gingko Biloba* and have high antioxidant activity.

3.2.4.3. Xylogalacturonan

As the name suggests this pectic component contains a primary chain of galacturonic acid with xylose residues as side chain. Xylogalacturonan is mostly present in reproductive tissues along with other tissues including leaves (Jensen et al., 2008). In the "hairy" portions of pectin, xylogalacturonan is a side chain of rhamnogalacturonan I (Zandleven et al., 2007). The ratio of β-xylose and galacturonic acid may vary significantly, depending on the origin of the xylogalacturonans (Caffall et al., 2009).

3.2.5. Arabinogalactan

Arabinogalactan comes under a class of hetero-polysaccharides or more precisely proteoglycans (Fig. 3.3d). This molecule is part of hemicellulosic polysaccharide in the cell walls of plants but also capable of cross-linking with membrane proteins possibly to play a role in the intercellular signaling, healing of damaged tissues and many other cellular events (Tan et al., 2013). They are categorized into two types; Arabinogalactan I (AG I) and Arabinogalactan II (AG II) based on arrangement of galactose and arabinose units. AG I consist of glactose residues with combination of β 1-3, β 1-4, and β1-6 linkages. In AG II the galactose backbone (β1-3 linked) contains terminal arabinose or rhamnose residue. The Arabinogalactan-Protein (AGP) complex contain more than ninety percent polysaccharide with some Hyp/Pro, Ala, and Ser/Thr rich peptides.

In the context of leafy vegetables, it was found that cabbage leaves mainly contain water soluble proteoglycan (Yasufuku et al., 2014). One of the characteristic features of AGP in leaves of brassicaceous (cruciferous) plants, Arabidopsis, radish, rape leaves and common plantain is the presence of L-Fucose in the peptidoglycan (Samuelsen et al., 1998).

3.3. Functional attributes of the polysaccharides from leaves

Various functional properties have been identified for the leaves originated polymeric compounds ranging from dietary fiber to prebiotic, immunostimulatory and antioxidant activity. The literature available on functional activities of these polymers are mostly *in vitro* studies. In absence of animal level studies via oral route of administration of these polysaccharides it is difficult to use them as functional food or medicine. Also, the exact structure of the polysaccharides is very much dependent on recovery methods so removal of any structural ambiguity is essential before initiating any functional studies. A review of the health benefits in connection to the monomer assembly is attempted to encourage studies on individual polysaccharide level analysis for their functional properties.

3.3.1. Dietary Fiber

Dietary fibers are polymers derived from mostly plant sources which do not undergo hydrolysis by human enzymes. The main dietary fibre components of leafy vegetables are cellulose, inulin, hemicellulosic polysaccharides and pectin substances. These fibres can be of two types water-soluble and water-insoluble fiber. Water soluble fibers have potential hypoglycaemic properties because they can downregulate post meal blood glucose level. Such hypoglycaemic properties have been confirmed for certain water soluble fibers like pectin. In addition to that there are studies suggesting possibility of reduction in occurrence of colon cancer (Englyst et al., 1988).

A dietary fiber may be active in their natural form with or without the other cellular components. Sometimes the Polysaccharides may require chemical or enzymatic modification to become active. Generally, the cellulose and hemicellulose component can expedite gut movement without any treatment. On the other hand, inulin in is incapable of accelerating gut movement and needs to be converted to short chain fatty acids by gut bacteria. Pectins, oligosaccharides and β-glucans cause slower movement of food in the gut and increases viscosity of the faeces. Net result of such slow bowel movement can check the blood cholesterol level, and decelerate sugar absorption from the food into the blood thus prevents quick hyperglycaemia after food intake (Liu et al., 2015). As a component of dietary fiber, arabinoxylans exists in many leafy vegetables such as spinach, parsley, cabbage, lettuce etc. (Dodevska et al., 2015).

A section of the dietary fibre is called *Prebiotics*. They are various group of polysaccharides or more precisely oligosaccharides with following properties; they do not get hydrolysed to monomers by acid or human enzymes in the gastrointestinal tract but gets fermented by intestinal microflora and acts as a preferred substrate for at least one of the beneficial bacteria species capable of colonizing in the colon. As result they restore healthy composition of colonic microflora and exert health benefit to the host body holistically (Carlson, 2018). Xylans, fructans, galactans are established prebiotics. However, many polysaccharides from plant tissues are capable of showing prebiotic effects. For example, human enzymes are incapable of solubilizing arabinoxylans as it contains arabinose and xylose linkages. It enters the colon in intact form and act as a source of food for saccharolytic bacteria along with *Bacteroides*, *Bifidobacterium*, *Clostridium*, *Lacticaseibacillus*, and *Eubacterium* to maintain a balanced gut condition (Sinha et al., 2011). Prebiotic polysaccharides have been identified in leafy vegetable such as *Lactuca sativa, Apium graveolens, Spinacia oleracea, Corchorus capsularis* etc. (refer Table 3.1). Since prebiotics support growth of a very narrow groups of gut microbiota unlike dietary fibres establishing their health benefit is more challenging and requires an interdisciplinary approach. To establish the prebiotic roles, advance *in situ* microbial growth monitoring can be done through flouroscence-probe based techniques and information can be further enhanced via simulated gut models.

3.3.2. Immuno-stimulant

Immunostimulants are diverse group of chemicals that can augment biological defence system of an animal against various pathogenic bacteria or virus. These substances can be derived from natural sources or chemically synthesised. Often the immunostimulants may work specifically as antigen which can induce production of some specific anti-body (e.g., vaccines). The other class of immunostimulants work differently without any antigenic property of their own. Instead they promote immune response of other antigens non-specifically. There are several types of stimulants with different mechanisms and functions such as complex hemicellulosic polysaccharide (e.g. arabinoxylan, arabinogalactan, etc.) in leafy vegetables (Aboughe-Angone et al., 2011). Often a mixture of polysaccharide in crude extract showing immunostimulant activity cannot be explained by a single mechanism. For example, hot infusion of *Maytenus ilicifolia* could prevent gastric ulcer in animals. The infusion contained heteropolysaccharide with residues of primarily arabinose and galactose along with small amount of galacturonic acid, 4-O-methylglucuronic acid, rhamnose, and glucose (Cipriani et al., 2006).

The mechanism behind non-specific immune response of these polysaccharides requires further investigation of phagocytosis, antibody synthesis, properdin and complement systems, interferon production and lymphocytes synthesis in relation to the polysaccharides. Particularly immune-stimulant polysaccharides will be an important area because many of the existing antibiotics are no longer effective due to growing resistance of the pathogens, their allergenicity and their immune suppressive properties, and inefficiency towards viral attack.

3.3.3. Antioxidant

Essentially substances with reducing property and ability to stop or decelerate the oxidation of cellular components by either direct scavenging of free radicals or by recycling of other free radical scavenger are called anti-oxidants. (Maestri et al., 2006). Leaves usually contain a huge pool of antioxidants in the form of pyrocatechol or a pyrogallol group (Fig. 3.4a), i.e. ortho-disubstituted phenols. However, ortho-disubstituted phenolic compounds are often found to be toxic hence sometimes synthetic antioxidants mostly para-disubstituted phenols are recommended (Wang et al., 2013). Majority of these anti-oxidants have some limitations that offers scope of alternative antioxidants.

Currently to obtain naturally occurring antioxidants leaf polysaccharides are being explored. The structural properties like chemical composition, molar mass, glycosidic bonds, and conformation of the carbons controls the antioxidant activity of a polysaccharide (Wang et al., 2016). Arabinoxylans because its linkages with ferulic acid exhibit antioxidant properties (Fig. 3.4b). The polysaccharide extraction condition in leaves can be optimized using statistical methods in order to maximize the antioxidant activity (Samavati & Manoochehrizade, 2003).

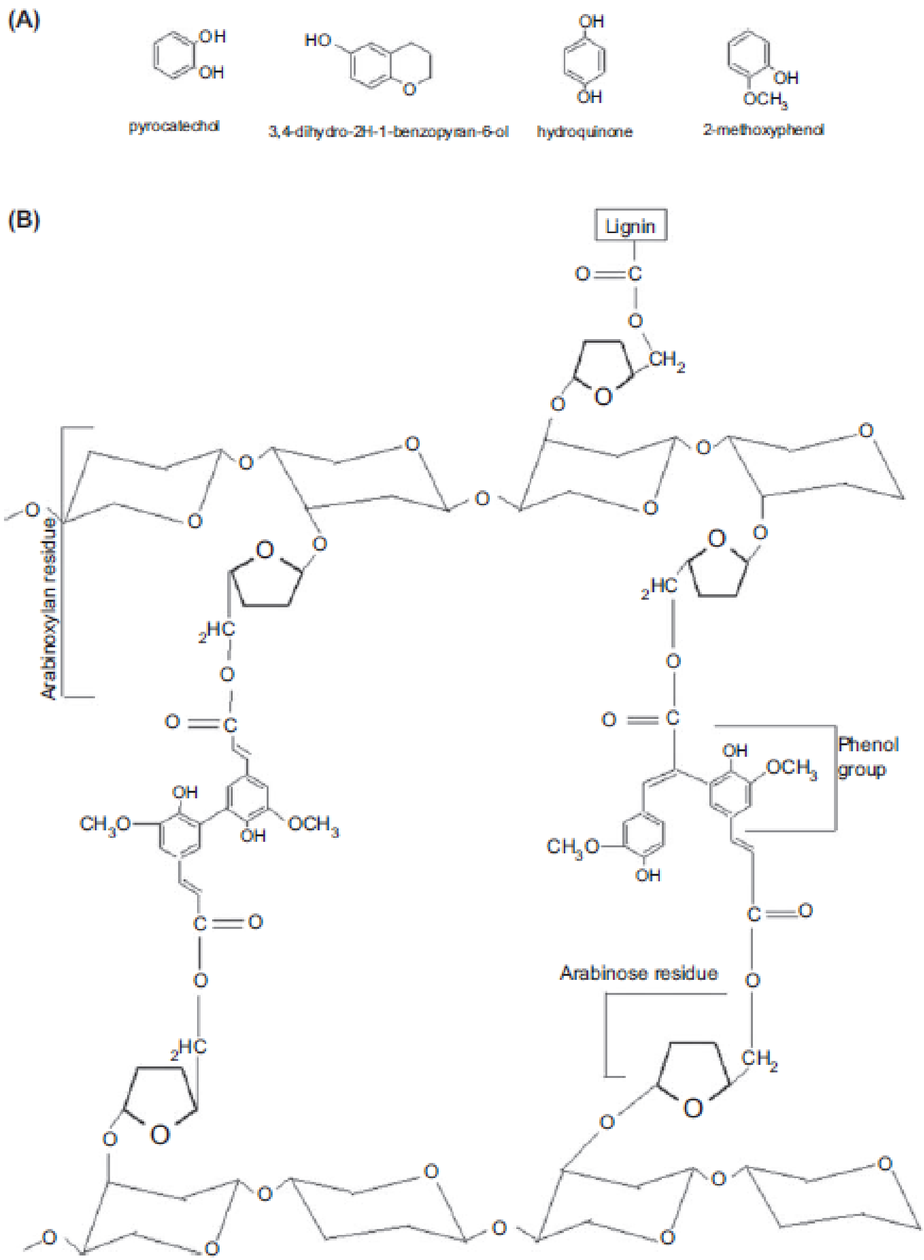

Fig. 3.4 (a) Basic chemical structure of phenolic antioxidants and (b) Generic structure of arabinoxylans with antioxidant activity

3.4. Polysaccharide from different leafy vegetables

Structure-function of the polysaccharides discussed in section 3.2 is distributed abundantly in different leaves. In this section some of the leaf sources are enlisted along with the polysaccharides and their possible beneficial effect to health (Table 3.1).

Table 3.1 Polysaccharides and their functional properties from some selected Leafy vegetables

Sl. No.	Leafy Vegetables	Polysaccharide				References
		Dietary Fiber	Prebiotic	Immuno-Stimulant	Antioxidant	
1.	*Lactuca sativa*	Homogalacturonan, Xyloglucan, Inulin	Homogalacturonan, Inulin	Homogalacturonan, Inulin, Xyloglucan	Inulin	Wagstaff et al., 2010; Hoffman et al., 2005; Williams et.al, 2017
2.	*Apium graveolens*	Homogalacturonan, Xyloglucan, Rhamnogalacturonan, Arabinogalactan	Homogalacturonan, Arabinogalactan	Homogalacturonan, Arabinogalactan, Xyloglucan	Rhamnogalacturonan	Petrova et al., 2014; Chen et al., 2017; Zujovic et al., 2016
3.	*Spinacia oleracea*	Xylan, Xyloglucan	Xyloglucan, Xylan	Xyloglucan	Xylan	Miller et al., 1995
4.	*Corchorus capsularis*	Xylan	Xylan	-	Sulfated Polysaccharides, Xylan, Rhamnogalacturonan	Eskander, 2018; Sarkar et al., 1952; Katayama et al., 2008
5.	*Trigonella foenum-graecum*	Galactomannan	Galactomannan	Galactomannan	-	Majeed et al., 2018; Srichamroen et al., 2008; Aboughe-Angone et al., 2011
6.	*Brassica oleracea var. capitate*	Arabinoxylan, Xyloglucan, Arabinogalactan	Arabinoxylan, Arabinogalactan, Xyloglucan	Xyloglucan, Arabinogalactan	Rhamnogalacturonan	Steven et al.,1984; Westereng et al., 2006
7.	*Morus alba*	Xylan	Xylan	-	Rhamnogalacturonan, Xylan	Katayama et al., 2008; Anand et al., 2009
8.	*Tamarindus indica*	Xyloglucan	Xyloglucan	Xyloglucan	---	Aboughe-Angone et al., 2011
9.	*Arabidopsis thaliana*	Homogalacturonan, Xylogalacturonan, Xyloglucan, Glucuronoarabinoxylan	Homogalacturonan, Xylogalacturonan, Xyloglucan, Glucuronoarabinoxylan	Homogalacturonan, Xylogalacturonan, Xyloglucan, Glucuronoarabinoxylan	Rhamnogalacturonan	Yapo et al., 2011; Harholt et al., 2010; Zablackis et al., 1995
10.	*Panax ginseng*	Arabinogalactan	Arabinogalactan	Arabinogalactan	Rhamnogalacturonan	Xiu-zhen et al., 2010; Abough-Angone et al., 2011
11.	*Gingko Biloba*	Arabinogalactan, Xylan	Arabinogalactan, Xylan	Arabinogalactan	Rhamnogalacturonan, Xylan	Kraus et al.,1991; Jin et al., 2002
12.	*Epimedium sp.*	Homogalacturonan	Homogalacturonan	Homogalacturonan	Rhamnogalacturonan	Chen et al., 2012
13.	*Thymus vulgaris*	Arabinogalactan	Arabinogalactan	Arabinogalactan	Rhamnogalacturonan	Vagi, 2005
14.	*Phaseolus vulgaris*	Xylan, Xyloglucan	Xylan, Xyloglucan	Xyloglucan	Xylan	Arribas et al., 1991
15.	*Plantago major*	Arabinogalactan, Glucomannan	Arabinogalactan, Glucomannan	Arabinogalactan, Glucomannan	Glucomannan	Adom et al., 2017; Lukova et al., 2017
16.	*Mesembryanthenum crystallinum*	Homogalacturonan, Arabinogalactan	Arabinogalactan, Homogalacturonan	Homogalacturonan, Arabinogalactan	Rhamnogalacturonan	Msakni et al., 2006
17.	*Artemisia princeps*	Arabinogalactan	Arabinogalactan	Arabinogalactan	Rhamnogalacturonan	Yamadat et al., 1986
18.	*Trifolium pratense*	Arabinoxylan, Xylan, Galactomannan, Galactoglucomannan	Arabinoxylan, Xylan, Galactomannan, Galactoglucomannan	Arabinoxylan, Galactomannan, Galactoglucomannan	Xylan	Gaillard et al., 1968
19.	*Impatiens parviflora*	Glucuronoxylan, Arabinogalactan	Glucuronoxylan, Arabinogalactan	Glucuronoxylan, Arabinogalactan	Rhamnogalacturonan, Xylan	Hromádková et al., 2014
20.	*Stevia rebaudiana*	Arabinogalactan, Xyloglucans, Heteroxylans	Arabinogalactan, Xyloglucans, Heteroxylans	Arabinogalactan, Xyloglucans, Heteroxylans	Heteroxylans	Oliveira et al., 2013; Puri et al., 2016
21.	*Moringa oleifera*	Arabinogalactan	Arabinogalactan	Arabinogalactan	-	Raja et al., 2016
22.	*Salvia officinalis*	Arabinogalactan	Arabinogalactan	Arabinogalactan	Rhamnogalacturonan	Capek et al., 2004

3.5. Effect of processing condition on polysaccharide structure and functional relationship

Polysaccharide characterization from leafy vegetables or their derived products (cooked or chopped vegetables) is dependent on the method of processing as well as extraction. Extraction of polysaccharide is a sequential process, right from drying to different extraction procedures or direct fresh extraction for different types of polysaccharide components. Drying is one of the primary steps in the extraction of polysaccharide from leaves in drying which not only reduces moisture content of the material but offers scope for plethora of reactions (e.g., hydrolysis, enzyme inactivation, cross-linking etc.). Polysaccharide quality in an economically important *Aloe vera* leaves has been reviewed extensively. Starting from microbial quality due to handling of leaves, filleting or crushing of the leaves, heating of the juice, drying every step altered the polysaccharide composition of the leaves (Ramachandra & Rao, 2008). It was also reported different pulp fraction of the leaves like cell wall, disintegrated cell organelles and mesophyll cell fluid are respectively rich in polygalactose, galacturonic acid, and mannans. Femenia et al., 2003 reported acemannan chains in *Aloe vera* leaves suffered significant changes when dried at higher temperature (70ºC). The mean molecular weight of the polysaccharide increased from 45 kDa to 75 kDa. Drying can be done via different mechanisms; solar drying, convective drying, vacuum drying, freeze drying, microwave drying, refractive window etc. Each of these methods have its own merits and demerits but freeze drying is best in terms of disturbance of the polysaccharide molecules. Polysaccharide are separated from leafy vegetables with selected solvents (water/hot & water/alcohol) or their mixture. Sometimes ultrasound, microwave, and enzymatic degradation is used to increase yield and/or selectivity of the polysaccharides.

Similarly processing conditions before consumption of leafy vegetables have major effect on structure of the polysaccharide molecules which alters their reactivity with the amylases and therefore bioavailability of the polysaccharide. The effect of processing condition is difficult to estimate because it varies dramatically depending on the polymer type and its exact structure. Also, polysaccharide modifies their environment in solution during processing. Soluble polysaccharide increases the viscosity of a solution, subject to their structure and chain length, concentration and presence of other species in the solvent (Lovegrove et al., 2017). Non-starch polysaccharides (NSPs) with charged functional groups like pectic polysaccharides are more soluble in polar solvents including water. pH of the solvent determines the charge on the NSPs. The charge distribution of the polysaccharides may have multiple influence reduction of their solubility, gelation, or in extreme case degradation of the polymeric chain. Since food particle size and compactness hinders the accessibility of the hydrolysing enzymes, slowing the starch digestion, the disruption of the cell structure by grinding and milling increases starch bioavailability. Moisture, cooking temperature, time and pressure control the starch gelatinization and thus, the transformation of starch from resistant starch to slowly digestible starch and then to rapidly digestible starch. RS starch is part of the wider group of dietary fibers. Physically inaccessible starch fraction is found in starchy foods that are not fractionated and refined. Ungelatinized starch is mainly structured as B-type crystal that are tightly packed and relatively dehydrated inside the granules. This dense structure hinders approach of amylases. Since, it is well known that thermal degradation has deliberative effect on the solubilizing the polysaccharide, the most effective process like moist heat cooking methods like boiling, steaming, frying, microwaving and autoclaving affect the content of resistant starch. In addition to that de-acetylation, loss of side chains of non-starch polysaccharides and their cross-linking with proteins (enzymatic and non-enzymatic browning) have also been established.

3.6. Negative physiological impact of plant polysaccharides: Food and drug interaction

Many food components are known for their interactions with drug molecules and in turn effect clinical efficacy of the drug. However, these effects may be additive, synergistic, or antagonistic depending on the chemistry of the drug and the food after digestion. So, nature and extent of the interaction is related to the bioavailability of the food component(s). One well-known case for leafy vegetables is interaction of Coenzyme Q-10 with P–glycoprotein the efflux transporter of the intestine. The Coenzyme available in many leafy vegetables and considered as a health supplement (Bushra et al., 2011). Another drug compound, Warfarin is used for prevention of blood clots and their passage in the human body. However, its effectiveness is largely dependent on correct dosage to avoid unsafe levels of anticoagulation. Vitamin K interferes negatively with warfarin hence leafy vegetables rich in vitamin K shows erratic anticoagulation behaviour during warfarin treatment. Especially presence of other vitamins A, E, or C may alter the steps in anticoagulation process (Manzi & Shannon, 2005). Such interactions are very much dependent on leaf matrix and the particle size in which the leaves are consumed. Polysaccharides of leafy vegetables therefore have role in controlling these drug-food interactions. Unfortunately, there are very little study done on the precise mechanism of leafy vegetable polysaccharides on drug-food interactions. Generally, it has been observed that fiber rich foods are capable of reducing the efficacy of drugs like simvastatin, ezetimibe, pravastatin and fluvastatin. In presence of pectin drug like acetaminophen absorbs at a slower rate through intestinal mucosa. So, in presence of polysaccharides delay in bioavailability of drug molecules can be anticipated even if there is no reduction in their absolute bioavailability.

3.7. Summary

Recently polysaccharides and oligosaccharides from leafy vegetables are attracting researchers globally because of its beneficial properties on human health. Cell wall derived polysaccharides and few other poly-/oligo- saccharides from leafy vegetables show promising prebiotic, immunostimulatory and antioxidant effect. Although, there is a considerable amount of literature on application of plant polysaccharide in food and non-food areas including medicine but polysaccharides from leafy vegetables are still much less known. Basic information about the structure and function of such polysaccharides is still evolving. Also, the broad definition of leafy vegetables encompasses over a thousand of plant species which needs to be explored for functional polysaccharides. It is evident in the present review that most of the functional polysaccharides in leaf tissues are complex heteropolysaccharides like pectin, glucuronoarabinoxylan, galactomannan etc.

The bioactivities of polysaccharides are related to their type of monomers, molecular weights, chemical components, branch degrees, and type of glycosidic bonds. The knowledge about these bioactivities is important not only for their beneficial effect but also to predict their undesired effect like drug-food interaction. Another finding of the review is the structural information of the polysaccharides is very much dependent on their extraction process and processing of the leaves. Indeed, these unique polysaccharides promising but their large number of sources and the inherent complexity of the molecules makes application of the leaf polysaccharides challenging and demands extensive study.

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Chapter 4

Development of a standardized process to assess antioxidant activity in H_2O_2 stressed yeast model

Chapter 4

4. Introduction

The various metabolic processes occurring in the body for the survival of the organism produce Reactive Oxygen Species (ROS) like superoxide ($O_2^{\bullet-}$), hydrogen peroxide (H_2O_2), hydroxyl (•OH), singlet oxygen ($^1O_2$) etc., as a byproduct. ROS may also be generated exogenously through exposure to ultraviolet light, water and air pollution, transition metals, heavy metals, pesticides etc. ROS maybe free radicals like superoxide, oxygen radical, hydroxyl etc. which contain one or more unpaired electron in their valence shell making them short lived, unstable and highly reactive. Additionally, ROS also includes non-radical species like hydrogen peroxide and singlet oxygen that readily react in the body leading to the formation of free radicals (Alic et al., 2001). ROS attack other molecules like proteins, lipids and DNA causing oxidative stress. Oxidative stress is a hallmark of aging and many acute and chronic diseases; inflammatory bowel disorder, cardiovascular diseases, chronic obstructive pulmonary disease, chronic kidney disease, neurodegenerative diseases, cancer etc. (Liguori et al., 2018). To prevent oxidative stress, ROS levels are kept under surveillance by various antioxidant systems present in the body.

Antioxidants include endogenous molecules like glutathione, superoxide dismutase, catalase, glutathione peroxidase and exogenous molecules like vitamin E, vitamin C, carotenoids and polyphenols (Alugoju et al., 2018). These antioxidants act by scavenging or quenching the free radicals generated during oxidative stress. The modern lifestyle of eating unhealthy or processed food, lack of exercise, exposure to different chemicals, increased use of drugs etc. or certain underlying diseases like inflammation or cancer further induces oxidative stress which often exceeds the antioxidant capacity of the body. It is generally believed that dietary or herbal sources of antioxidants can restore such oxidative imbalance (Carocho & Ferreira, 2013). However, identifying genuine antioxidant sources and quantifying their antioxidant potential still remains a challenge.

The commonly used assays for determining *in vitro* total antioxidant activity of a sample are trolox equivalence antioxidant capacity (TEAC), oxygen radical absorbance capacity (ORAC), ferric reducing ability of plasma (FRAP) and cupric reducing antioxidant capacity (CUPRAC) (Avery & Avery, 2001). TEAC, FRAP and CUPRAC assays are spectrophotometric assays that measure the changes in the absorbance of a molecule post reduction by the antioxidants like $ABTS^{\bullet+}$, ferric ion and copper (II)-neocuproine reagent respectively. On the other hand, ORAC is a fluorometric assay that measures the reduction in the fluorescence quenching by an antioxidant (Avery & Avery, 2001). Although, these TAC assays are quite useful in screening antioxidants from a variety of dietary or food supplements due to its ease, short assay time and low cost, there lies a major challenge. The *in vitro* systems do not consider the uptake of a molecule through cell membrane, its metabolism in the cell and the biokinetics (Bayliak et al., 2016). Hence, these assays are not recommended in testing the antioxidant capacity of a food item at a cellular level. In fact, United States Department of Agriculture (USDA) has rendered ORAC values as useless in promoting food and dietary supplements. Alternatively, cell line based or clinical studies are costly and time consuming respectively and are not suitable for preliminary screening of a wide range of products. Hence, single cell organisms like yeast are preferred for antioxidant screening purposes since they have many conserved cellular processes with humans, including endogenous antioxidant regulation systems.

Saccharomyces cerevisiae also known as baker's yeast or brewer's yeast is a single cell eukaryotic organism that possess many conserved biological processes with human like cell cycle, response to stress, translational regulation, mitochondrial oxidative phosphorylation, amino acid metabolism and autophagy (Bayliak et al., 2006). Although the two cell types diverged around 1 million years ago, yeast cell shows 23% homologous genes with the humans. The small size, short generation time, cost effectiveness, easily genetically modifiable property and ease of work makes *S. cerevisiae* an ideal model system to study various molecular processes including oxidative stress (Martorell et al., 2011). The common antioxidant system between *S. cerevisiae* and human includes; enzymatic as well as non-enzymatic antioxidants. As part of the primary antioxidant system, three enzymes that prevent the formation of free radicals or neutralize free radicals are glutathione peroxidase (GPx), catalase (CTT and CTA) and superoxide dismutase (SOD1 and SOD2) (Belinha et al., 2007;

Rahman, 2009). Glutathione peroxidase and catalase eliminates hydrogen peroxide by reducing it to water whereas superoxide dismutase converts superoxide anions into hydrogen peroxide (Carocho & Ferreira, 2013). The secondary enzymatic defense includes glutathione reductase and glucose-6-phosphate dehydrogenase which indirectly help in detoxification of peroxides in the glutathione redox cycle (Cotelle et al., 2001). Glutathione, thioredoxin and glutaredoxin are part of the non-enzymatic antioxidant system (Carocho & Ferreira, 2013). These endogenous antioxidant molecules can be an indicator of the ROS-antioxidant balance in the eukaryotic cells.

In this work, *Saccharomyces cerevisiae* has been used as a model organism to assess the antioxidant activity of a compound or a mixture of compounds (Martorell et al., 2011). In this study, oxidative stress is induced by hydrogen peroxide (H_2O_2). Two yeast strains, one wild and another SOD mutated, were studied under different concentration of H_2O_2 in the presence or absence of the antioxidant molecule(s) understudy and the difference of stress response markers are observed to evaluate the antioxidant activity. Generally, the oxidative stress responses are vitality and viability of the cells and different enzymatic and non-enzymatic molecules that are part of the native antioxidant system. Such protocols are often not standardized and cannot be used as a platform assay for screening of antioxidant-rich natural products. In this study effect of the appropriate mode of exposure, age of yeast cells (exponentially growing or stationary), the concentration of the oxidative stress inducer (i.e., H_2O_2), sequence of addition of inducer and antioxidant activity has been studied. This research aims to develop an optimized method for cellular-level antioxidant assay which can be used as standard preliminary method of screening dietary supplements and food items with very high antioxidant property.

4.1. Methodology

Saccharomyces cerevisiae strains, EG103 (wild strain) and EG133 (lacking SOD1 that encodes for Cu/Zn-SOD and SOD2 that encodes for Mn-SOD genes) growth characteristics were analysed during both exponential phase and stationary phase with lethal doses of H_2O_2 as an external oxidant to the cell. The intracellular markers and reducing capabilities were estimated to investigate the antioxidant effect at stress conditions on different sequences of addition of quercetin.

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4.1.1. Selection of appropriate mode of exposure and age of yeast cells for antioxidant assay against H_2O_2 induced oxidative stress

4.1.1.1. *Saccharomyces cerevisiae* growth conditions

Wild-type yeast strain (EG103) and the isogenic mutant strain sod1Δ and sod2Δ (EG133) were kindly provided by Dr. Lindsay Kane Barnese (Concordia University, Irvine US) and Dr. E. Gralla (University of California, Los Angeles, CA, USA). Yeast cells were grown in a 1:5 ratio of YPD (Yeast Extract–Peptone–Dextrose) medium (pH 6.2) at a shaking condition of 130 rpm at 30ºC. Yeast cell growth was measured with the optical density at 600 nm to estimate the growth phases of the model organism. The exponentially growing phase (t_{mid}) and stationary phase (t_{max}) were estimated for the stress study.

4.1.1.2. Yeast oxidative stress assay at growing phase

Yeast cells were inoculated into 50 mL of YPD broth and grown at 30°C with orbital shaking at 130 rpm to obtain its mid-log phase with an initial population of ~2×10^9 cells/mL. To observe the susceptibility of yeast to H_2O_2, various concentrations of H_2O_2 (0-10 mM) added to growing cells, and cell survival was monitored by regular intervals.

4.1.1.3. Yeast oxidative stress assay at resting phase

Exponentially growing yeast cells at t_{mid} and stationary phase cells at t_{max} were washed and divided into several sub-aliquots of ~2×10^9 cell/mL for replicates. Cells were suspended with phosphate buffer saline (PBS, pH 7.5) and treated with 0-5 mM of H_2O_2 and incubated for 1 h at 30°C. Washed cells were serially diluted for plating on YPD rich agar medium and grown for 48 h at 30ºC.

4.1.2. Cell free extract preparation

Cell free extracts of wild type (EG103) and sod mutant strain (EG133) of both treated and untreated cells were prepared as described by Lushchak et al. (2005). Cells were harvested by centrifugation for 5 minutes at 15,000 × *g* for 5 minutes at 4°C and washed with 50 mM potassium phosphate buffer (pH 7.5). After centrifugation, cells were suspended in lysis buffer (1 mM phenylmethylsulphonyle fluoride, 0.5 mM EDTA and 50 mM potassium phosphate buffer of pH 7.5). Glass beads (0.5 mm diameter) were added to the cell suspension. The cell suspensions were vortexed for 15 cycles of 1 minute of vortexing followed by 1 minute of cooling in ice. The homogenate was collected and centrifuged at 15000 × *g* for 10 minutes at 4°C to remove lysed cells and glass beads. The cell extract was kept on ice for assessing antioxidative biomarker assays.

4.1.3. Effect of quercetin on stress resistance in yeast cells

Stationary phase cells were suspended in phosphate buffer saline (pH 7.5) and pre-treated with 100 µM quercetin and 5 mM H_2O_2 in different aliquots. Cells were washed and 100 µM of quercetin was added in H_2O_2 pre-treated cells, whereas 5 mM of H_2O_2 was added in 100 µM quercetin pre-treated cells subsequently. The suspended cells were further incubated for 1 h at 30ºC. The cells were harvested for cell viability assays and biomarker assays for analysing the effect of quercetin on stress resistance in yeast cells.

4.1.4. Analytical Methods

4.1.4.1. Cell viability assay

To determine cell viability, the yeast cells from the culture were centrifuged (g, time), washed with phosphate buffer saline (PBS, pH 7.5) and suspended with the same volume. Cell suspension (100 µL) of 10^6 dilution was spread on YPD agar and incubated at 30ºC. Colony-forming units were counted after 48 h (Jett et al., 1997) (Appendix B.1).

4.1.4.2. Dry cell weight

The culture was centrifuged at 15,000 × *g* for 5 minutes. The samples were gently washed with sterilized distilled water to remove the culture medium and repeated for 2 times. The culture dried at 105ºC in a hot air oven until it reached its equilibrium moisture content (Appendix B.2).

4.1.4.3. Semi-quantitative spot assay

Treated and untreated wild type (EG103) and sod mutant (EG133) strains were serially diluted to 10^6 dilutions and spotted (5 µL) onto the YPD plates. Plates were incubated for 48 h at 30ºC and plates were analysed (Arslan et al., 2018).

4.1.4.4. Estimation of soluble yeast protein

Protein was estimated (Smith et al., 1985) by the following reagent:

a) Reagents:

i. Bicinchoninic Acid (BCA) solution

ii. 4% (w/v) $CuSO_4.5H_2O$

b) Procedure:

A 50 mL BCA solution and 1 mL $CuSO_4.5H_2O$ solution were mixed prior to the protein estimation. In a test tube, 2 mL of the mixture and 0.1 mL of the protein sample were mixed to form a uniform green colour solution. The reaction mixture was incubated for 30 minutes at 30°C. The absorbance of the sample was read at 562 nm against the appropriate blank in each case. The amount of protein was determined form a standard plot of bovine serum albumin (BSA) (Appendix B.3).

4.1.4.5. Antioxidative biomarker assays

4.1.4.5.1. Enzymatic biomarkers

Catalase activity (CAT) was determined spectrophotometrically by calculating the reduction of H_2O_2 at 240 nm (Beers et al., 1952). Glutathione peroxidase activity (GPx) was determined by monitoring the NADPH consumption rate at 340 nm (Mannervik, 1985). Glutathione reductase activity (GR) was determined by increase in absorbance caused by the reduction of DTNB [5,5'-dithiobis (2-nitrobenzoic acid)] at 412 nm (Massey & Williams, 1965). Superoxide dismutase was determined by decrease in rate of reduction of cytochrome c (Crapo et al., 1978) (Appendix B.4).

4.1.4.5.2. Non-Enzymatic biomarkers

Total glutathione content was determined by HPLC method (refer Appendix B.8 for standard curve) using the method of Sutariya et al. (2012). Iron Reducing power (IRP) of yeast cells was determined with Potassium Ferricyanide Reducing power assay (Oyaizu, 1986). The free radicals scavenging potential (ARSA) of yeast cells was determined with 2,2′-azinobis-3-ethylbenzothiazoline-6-sulfonic acid assay (Re et al., 1999). Lipid peroxidation inhibition capacity (LPOX) yeast cells was estimated with Thiobarbituric acid-reactive species assay (Bernheim et al., 1948) (Appendix B.5, B.6, B.7 and B.8).

4.2. Statistical Analysis

The experiments were repeated thrice, and the data presented as means ± S.E. Values with $P < 0.05$ were considered statistically significant unless mentioned otherwise.

4.3. Results and Discussion

In this context, *Saccharomyces cerevisiae* has been used to assess the antioxidant activity of a compound or a mix of compounds (Martorell et al., 2011). In these assays, oxidative stress is induced by acetic acid, H_2O_2, paraquat, heavy metal ion, etc. in yeast cells in the presence or absence of the antioxidant molecule(s) understudy and the difference of stress response markers in the two exposures i.e., with or without the antioxidant molecule(s) is observed to evaluate the antioxidant activity. Generally, the oxidative stress responses are vitality & viability of the cells and different enzymatic and non-enzymatic molecules that are part of the native antioxidant system of the yeast cells. Such protocols are often not standardized and cannot be used as a platform assay for screening of antioxidant-rich natural products. In this study effect of the appropriate mode of exposure, age of yeast cells (exponentially growing or stationary), the concentration of the oxidative stress inducer (i.e., H_2O_2), sequence of addition of inducer and antioxidant activity has been studied.

4.3.1. Selection of appropriate mode of exposure and age of yeast cells for antioxidant assay against H_2O_2 induced oxidative stress

Exposure to H_2O_2 triggers oxidative stress causing redox imbalance in many cells (Bayliak et al., 2006). To examine the effect of this ubiquitous oxidant in yeast cell, various amounts of H_2O_2 (0-10 mM) were added to wild-type (EG103) and SOD double mutant *S cerevisiae* cultures (EG133) growing in YPD. The aim was to find out whether oxidative stress follows a dose-dependent response with viability/vitality and growth kinetics of the yeast cell in agitated culture. In a typical growth kinetics data of microbes in batch culture, four phases can be identified; (i) the lag phase, the preparatory time for cells to grow in new environment (in the present case after the addition of H_2O_2), (ii) the acceleration phase, when the first derivative of the cell numbers (or any of the covariant like OD) rises to reach a maximum, (iii) the deceleration phase, where the first derivative of the cell numbers (or any of the covariant like OD) decreases to reach zero, and (iv) the stationary phase when no more nutrient is left and/or toxic products have reached a lethal range (Navarro-Pérez et al., 2022). Such profile indicates changes in vitality and viability of a microbial population over time in liquid culture conditions. For this experiment, loop full of culture from yeast slants of both the wild type and SOD mutant strains were inoculated in YPD and grown till mid-log phase. Consequently, 1 mL of the culture was reinoculated in fresh 50 mL of YPD with various concentrations of H_2O_2 and grown till stationary phase. The OD of the cultures were measured every 1 h. For the wild and the SOD mutant strains, the time duration for the acceleration phases are shown in Table 4.1a.

Table 4.1a Acceleration phase lag of EG103 (wild) and EG133 (sod1Δ sod2Δ) *S. cerevisiae*

Growth Parameter	**EG103 (Wild)**					
	Control	**0.5 mM**	**1 mM**	**2.5 mM**	**5 mM**	**10 mM**
μ (h^{-1})	0.234±0.00	0.197±0.00	0.166±0.00	0.021±0.00	0.014±0.00	0.008±0.01
t_g (h^{-1})	2.9±0.00	3.5±0.00	4.2±0.00	33.8±5.38	51.0±9.77	127.4±76.43
D.C.W. (mg/mL)	3.9± 0.00	3.8±0.00	3±0.10	0.4±0.00	0.36±0.07	0.34±0.04
CFU (cells/mL)	1.13×10^9	6.8×10^8	2.4×10^8	NQ	NQ	NQ
Growth Parameter	**EG133 (sod1Δ sod2Δ)**					
	Control	**0.5 mM**	**1 mM**	**2.5 mM**	**5 mM**	**10 mM**
μ (h^{-1})	0.12±0.01	0.05±0.00	0.02±0.00	NQ	NQ	NQ
t_g (h^{-1})	5.7±0.58	13.9±0.46	28.6±3.49	NQ	NQ	NQ
D.C.W. (mg/mL)	3.4±0.10	1.9±0.05	0.6±0.00	0.5±0.00	0.4±0.03	0.3±0.03
CFU (cells/mL)	1.48×10^9	2.3×10^8	NQ	NQ	NQ	NQ

Note: NQ: Not quantifiable; μ: Specific growth rate; t_g: Generation time; D.C.W.: Dry cell weight; CFU: Colony forming unit; Stress concentration: mM of H_2O_2. Results were expressed as mean ± standard error (SE) of triplicate runs.

Table 4.1a indicates that with increasing concentrations of H_2O_2, the yeast strains showed a lag in the acceleration phase. Additionally, beyond 2.5 mM of H_2O_2 the SOD mutant strain showed no change in OD of the culture suggesting that the cells ceased to grow in such toxic environment. Moreover, the specific growth rate of the cultures was calculated and the results are given in Table 4.1b.

Table 4.1b Effect of H_2O_2 stress in exponentially growing yeast cells

Time (h)	**EG103 (Wild)**						**EG133 (sod1Δ sod2Δ)**					
	Control	**0.5 mM**	**1 mM**	**2.5 mM**	**5 mM**	**10 mM**	**Control**	**0.5 mM**	**1 mM**	**2.5 mM**	**5 mM**	**10 mM**
2	0.22	0.10	0.01	ND	-0.01	-0.01	0.17	0.08	0.00	ND	-0.01	-0.01
3	0.20	0.22	0.04	0.01	-0.01	0.00	0.12	0.10	0.23	-0.03	-0.02	-0.02
4	0.20	0.17	0.12	0.04	0.01	0.02	0.09	0.05	0.20	0.00	0.03	0.02
6	0.12	0.15	0.22	0.00	0.01	0.00	0.10	-0.01	-0.25	-0.03	-0.01	-0.01
8	0.01	0.08	0.07	0.01	0.01	0.00	0.06	0.00	-0.01	0.02	-0.01	0.00

Note: ND: Not detectable; Gray colour: lag in the acceleration phase

Results indicate a reduction in specific growth rate with increasing concentration of H_2O_2 for both the strains. It has been reported that in response to DNA damage, yeast cells halt in the G_1 phase to restore antioxidant enzyme system before further cell division (Flattery-O'Brien & Dawes, 1998). Yeast and human cells share some of the features of such G_1 arrest responses (Alic et al., 2001). To further confirm whether there is any dose-response relation between H_2O_2 concentration and average cell growth rate over 8 h of H_2O_2 exposure, cells were plated from the stationary phase and colony forming unit (CFU) was calculated. EG133 strain showed complete loss of vitality above 0.5 mM concentration of H_2O_2 unlike the EG103 wild strain which could with stand up to 1 mM of the oxidant. The wild and the mutant strain showed no colony-forming unit after 8 h of growth at 2.5 and 1 mM H_2O_2 exposure respectively (Fig. 4.1). Higher susceptibility of EG133 towards oxidative damage was expected since it lacked the native antioxidant enzyme i.e., two superoxide dismutases essential for preventing the mitochondrial protein from oxidation in yeast (O'Brien et al., 2004). This study showed a quantitative relation between oxidant concentration with viability and vitality and cell growth rate of EG103 and EG133.

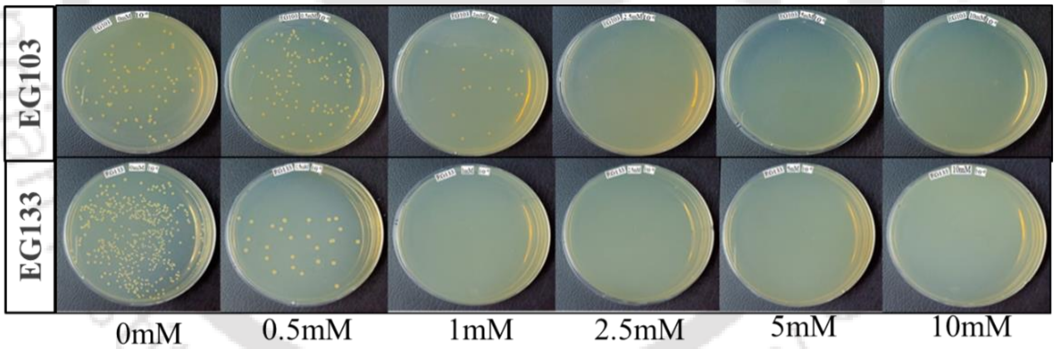

Fig.4.1 Effect of H_2O_2 stress in exponentially growing yeast cells

So, to study if antioxidant molecule like quercetin can reverse the viability and vitality loss of the two yeast strains after 1 mM hydrogen peroxide exposure, quercetin was added to the cultures. Two parallel sets of experiments were performed. In the first set, quercetin was added 1 h prior to the addition of H_2O_2 and in the second set quercetin was added 1 h post H_2O_2 exposure. It was observed that in the presence of quercetin the growth data was erratic, with as high as 50% and 100% variation in the lag time and specific growth rate respectively. It is possible that some interaction or reaction between the undefined natural media like YPD and quercetin in presence of H_2O_2

might have created variation in effective quercetin concentration in the liquid as well as in the yeast cell. Apart from the batch to batch variation, it also created uncertainty in understanding whether any change in yeast viability or growth parameter is due to the target antioxidant molecule or product of such H_2O_2-growth media-antioxidant interaction. Similar uncertainties may occur while screening of natural (antioxidant) extracts. Thus, henceforth we rejected the *in situ* shake culture mode of exposure for the development of oxidant-antioxidant assay and used resting cells of yeast for further studies.

Table 4.2 Effect of quercetin on H_2O_2 stressed cell viability assay

Yeast type	Cell viability (x 10^6)				
	Control	H	A	HA	AH
EG103 (wild)	505 ± 25	ND	660 ± 160	10 ± 0.00	330 ± 10
EG133 (sod1Δ sod2Δ)	2955 ± 135	ND	2140 ± 300	5 ± 0.5	280 ± 70

Note: ND: Not detectable; C: Control; H: 5 mM H_2O_2; A: 100 µM quercetin; HA: 5 mM H_2O_2+100 µM quercetin; AH: 100 µM quercetin+5 mM H_2O_2. Results were expressed as mean ± standard error (SE) of triplicate runs.

To assess the effect of H_2O_2 addition on vitality of resting cells, cells from exponential phase and stationary phase were harvested, exposed to 0-5 mM H_2O_2 in buffer for 1 h and spot assay was done. Cells from exponential phase of EG103 and EG133 showed colonies upto 5 mM and 2.5 mM H_2O_2 respectively indicating that the cells were able to revive and proliferate. However, at 2.5 mM and 1 mM of H_2O_2 exposure for EG103 and EG133 significant loss of vitality could be observed (Fig. 4.2a). Similar spot assay was performed with cells from stationary phase and results showed that at 5 mM and 2.5 mM concentrations of H_2O_2, EG103 and EG133 cells showed comparatively better vitality and viability than the exponentially growing cells (Fig. 4.2b). This suggested that stationary phase cells were more resistant to oxidative stress than exponential phase cells. Previous study reported that the permeability constant for H_2O_2 was 5 times lower in cells grown to stationary phase (0.017±0.004 min^{-1} $OD600^{-1}$) than in exponentially growing cells (0.083±0.028 min^{-1} $OD600^{-1}$) (Sousa-Lopes et al., 2004). Therefore, tolerance of the oxidant by the stationary cells could be due to decrease in permeability and uptake at the plasma membrane. The tolerance was found to be better in case of EG133 cells than the EG103. This substantiates that resting cells from exponential phase of both EG103 and EG133 can be used as a yeast model to study oxidant-antioxidant system for different herbal extracts.

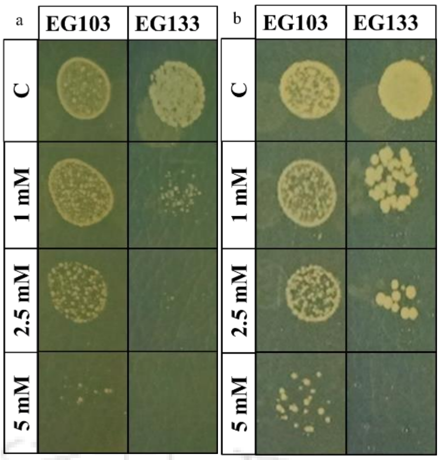

Fig. 4.2 Spot assay of (a) exponentially growing cells (b) and stationary phase cells of EG103 (wild) and EG133 (sod1Δ sod2Δ)

4.3.2. Effect of H_2O_2 concentration on antioxidant markers in wild and SOD mutant *Saccharomyces cerevisiae*

Many eukaryotes including human and yeast, invoke similar antioxidant mechanisms by regulating the expression of the genes involved as well as by regulating the enzymatic activity to reduce the ROS and RNS to a basal level permissible for cell survival. In this study the aim was to verify that once exposed to oxidative stress whether yeast cells trigger increased activity of antioxidant enzymes; catalase (CAT), glutathione peroxidase (GPx), superoxide dismutase (SOD) and glutathione reductase (GR) and non-enzymatic marker reduced glutathione (GSH) and whether they follow a dose-response relation. Activities of the enzymes substantiate conclusively if there is any adaptive response unlike total cell protein or mRNA level. In this study, when both the yeast strains were treated with increasing concentration of H_2O_2 (0-5 mM) all four enzymes; CAT, GPx, SOD and GR showed enhanced specific activity. 5 mM H_2O_2 could induce 2-fold and 4-fold increase of CAT level in EG103 and EG133 strains respectively compared to the untreated levels (Fig. 4.3a). It is also noteworthy that the basal specific activity level of CAT in EG103 is twice that of EG133 which may be due to strain specificity (Bayliak et al., 2006). A similar rate of increase in catalase activity was observed in wild strain however the catalase activity was less in mutant strain (Longo et al., 1997). This difference in activity may be due to differential expression and/or activation of the two catalase isoforms of *S. cerevisiae* i.e., CTT1 and CTA1. CTT1 is localized in the cytosol, and CTA1 in peroxisomes. CTT1 is known to be overexpressed under oxidative stress unlike CTA1 but they can act in consortium to breakdown the cellular H_2O_2 into water and molecular oxygen especially at 2 mM level concentration (Izawa et al., 1996). SOD levels increased approximately 2.5-fold, whereas GR increased 2.2-fold.

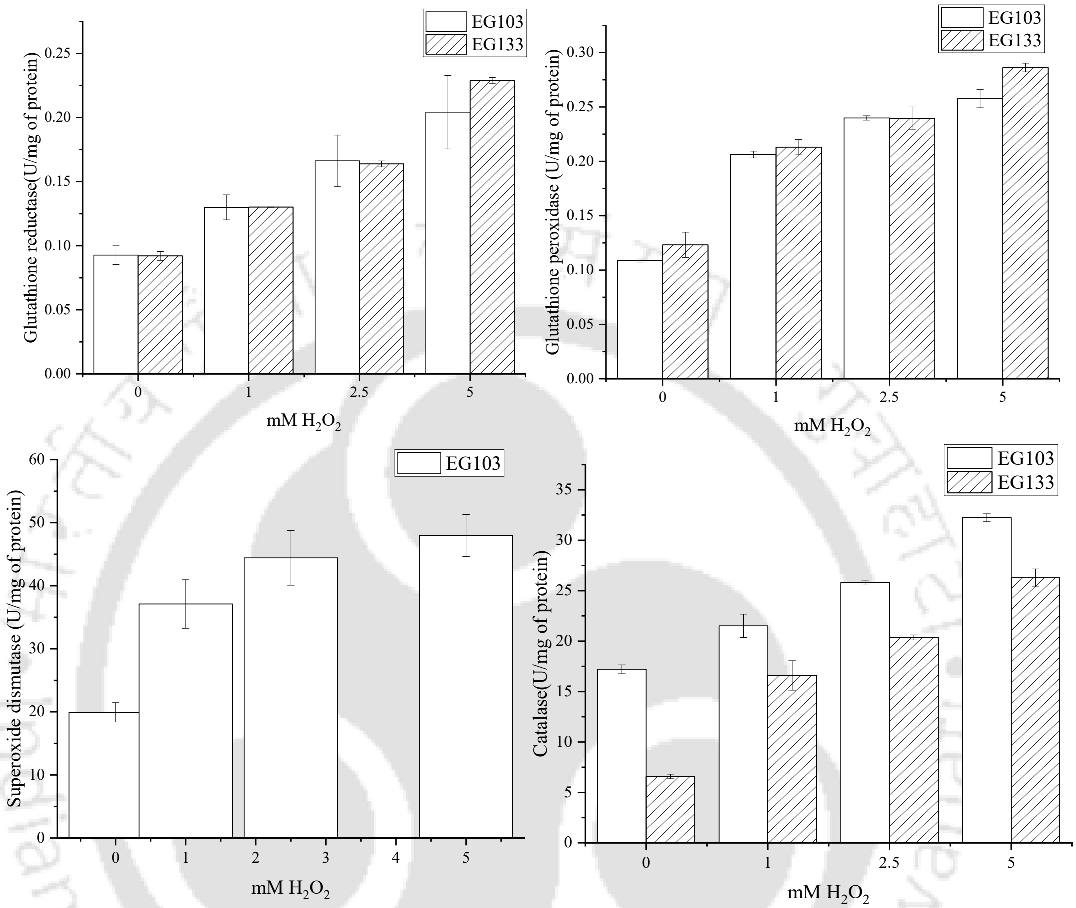

Fig. 4.3a Effect of H_2O_2 on enzymatic markers of EG103 (wild) and EG133 (sod1Δ sod2Δ). Results were expressed as mean ± standard error (SE) of triplicate runs.

In case of both the strains, induction of GPx was 2.4-fold for 5 mM H_2O_2 (Fig. 4.3a). This induction trend for GPx under oxidative stress was similar to previous findings (Manfredini et al., 2004). *S. cerevisiae* can convert peroxide molecules to its corresponding alcohol using three GPxs (GPx1, GPx2 and GPx3) and GSH as the e-donor substrate (Avery & Avery, 2001). Its localization in the membrane helps the enzyme to work against membrane lipid peroxidation. At higher H_2O_2 levels, GPx3 may play role of a sensor and transduce a key transcription factor, Yap1 for the transcription of other antioxidant proteins, which plays an important role in regulating the transcription of genes involved in the oxidative stress response (Delaunay et al., 2002). Another antioxidant molecule GR maintains the supply of total glutathione (GSH) since in its reduced form, GSH is capable of neutralizing variety of reactive oxygen species. GSH concentration in both the strains followed an exponentially decreasing trend when they were exposed to increasing concentration of H_2O_2 (Fig 4.3a).

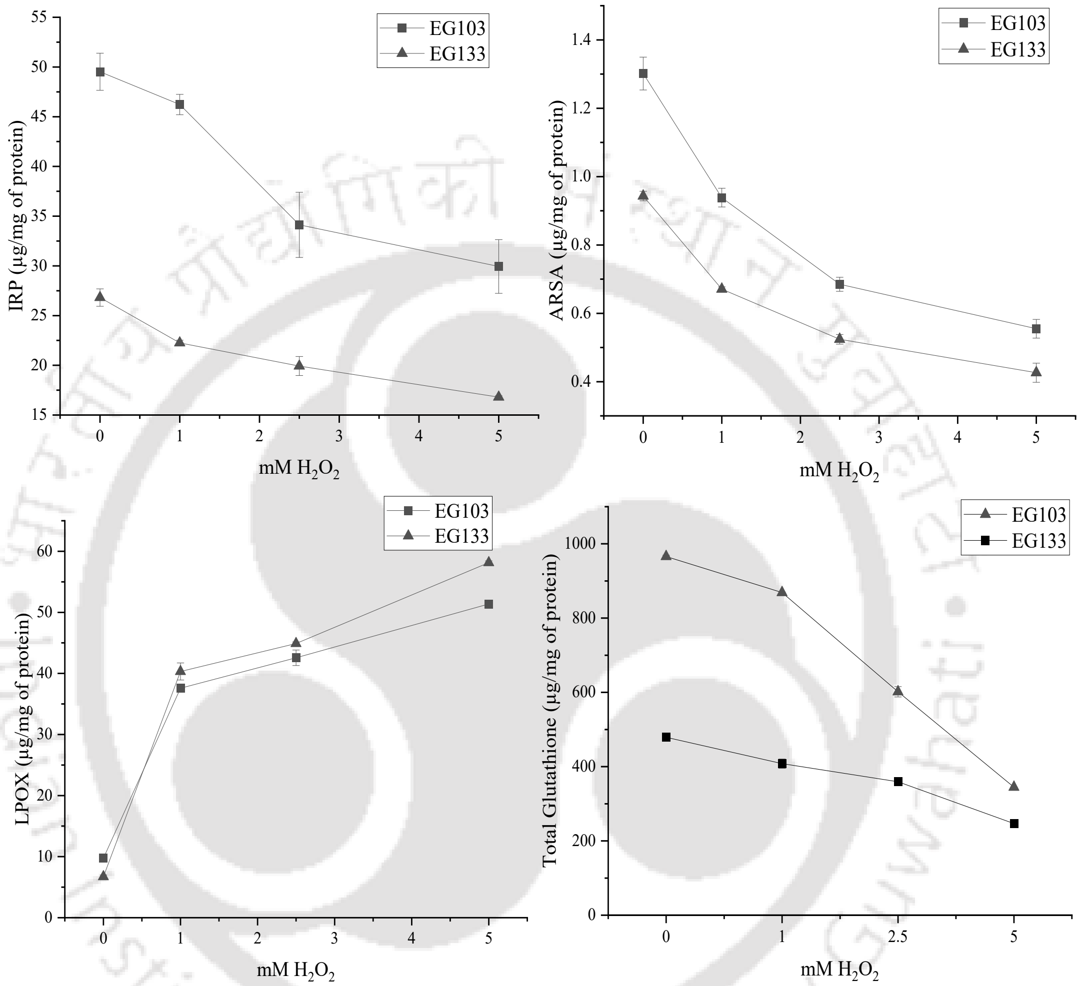

Fig. 4.3b Effect of H_2O_2 on non-enzymatic markers of EG103 (wild) and EG133 (sod1Δ sod2Δ). IRP: Fe^{3+} Reducing power; ARSA: ABTS radical scavenging activity; LPOX: Lipid peroxidation. Results were expressed as mean ± standard error (SE) of triplicate runs.

It was found that there were 2.8-fold and 2-fold decrease in total glutathione in EG103 and EG133 when exposed to 5 mM of the oxidant. GSH is oxidized non-enzymatically to glutathione disulfide (GSSG) by electrophilic substances e.g., free radicals, H_2O_2 etc. The efflux of the oxidised GSSG causes depletion of the total glutathione in cells. Total glutathione reduction is an early hallmark of cell death especially during oxidative stress (Franco & Cidlowski, 2012). Additionally, the antioxidant activity Iron/ Fe^{3+} ion Reducing power (IRP), the ABTS free radicals scavenging potential

(ARSA) and extent of lipid peroxidation (LPOX) of the yeast cell were studied to understand if the entire antioxidant associated metabolomic changes due to the oxidant. Fig. 4.3b shows that in presence of 5 mM H_2O_2 the reducing power (IRP) and radical scavenging activity (ARSA) decreased about 1.6-fold and 2.3-fold in both strains respectively. Simultaneously, lipid peroxidation increased 5 times and 8 times in EG103 and EG133 respectively (Fig. 4.3b). The above observations suggest that 5 mM H_2O_2 can be selected as the optimal oxidative stress for EG103 and EG133 for subsequent antioxidant assay where the vitality and eight other oxidative stress indicators changed in a predictable fashion compared to the untreated cells.

4.3.3. Effect of quercetin on stress resistance in yeast cells

In order to evaluate the protective effect of quercetin, stationary phase cells of *S. cerevisiae* (both wild and SOD double mutant) were exposed to 5 mM H_2O_2 and 100 μM quercetin in two different conditions and after 1 h of incubation, viability & vitality of the cells was checked with CFU and Spot assay method. In first condition (HA), quercetin was added 1 h after the addition of H_2O_2 to the resting cells whereas in the second condition (AH) quercetin was added 1 h before the addition of H_2O_2. Both conditions were compared with untreated as well as exclusively H_2O_2 (H) or quercetin (A) treated cells. The CFU data (Table 4.2) and spot assay (Fig. 4.4a) revealed that quercetin alone had no significant effect on cellular viability and vitality for both wild and mutant strains compared to their untreated cells. Interestingly, when the antioxidant was added after the H_2O_2 exposure, it could not reverse the effect of the oxidative stress. Table 4.2 indicates there was hardly any cell growth in HA condition similar to the cells exposed to H_2O_2 alone (H) (Fig. 4.4b). In the AH condition where cells were pre-treated with quercetin and then exposed to H_2O_2, a noticeable amount of cell survival was observed in spot assay as well as in CFU assay. Results showed 65% survival rate for the wild strain and 9% for the mutant strain (Fig. 4.4a and 4.4b). Previous study reported that quercetin pre-treatment protected wild and the endopeptidase proteinase A (pep4) mutant from oxidative and apoptotic stress-induced sensitivity by scavenging ROS and extends chronological lifespan (Alugoju et al., 2018). Additionally, other results suggested that quercetin may act as a modulator of cell signalling pathways related to carbohydrate metabolism and cell integrity to exert its protective effects against oxidative stress (Vilaca et al., 2012).

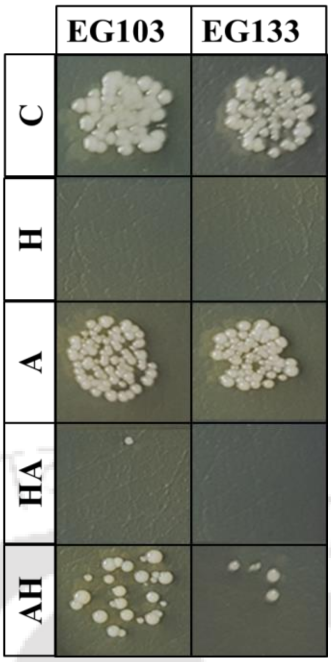

Fig. 4.4a Effect of quercetin on H_2O_2 stressed cell in spot assay. C: Control; H: 5 mM H_2O_2; A: 100 µM quercetin; HA: 5 mM H_2O_2+100 µM quercetin; AH: 100 µM quercetin+5 mM H_2O_2

However, in the SOD mutant yeast higher loss of cell viability and vitality suggests the exogenous antioxidant like quercetin at such lower concentration might not compensate for the endogenous antioxidant system like SOD. This indicated that quercetin protects cells against oxidation induced not only by H_2O_2. The related study suggested that for a proper antioxidant study method, the target antioxidants should be added prior to inducing oxidative stress.

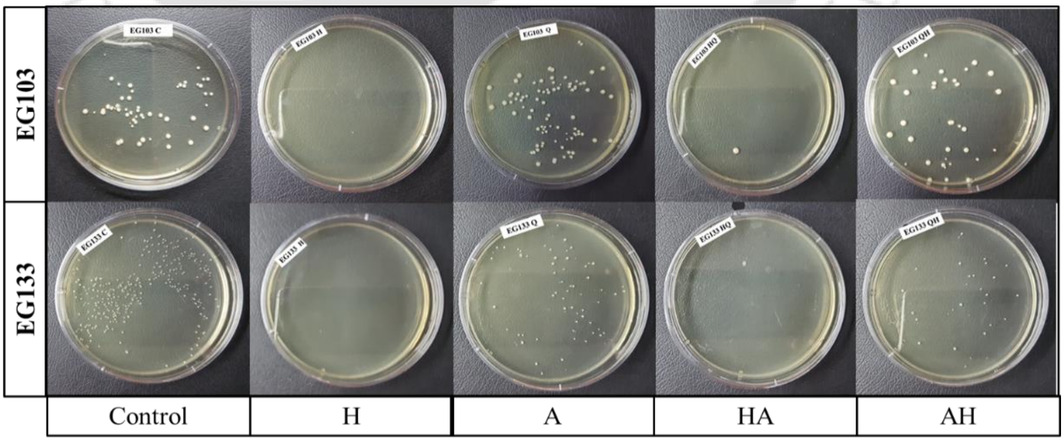

Fig. 4.4b Effect of quercetin on stress resistance in yeast cells. C: Control; H: 5 mM H_2O_2; A: 100 µM quercetin; HA: 5 mM H_2O_2+ 100 µM quercetin; AH: 100 µM quercetin + 5 mM H_2O_2.

4.3.4. Effect of quercetin on antioxidant markers of oxidative stressed yeast cells

The results obtained from the cell viability and vitality assays shows that even 100 µM quercetin had a significant effect on oxidative damage of EG103 and EG133 yeast cells. To investigate the possible mechanism and quantitative relation between quercetin addition and cell viability and vitality, eight anti-oxidative markers were estimated (as previously stated in Fig. 4.3). The specific activity of the endogenous markers i.e., GR, CAT, GPx, SOD and total GSH for both HA and AH conditions is given in Table 4.3a. The total antioxidant activity was done by the IRP, ARSA and LPOX assays and the results are shown in Table 4.3b. Considering exclusively hydrogen peroxide-treated cells as (stress) positive control, the fold change in the eight antioxidant markers for the two treatment conditions (HA & AH) were calculated (Table 4.3c).

Table 4.3a Effect of quercetin on marker enzyme on H_2O_2 stressed on wild (EG103) and sod mutant (EG133) yeast cells

Yeast type	Enzymatic antioxidant activity	U/mg protein				
		Control	H	A	HA	AH
EG103 (wild)	Glutathione reductase	0.08 ± 0.001	0.21 ± 0.003	0.09 ± 0.003	0.18 ± 0.008	0.11 ± 0.003
	Catalase	14.50 ± 0.34	26.98 ± 0.00	16.19 ± 0.68	21.92 ± 0.34	17.88 ± 0.34
	Glutathione peroxidase	0.08 ± 0.008	0.24 ± 0.00	0.09 ± 0.004	0.20 ± 0.005	0.14 ± 0.001
	Superoxide dismutase	12.76 ± 0.41	43.21 ± 0.41	13.99 ± 0.82	37.45 ± 0.41	17.28 ± 0.00
EG133 (sod1Δ sod2Δ)	Glutathione reductase	0.08 ± 0.001	0.19 ± 0.005	0.09 ± 0.003	0.18 ± 0.010	0.12 ± 0.001
	Catalase	14.11 ± 0.59	22.05 ± 0.88	15.29 ± 0.59	20.00 ± 0.59	17.05 ± 1.76
	Glutathione peroxidase	0.10 ± 0.001	0.24 ± 0.003	0.10 ± 0.002	0.21 ± 0.001	0.15 ± 0.008
	Superoxide dismutase	ND	ND	ND	ND	ND

Note: ND: Not detected. C: Control; H: 5 mM H_2O_2; A: 100 µM quercetin; HA: 5 mM H_2O_2+100 µM quercetin; AH: 100 µM quercetin+5 mM H_2O_2. Results were expressed as mean ± standard error (SE) of triplicate runs.

Table 4.3b Effect of quercetin on non-enzymatic markers on H_2O_2 stressed wild (EG103) and sod mutant (EG133) yeast cells

Yeast type	Non-enzymatic antioxidant activity	µg/mg protein				
		Control	H	A	HA	AH
EG103 (wild)	Total GSH	937.73 ± 22.37	181.14 ± 6.63	1045.46 ± 32.32	258.20 ± 12.43	797.68 ± 14.92
	IRP	53.65 ± 2.45	25.33 ± 2.09	56.19 ± 2.81	37.31 ± 1.36	49.66 ± 5.36
	ARSA	115.08 ± 1.87	26.04 ± 2.67	117.22 ± 2.41	50.64 ± 12.83	79.25 ± 3.48
	LPOX	14.63 ± 0.13	37.45 ± 0.89	16.02 ± 0.25	33.65 ±1.65	23.00 ± 0.13
EG133 (sod1Δ sod2Δ)	Total GSH	504.33 ± 4.97	141.36 ± 0.00	493.55 ± 4.14	230.03 ± 14.09	459.58 ± 3.31
	IRP	37.35 ± 1.11	18.99 ± 1.42	40.84 ± 1.11	25.32 ± 0.79	33.08 ± 0.95
	ARSA	103.59 ± 3.96	17.81 ± 2.10	103.36 ± 3.26	25.50 ± 0.47	64.43 ± 7.69
	LPOX	6.79 ± 0.77	21.60 ± 0.77	7.23 ±0.77	18.39 ± 0.88	12.86 ± 0.66

Note: C: Control; H: 5 mM H_2O_2; A: 100 µM quercetin; HA: 5 mM H_2O_2+100 µM quercetin; AH: 100 µM quercetin+5 mM H_2O_2. Results were expressed as mean ± standard error (SE) of triplicate runs.

Table 4.3c Effect of H_2O_2 on viability markers of wild (EG103) and sod mutant (EG133) yeast cells

Yeast type	Enzymatic activity	U/mg protein			Non-enzymatic antioxidant activity	µg/mg protein		
		H	HA	AH		H	HA	AH
EG103 (wild)	**Glutathione reductase**	+2.6	2.3	1.4	**Total GSH**	-5.2	-3.6	-1.2
	Catalase	+1.9	1.5	1.2	**IRP**	-2.1	-1.4	-1.1
	Glutathione peroxidase	+3	2.5	1.8	**ARSA**	-4.4	-2.3	-1.5
	Superoxide dismutase	+3.4	2.9	1.4	**LPOX**	+2.6	+2.3	+1.6
EG133 (sod1Δ sod2Δ)	**Glutathione reductase**	+2.4	2.3	1.5	**Total GSH**	-3.6	-2.2	-1.1
	Catalase	+1.6	1.4	1.2	**IRP**	-2	-1.5	-1.1
	Glutathione peroxidase	+2.4	2.1	1.5	**ARSA**	-5.8	-4.1	-1.6
	Superoxide dismutase	ND	ND	ND	**LPOX**	+3.2	+2.7	+1.9

Note: ND: Not detected; H: 5 mM H_2O_2; A: 100 µM quercetin; HA: 5 mM H_2O_2+100 µM quercetin; AH: 100 µM quercetin+5 mM H_2O_2; IRP: Fe^{3+} Reducing power; ARSA: ABTS radical scavenging activity; LPOX: Lipid peroxidation; GSH: Glutathione.

This supports less requirement of the primary endogenous antioxidant enzyme systems (CAT, SOD, GR and GPx). However, this trend was not observed when the antioxidant molecule was added alone. Perhaps at a basal level of these antioxidant enzymes in absence of any oxidative stress a polyphenol like quercetin might not down regulate the antioxidant enzymes. Also, when quercetin was added before the stress adaptation was better which was also reported in previous study where cells pre-treated with quercetin increased stress resistance of yeast cells via prevention of oxidation of important proteins, including antioxidant enzymes (Bayliak et al, 2016). So, quercetin may not stimulate but protect the primary antioxidant enzymes from oxidative structure-function loss. To further verify antioxidant effect of quercetin the non-enzymatic antioxidant markers like total GSH, IRP and ARSA were expressed in percentage to that of untreated cells (control; C) as positive control. It was found that in HA treatment, the total glutathione content decreased by 3.6-fold in EG103 and 2.2-fold in EG133, whereas in case of AH treatment, the decrease in total GSH was about 1.2-fold and 1.1-fold in EG103 and EG133. Which is in sync with theory that quercetin can upregulate synthesis of GSH and support antioxidant system of eukaryotic cells (Qi et al., 2022). These results suggest that quercetin prevents a redox imbalance by a mechanism independent of the upregulation of the pentose phosphate pathway (Belinha et al., 2007). But interestingly, this effect was pronounced in the SOD mutant cell which indicates quercetin can actually take part in multiple metabolic path.

The whole cell level antioxidant markers i.e., reducing power (IRP) and radical scavenging potential (ARSA) were more in case of AH treatment. In case of EG103, decrease in reducing power was 1.4-fold in HA and 1.1-fold in AH treatment whereas in case of EG133 it was 1.5-fold in HA and 1.1-fold in AH treatment compared to the untreated cells. Additionally, radical scavenging potential of EG103 in HA treatment was 2.3-fold and AH it was 1.5-fold lesser than that of the untreated cells. In case of EG133, ARSA was 4.1-fold in HA treatment and 1.6-fold in AH treatment. Lipid peroxidation was also expressed as a percentage of lipid peroxidation level of exclusively H_2O_2 treated cells (H). It was found that the decrease in lipid peroxidation of EG103 and EG133 was 2.3-fold and 1.6-fold in HA treatment. However, in AH treatment the decrease in lipid peroxidation was about 2.7-fold and 1.9-fold in both wild and mutant strain (Table 4.3c). One possible reason for low lipid peroxidation in presence of quercetin can be polyphenolic compounds are preferentially incorporated into membrane lipid bilayers and act as hydrogen donors, trapping free radicals, inhibiting the formation of lipid radicals, and recycling other antioxidants, such as R-tocopherol (Cotelle, 2001).

4.4. Summary

In this work, we confirmed that growing as well as resting cells of wild (EG103) and mutant (EG133) (SOD1 & SOD2) deficient strain of *S. cerevisiae* yeast responded to H_2O_2 exposure in a dose dependent manner. Out of the two strains EG133 was more susceptible to oxidative damage because of its deleted antioxidant expressing gene. To study oxidative stress and its repairing via an antioxidant molecule, growing yeast cells was not suitable due to the possibility of *in situ* reaction between growth media component and target antioxidant molecule plus H_2O_2. Further in terms of growth phase of the yeast cells, the stationary phase cells were less susceptible compared to the mid-log phase cells (could with stand 5 mM H_2O_2) to the oxidant. Therefore, stationary phase cells in resting condition is an appropriate cell model to assay physiologically relevant antioxidant assay. Using 5 mM H_2O_2 as an oxidative stress and quercetin as an antioxidant the viability and vitality changes in both the yeast cells were recorded. It was apparent that incubating the resting cells of EG103 and EG133 with 100 µM quercetin before adding H_2O_2 could improve the cell vitality and viability. However, addition of same amount of quercetin after H_2O_2 addition could not reverse the viability loss due to the oxidant. Further, eight antioxidant markers comprised of enzymes (CAT, SOD, GR, and GPx), (Total GSH, and total antioxidant assays (IRP, ARSA, and LPOX) showed a specific trend. This protective effect of quercetin in both treatments was correlated with a reduction in the levels of ROS marker enzymes and a lower degree of glutathione oxidation. Hence, the above optimised *S. cerevisiae* experimental system and the various markers can be used as an indicator for oxidative stress (5 mM H_2O_2 exposed) and is suitable as an effective model to screen antioxidant molecules (or extracts).

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Chapter 5

Impact of different drying methods on polyphenols and antioxidant potential of four selected leafy vegetables

Chapter 5

5. Introduction

Many of the herbs are not only part of traditional cousins but also pose important health benefits. With the increasing awareness about healthy food or herbal remedies, there is a great demand for such products. In 2017, the global herbal supplements market was worth USD 5.26 billion and as per current estimate, it will continue to grow at a CAGR of 6.2% till 2025 (Herbal supplements market size & share: Industry report, 2018-2025). Most of the commercial herbs (roots, leaves, flowers, etc.) or herbal products are marketed in dehydrated form as a single powder or as a polyherbal mix for culinary or medicinal use. Often the dried plant parts are used as a feed material for different types of extraction for product formulation. Hence drying is one of the most common yet critical techniques used to extend the shelf life of herbal and other plant products that should pose the desired sensory and functional properties (Belwal et al., 2022).

Traditional drying techniques like shade or sun drying are inconsistent, prone to microbial contamination and oxidative damage due to longer drying time and only suitable for domestic or small-scale purposes. Several other drying methods available for plant products are; modified solar drying, hot air drying, heat pump drying, infrared drying, vacuum drying, freeze-drying and so on so forth. The most common and favored drying method for a small-scale industry or in lab scale is the low temperature hot-air oven drying (Choudhary et al., 2021). However, oven drying takes a longer time and pose a threat to the bioactive compounds of plant products due to high temperature and atmospheric oxygen. Microwave is one of the drying techniques where the indirect electrical method is used to heat and subsequently evaporate the moisture from plant products. In a microwave, the water evaporates locally at the vapour phase and expands to burst out of the solid matrix. This creates a possibility of porous structure in mechanically strong matrices (Monteiro et al., 2016; Scaman et al., 2014). The interaction of electromagnetic waves with solid matter (to be dried) depends on the permittivity and permeability of the material.

Centella asiatica (CA), *Eryngium foetidum* (EGF), *Enhydra fluctuans* (ENF), *Marsilea minuta* (MN) are four herbs known for its culinary and medicinal use. *Centella asiatica* (CA) is an important medicinal herb in many ethnic societies worldwide. Its extracts are used for the treatment of wounds and various skin conditions such as (leprosy, lupus, eczema, psoriasis), diarrhea, fever, amenorrhea, and diseases of the female genitourinary tract (Brinkhaus et al., 2000). *Enhydra fluctuans* Lour, a leafy vegetable, known for its used in treating inflammation, skin diseases, and small pox (Ali et al., 2013). *Eryngium foetidum*, a tropical herb, is used as flavouring agent and is effective against inflammation and bacterial and viral infection. *Marsilea minuta*, a natural medicine for dermatological, digestive, respiratory and psychological diseases have been reported in many ethnomedicinal surveys.

Moisture content is the most important quality parameter for fresh and dried herbs since it decides the shelf life and other processing ability of the product. Many national and international bodies like FSSAI, FAO, OECD, AOAC, ISO, AOCS, and the Ministry of Ayush have prescribed the standard LOD methods of MC determination. Typically, 5-10 g of sample is kept for drying in a hot air oven at 105°C for a prescribed hour and by the difference of weight, moisture content of the sample is determined. But drying time at 105°C is in the range of hours and shows intra-sample variation (AOAC, FSSAI, FAO, OECD, AOAC, ISO, AOCS, and the Ministry of Ayush). Therefore, an alternative fast and reliable method for moisture content determination can be microwave-based loss on drying method (Nelson, 1977, 1991; Kraszewski et al., 1997, 1998).

In order to increase the shelf life of four herbs *Centella asiatica*, *Eryngium foetidum*, *Enhydra fluctuans*, *Marsilea minuta*, for culinary or medicinal usage and for analysing their composition, drying is essential. In the first part of the work, microwave oven-based drying was evaluated for the effective moisture content determination of these herbs. In the second part, microwave drying was tested to determine if it can replace hot air oven drying with respect to quality parameters like the polyphenol content and antioxidant properties of the four plants. Additionally, the study compared the quality of the microwave-dried product with freeze-dried product.

5.1. Methodology

5.1.1. Plant sample preparation

Centella asiatica (CA), *Eryngium foetidum* (EGF), *Enhydra fluctuans* (ENF), *Marsilea minuta* (MN) were grown extensively between April to December. The plants were harvested at matured state between 2 to 3 months. The specimen was recognized by the Botanical Survey of India, Shillong (Appendix E.1).

5.1.2. Methods of drying

5.1.2.1. Hot air drying at low temperature

Equal amounts of samples were dried at 50°C on a perforated tray with an average flow rate of 0.1-3.6m/s and weighed every hour for each sample.

5.1.2.2. Microwave drying

A domestic microwave oven (IFB, 20BC4, India) with a maximum output of 800W at 2450 MHz was used. The dimension of the microwave cavity was 262 mm × 452 mm × 390 mm. The oven was equipped with a rotating glass plate at its base. The samples were placed in a borosil glass bowl with a dimension of 150 mm × 75 mm and dried at 720W till the sample reached its equilibrium moisture content.

5.1.2.3. Freeze drying

The plant materials of 40 g were placed in a freeze-drier (NovaDryer-HF100, Senova) at -40°C in a vacuum of 10 Pa and dried for 48 h. The weight change of the samples was recorded once after 12 h.

5.1.3. Comparison of microwave oven and convective oven drying for determination of moisture content in herbs

5.1.3.1. Moisture content comparison

The moisture content of the leaf samples was determined as follows; 40 g of sample was weighed and dried in a hot air oven at 105±2°C and microwave oven (720W) until constant weight. Moisture content was estimated by the difference of weight method. The moisture content was calculated by two different methods of drying (Appendix C.1). Then, the moisture content values estimated by the LOD methods were correlated.

5.1.3.2. Effective moisture diffusivity estimation

The effective moisture diffusivity estimated from the slope of semilogarithmic plot of moisture ratio (M_R) from experimental data versus time. The slope of the straight line was considered as the quantity of the effective diffusivity as described in Appendix C.2.

5.1.3.3. Estimation of intra-sample variation

Equal weight of ten sets of samples of an herb CA was taken in different batches for drying. The samples were dried in hot-air oven at 105ºC and a microwave oven at 720W until constant weight was reached. The variation in moisture content was estimated in the Box-Whisker plot.

5.1.3.4. Spatial distribution of temperature and flow rate estimation

The temperature of different locations was measured with an IR thermometer in the cabinet of oven driers and microwave oven. The air flow rate of the oven drier was measured in the same locations with the anemometer.

5.1.4. Drying characteristics of four herbs in three different types of driers and properties of their powder

The effect of hot air oven (105ºC) drying, hot air drying at low temperature (50ºC), microwave oven at 720W and freeze-drying (-40ºC) on four varieties of herbs were estimated in terms of drying rate and water activity, particle size, bulk density and tapped density.

5.1.4.1. Analytical Methods

5.1.4.1.1. Water activity (a_w)

Water activity (a_w) indicates the amount of water available for chemical and biochemical reactions (Sandulachi, 2012). It was determined by a humimeter RH2 water activity meter and analyzed at a temperature of 21 ± 2°C.

5.1.4.1.2. Particle size, bulk and tapped density

Particle size was estimated using the sieve analysis method. A set of standard sieves was used to separate different size fractions of the leaf powder. The bulk density and apparent porosity were determined in according to the respective USP procedure (US Pharmacopoeia, 2000) (Appendix C.4 and C.5).

5.1.5. Effect of three different drying on extractability of alcohol soluble components and antioxidant activity of the resultant extract

The effect of hot air drying at low temperature (50ºC), microwave oven at 720W and freeze-drying (-40ºC) for extraction of antioxidant rich polyphenols were estimated with different analytical methods as described below.

5.1.5.1. Analytical Methods

5.1.5.1.1. Total soluble solids

The soluble solids of 4 g of dried powder of *Centella asiatica* (CA), *Eryngium foetidum* (EGF), *Enhydra fluctuans* (ENF), *Marsilea minuta* (MN) were extracted in 400 mL of methanol at 37°C for 48 h (Appendix E.3). The loss on drying method was used for determining total solids of the beverages. 5 mL of the samples were dried and the difference of weight was used to calculate mg of solids/g of dry weight of powder (Appendix C.3).

5.1.5.1.2. Total phenolic content (TPC)

Folin's reducing power assay is well recognized for estimating total phenolics of the extracts (Berker et al., 2013). The total phenolic content (TPC) of the extracts were determined using the Folin and Ciocalteu reagent, with a modification of Singleton and Rossi (1965). 0.2 mL of extracts were dissolved in 0.6 mL of distilled water, and 0.2 mL of 1 N Folin Ciocalteu's reagent was mixed to the reaction mixture and incubated for 5 minutes at 25°C. 1 mL of 8% sodium carbonate (Na_2CO_3) was added and incubated at 25°C for 1 h. The absorbance was measured at 750 nm using UV-visible spectrophotometer (Shimazu UV-1900). The results of total phenolic contents were expressed as mg of gallic acid equivalent (GAE)/g of dry powder (Appendix C.9).

5.1.5.1.3. Total flavonoid content (TFC)

The total flavonoid content was estimated as described by Patel et al. (2010). 200 µL of extracts dissolved in 5% of 0.1 M sodium nitrate ($NaNO_3$) and incubated for 6 minutes at 30ºC. 10% of 0.1 M aluminium chloride ($AlCl_3$) was added to the reaction mixture and allowed to react for 5 minutes. 1 M of sodium hydroxide was added and absorbance was measured in UV-Vis Spectrophotometer (Shimazu UV-1900) at 410 nm after 40 minutes of incubation. The results of total flavonoid contents were expressed as mg of quercetin equivalent (QE)/g of dry powder (Appendix C.10).

5.1.5.1.4. Reducing power (IRP)

The reducing power of samples was measured using the method of Oyaizu (1986) with slight modification. 100 µL of extracts dissolved in 300 µL phosphate buffer (0.2 M, pH 6.6) and 300 µL of 1% potassium ferricyanide ($K_3[Fe(CN)_6]$) incubated at 50ºC for 20 minutes. The reaction was stopped with the addition of 300 µL 10% trichloroacetic acid. Absorbance was measured at 700 nm with the addition of 800 µL distilled water and 200 µL of 0.1% ferric chloride ($FeCl_3$). Results were expressed as mg ascorbic acid (AA) equivalent/g of dry powder (Appendix B.5).

5.1.5.1.5. Radical scavenging activity (ARSA)

The free radicals scavenging potential (ARSA) of extracts were determined using modified Re et al. (1999) method. ABTS radical cation ($ABTS^{\bullet+}$) was produced with 7 mM ABTS solution and 2.45 mM potassium persulphate ($K_2S_2O_8$) and equilibrated at 30ºC for 16 h before use. The $ABTS^{\bullet+}$ solution was diluted with acetate buffer (4.5 pH) and incubated for 30 minutes for a stable absorbance of 0.70 ± 0.02 at 734 nm. 1.8 mL of the ABTS radical solution was mixed with 90 µL of extracts and incubated for 6 minutes. The absorbance was measured at 734 nm using UV-Visible spectrophotometer (Shimazu UV-1900). The results were expressed as mg trolox (TE) equivalent/g of dry powder (Appendix B.6).

5.1.5.1.6. Lipid peroxidation inhibition (LPOX)

A modified thiobarbituric acid-reactive species assay was used to measure the lipid peroxidation inhibition potential of extract with a slightly modified method of Ohkawa et al. (1979). The egg-yolk homogenates were used as a test lipid media. Egg homogenate (250 µL, 10% in distilled water, v/v) and 50 µL of extracts were mixed and made up to 500 µL by adding methanol. Subsequently, 25 µL $FeSO_4$ (0.07 M) was mixed and incubated for 30 minutes to induce lipid peroxidation. 750 µL of 20% acetic acid (pH 3.5) and 750 µL of 0.8% thiobarbituric acid (TBA) (w/v) (prepared in 1.1% sodium dodecyl sulphate) and 25 µL of 20% trichloroacetic acid (TCA) were added to the reaction mixture, vortexed, and then heated at 95ºC for 60 minutes. After cooling, 3 mL of 1-butanol was added to each tube and centrifuged (Remi, CPR-24 Plus) at 6000 × *g* for 10 minutes. The absorbance of the organic upper layer was measured against 3mL butanol at 532 nm. The results were expressed as mg malondialdehyde (MDA)/g of dry powder (Appendix B.7).

5.1.5.1.7. Effect of drying on polyphenol oxidase activity

Polyphenol oxidase activity was estimated as described by Tan et al. (2015). Crude extracts containing polyphenol oxidase enzyme were prepared by suspending 1 g of dried samples in 10 mL of 0.2 M potassium phosphate buffer, pH 7.0, containing 1% PVP-40 (w/v) and 1% Triton X-100 (v/v) at 4°C for 1 h in a shaker incubator. The suspensions were centrifuged at 10, 000 rpm for 1 h at 4°C. The supernatant, stored at -20°C, was used for enzymatic analysis within 7 days. In a 2.9 mL reaction mixture with 1 mM catechin, 0.05 M potassium phosphate buffer (pH 6.5), the reaction was started by adding 0.1 mL of PPO enzyme extracts. Reference cell was prepared containing only the reaction mixture without the enzyme extracts. The absorbance of the reaction mixture was measured every minute at 435 nm. The initial linear part of the absorbance plot was used to calculate the activity. PPO activity was expressed as ΔA435/min/g of dry powder (Appendix C.6).

5.1.6. Effect of drying on polyphenols of selected for herbs using HPLC

A signature chromatogram was developed for the extracts using an Agilent 1100 Series liquid chromatography (USA) equipped with a UV/DAD detector. Chromatographic separation was performed using a Poroshell 120 EC-C18 (4.6 mm × 100 mm, 2.7 µm) column. Eluent solvent had a constant flow rate of 1.0 mL/min. The mobile phase was distilled water with 0.1% glacial acetic acid (solvent A) and acetonitrile with 0.1% glacial acetic acid (solvent B). The gradient was as follows: 0–3.25 min, 8–10% B; 3.25–8 min, 10–12% B; 8–15, 12–25% B; 15–15.8 min, 25–30% B; 15.8–25 min, 30–

90% B; 25–25.4 min, 90–100% B; and 25.4–30 min, 100% B. The injection volume was 20 µL, and the temperature was kept constant at 25°C. The detection wavelength was chosen considering the absorption maximums of UV spectra of the selected phenolic compounds, i.e., 280 nm (Krstonosic et al., 2020). This HPLC method was validated on known standard compounds and the compound in the extracts were identified based on peak retention time. The total run time for the analysis of compounds and type of extracts was 27 minutes. The reproducibility of HPLC analysis was examined by injection of a standard mixture with 1 mg/mL concentration.

5.1.7. Chemical profiling of one of the selected herbs for similarity analysis of drying process

The phenolic compounds of CA dried in 50ºC, microwave (720W) and freeze (-40ºC) were identified by using an LC system coupled to a triple quadrupole mass spectrometer (Agilent 6410 Triple Quad MS-MS) equipped with an ESI source. The chromatographic separation of the phenolic compounds was carried out on Eclipse Plus column C18 (100 × 4.6 mm i.d., particle size 3.5 µm). The temperature of the column was set at 40°C and the injection volume of the samples was 5 µL. The negative mode compounds were isolated in mobile phase consists of 0.1% acetic acid in 5 mM ammonium acetate (eluent A) and acetonitrile (eluent B) at a flow rate of 0.40 mL/min. The gradient conditions were as follows: 0–5 min, 2-2% B; 5–20 min, 2-40% B; 20–30 min, 40-90% B; 30–40 min, 90–2% B; 40–45 min, 2-2% B. The capillary voltage was of 135V; nebulizing gas (N2) flow rate was 11 L/min, and the heat block and de-solvation line temperatures was of 300°C, respectively. Mass spectra was recorded between m/z 15–1650. The main phenolic compounds of CA were identified by comparing their mass spectrometry fragmentation patterns.

5.2. Statistical Analysis

All experimental data was expressed as mean ± standard error of triplicate runs. The Origin 9.0 program (2022) was used to analyse the data and mean values were statistically significant ($p < 0.05$).

5.3. Results and Discussion

In order to increase the shelf life of four herbs *Centella asiatica*, *Eryngium foetidum*, *Enhydra fluctuans*, *Marsilea minuta* for culinary or medicinal usage and for analysing their composition drying is essential. In the first part of the work, microwave oven-based drying was compared with conventional convective or hot air oven based drying for moisture content determination so that a microwave oven-based method can be developed as a rapid and economical way of moisture content determination. In the second part an attempt has been made to find a commercially viable method for drying of herbs. As an alternative to traditional sun or shade drying three different drying technologies convective, microwave and freeze drying were evaluated to dry the herbs and their quality was evaluated.

5.3.1. Comparison of microwave oven and convective oven drying for determination of moisture content in herbs

Accurate and rapid moisture content (MC) determination of fresh or dried plant tissues and their powders is essential for research laboratories as well for herbal Industries. MC determination is important to control shelf-life as well as compositional analysis of herbal products. Often the prescribed method of MC determination by various regulatory agencies is by calculating the weight loss of a sample on (complete) drying at 105ºC in a hot air oven (WHO, 2007; AOAC, 2005). However, the method has two major limitations, firstly longer time of drying for complete removal of moisture and secondly broader intra-sample variation.

In this study, four medicinally valuable plant samples were dried by two different methods; by microwave drying at 720W power and by well-known hot air oven at 105°C. Both the processes were compared for complete moisture removal. Indeed, the drying rate in the domestic microwave oven was one order of magnitude faster. Fig. 5.1 indicates the moisture diffusivity in all the samples under microwave drying was about ten times more than that in the hot air drying at 105ºC. In the hot air oven complete removal of moisture from all four samples took at least 7 h whereas in microwave oven it took less than 16 minutes.

Considering the hot air oven method as a gold standard, the moisture content determined for four medicinal plants *Centella asiatica*, *Eryngium foetidum*, *Enhydra* *fluctuans*, and *Marsilea minuta* using microwave oven was compared with the moisture content determined by hot air oven.

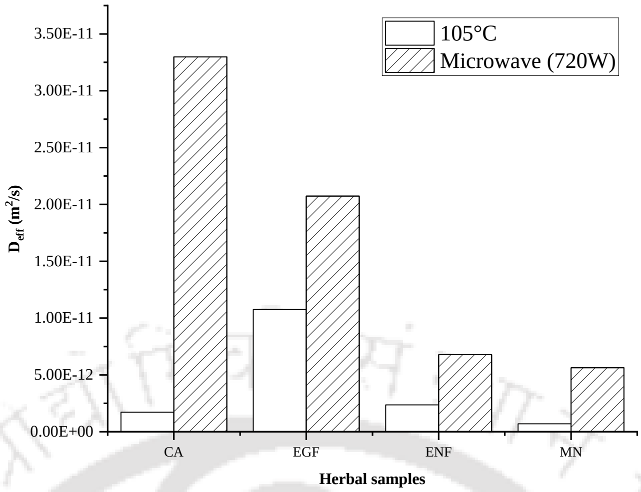

Fig. 5.1 Moisture diffusivity in four herbs under microwave drying and hot air drying at 105°C

The Pearson, and Spearman correlation coefficient between the MC determined by both the methods were respectively 0.9 and 0.76 (Table 5.1). This finding supports that the microwave oven drying is suitable for MC determination of herbal leaves like hot air oven. The method is further examined for the intra-sample variation. MC of an herbal sample (*Centella asiatica*) was measured ten times with both the methods and the dispersion of the MC data was compared with a Box-Whisker Plot (Fig. 5.2).

Table 5.1 MC comparison of different samples in 105°C and Microwave drying (720W)

105°C	Microwave (720W)
0.89	0.89
0.89	0.89
0.87	0.87
0.87	0.87
0.89	0.84
0.89	0.84
0.72	0.77
0.70	0.77

The origin of variation in a hot air oven was studied and the heterogeneity of air flow rate and temperature in different locations of the hot air oven was observed. The samples kept at various trays faced different local air conditions and therefore suffered different extents of drying. It is well known that hot air ovens without forced convection will have spatial heterogeneity of temperature.

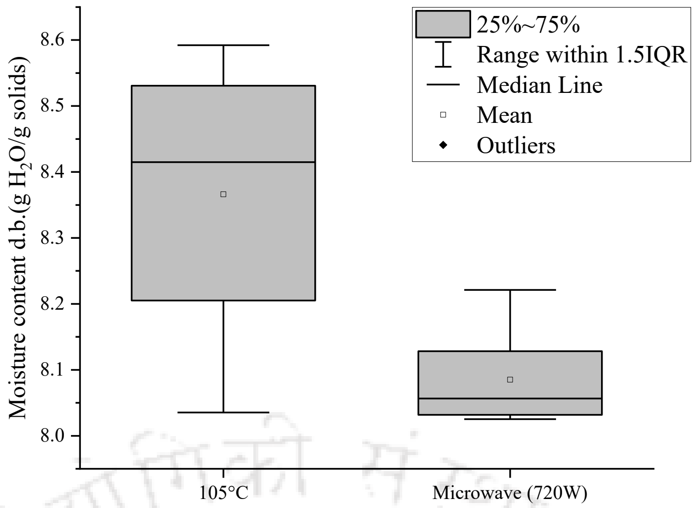

Fig. 5.2 Dispersion of the moisture content of 105ºC and microwave drying with a Box-Whisker Plot

However, to identify the extent of spatial temperature and air flow distribution, four laboratory hot air ovens with forced convection were studied and surprisingly all of them showed significant non-uniformity. The extreme air velocities in two different locations inside the dryer cabinet was observed 0.1 and 3.6 m/s. Whereas the lowest and highest temperature seen inside the same cabinet was 95ºC and 107ºC. Difference of 10 ºC and flowrate differences of one order of magnitude can considerably under dry or over dry the samples. Table 5.2 and 5.3 indicates the heterogeneity of temperature & airflow rate inside the dryer cabinet used for the present study.

Table 5.2 Spatial distribution of temperature and air flow rate in hot air oven

Oven drier (105°C)			Tray drier (50°C)		
Cabinet locations	**Flow rate(m/s)**	**Temperature (°C)**	**Cabinet locations**	**Flow rate(m/s)**	**Temperature (°C)**
Near Fan	2.9±0.09	107±1.73	**Middle Right (Near Fan)**	3.6±0.15	51.2±0.66
Up Middle	0.7±0.06	103±1.73	**Middle Middle**	0.8±0.09	50.6±1.18
Down Middle	1.5±0.09	97±1.45	**Middle Left**	0.5±0.09	48.9±1.24
Up Right	0.7±0.15	94±2.03	**Top Right**	0.4±0.06	48.2±0.66
Down Right	1.2±0.15	95±1.15	**Top Middle**	0.3±0.06	47±1.36
			Top Left	0.1±0.03	46.7±0.49
			Down Right	1.7±0.20	42.6±1.24
			Down Middle	1.3±0.15	43.2±1.07
			Down Left	0.3±0.06	42.8±1.01
			Infront of Door	0.08±0.01	42±1.13

Table 5.3 Spatial distribution of temperature in microwave oven

Microwave (720W)	1 min	2 min	3 min	4 min	5 min	6 min	7 min	8 min	9 min	10 min
Left Boundary	72±0.88	74±0.33	71±0.58	71±0.33	73±0.67	72±0.33	72±0.33	72±0.58	74±0.58	73±0.88
On Plate	99±0.52	100±0.39	100±0.33	103±0.58	104±0.33	105±0.58	106±0.58	105±0.88	104±0.33	105±0.33
Right Boundary	93±0.58	97±0.58	96±0.58	95±0.58	90±0.58	93±0.58	96±0.58	97±0.88	92±0.88	95±0.88
Upper	112±0.61	104±0.62	105±0.41	107±0.41	105±0.62	107±0.62	105±00.62	103±0.41	103±0.62	109±0.62

It can be anticipated designs of laboratory hot air ovens may not always ensure uniform airflow. Many times, finer mistakes in the design of such ovens may create poor mixing and therefore poor temperature control. Computational fluid dynamics can be used to optimize the design of a hot air oven for narrow temperature & air velocity distribution within the cabinet (Babu et al., 2020). Another issue we could identify is solid loss due to high air flow rate in hot air ovens especially for friable materials like leaves, flowers etc. Such issues are less likely in presently available domestic microwave ovens (Su et al., 2022). Though standing wave pattern of microwave inside the oven and dielectric heterogeneity of plant tissues cause some non-uniformity in heating of the sample volume. Ceramic/Stainless steel enamel cavity, appropriate cavity geometry, controlled frequency and turntable plate for holding the samples make most of the domestic microwave oven suitable for uniform heating of plant materials. Therefore, for small volume of samples (5-25 g) uniformity of microwave ovens are superior than that of hot air oven. In our study also microwave oven showed significantly lower intra-sample variation compared to hot air oven (Fig. 5.2). Often it is anticipated at high temperature essential oil of many medicinal plants may deteriorate in terms of quality and yield. Distillation method of MCD is often preferred for such medicinal plants with high oil content (WHO, 2007). The method is problematic due to difficulty in recovery of the condensate and cleaning the distillation set up. Also, the formation of emulsions may be hard to be separated and assessed for oil and moisture content. For fresh plant tissues still, the loss on complete drying is suitable method considering the higher moisture content (70-95%) compared to the oil content. Oil concentration in plant parts are typically less than 10% except some seeds. However, the commercial Karl Fischer tilt rotors costs couple of thousand USD and often a complex system for regular use in academic or industrial labs. Even 1% moisture content in a standard 5 g sample will cause 0.05 g of change which is achievable for all practical purposes. In case of microwave drying general concern is volatilization of solids in a sample leading to overestimation of moisture content (Ullah et al., 2020). Following reaction shows the carbonization (charring) of sugars. For each gram of hexose(equivalent) about 0.6 gram of weight loss happens.

$$C_{12}H_{22}O_{11} \rightarrow 11H_2O \ + 12C$$

We simulated the effect of different percentages (0.5-50%) of volatilization and also the effect of different degrees (0.5-50%) of incomplete drying on the estimated moisture content of a sample (Appendix C.7 and C.8). The standard deviation of the all the simulated moisture content values was 0.322%. Therefore, the correct rounding off-figure for representing the moisture content determination was considered upto one decimal place (van Reeuwijk, 1998). For the same accuracy of MC values, it was found with less than 5% volatilization or 5% lesser drying the MC values does not change significantly for a sample irrespective of its MC. Hence an herbal product with a sugar/hexose content as high as 8% will show insignificant error in MC even with complete carbonization. Generally, fresh herbal crops like flowers, leaves, rhizomes etc. contain 70-95% moisture. Same simulation showed that no error can be detected in MC determination even if there is 15% under drying or 15% solid volatilization for any sample with more than 70% MC. Therefore, when MC to be determined for fresh (expected MC >70% in wet basis)and dried (expected MC <10% in wet basis) herbal substances microwave oven-based method might fail if the thermo-labile compounds respectively crosses 15% and 5% considering 5 g of sample size. The thermo-labile compounds may be essential oils, sugars or other heat-sensitive compounds. In addition to non-uniform energy distribution, another reason for the lack of repeatability was found to be heterogeneity of samples. Many a times fresh herbal samples may contain different tissues (e.g., stem and leaves together) which will have different drying behavior and moisture content.

5.3.2. Drying characteristics of four herbs in three different types of dryer and properties of their powder

In a separate set of experiment, microwave drying was compared with two drying methods; a commercially popular drying method i.e., convective tray drying (at 50ºC) and the other one is a peer accepted sophisticated drying technique, i.e. freeze drying. Convective drying is very common form of drying in industries. However, it is a slow and poor drying process in terms of bioactives on the other hand freeze drying is a costly process to be adopted for common usage. In the present trial, microwave drying was acceded to check its suitability to prepare dried herbs for further used as herbal beverages (decoction and infusion), ingredients for curries or cousines or comonent of herbal medicine preparation (e..g, hydroalcoholic extract) quality analysis of herbal products.

For the three drying methods, moisture content of the sample was estimated for different time intervals till the constant weight of the sample was reached. The order of time to reach the equilibrium moisture content was microwave drying (8-12 min) < low temperature convective drying (50ºC) (9-16 h), freeze drying (36-48 h). As expected, the drying time was dependent on the herb variety since the surface area and thickness of the leaf and the residual stem as well as the internal cell structures, were different. *Eryngium foetidum* and *Enhydra fluctuans* took respectively fastest and slowest time to reach EMC in both convective and microwave drying. For freeze drying, we could take weight change only after every 12 h and all the four samples reached equilibrium content between 36-48 h (Appendix E.2). Since the sublimation and subsequent diffusion rate of water molecules in sub zero temperature was much slower than the that duirng drying at 50 or higher temperature freeze drying took longest time to dry. However, in all three methods the equilibrium moisture content was quite low and the highest EMC was observed for *Enhydra fluctuans* 2% in case of microwave drying (Table 5.4).

Table 5.4 Order of time to reach the equilibrium moisture content of herbal samples

	Drying time to reach EMC			Initial moisture content (%, wb)	Equilibrium moisture content		
Sample Name	**50°C drying, h**	**Microwave (720W, 90%), min**	**Freeze drying**		**50°C**	**Microwave (720W, 90%)**	**Freeze drying**
CA	8	13	48	89.8	1.8	1	0
ENF	12	16	48	89.6	0.2	2	0
EGF	8	9	48	87.5	0.9	0	1
MN	9	15	48	77.9	1	0	1

This indicates that microwave drying is the fastest method for drying herbs to achieve a desired moisture content. For consistent results (sensory quality, bioactivity etc.) of an infused beverage, soup, sprinkle, medicinal decoction etc. herbs are often used in a powdered form where its soluble components get extracted in the (aqueous) solvent. Both qualitative and quantitative extraction of the molecules depends on particle size as well as its porosity of the dried herbal powders. Specific drying technique i.e., moisture removal mechanism, temperature of drying and rate of moisture removal of the herbal product controls not only the composition of the molecules (degradation or derivatization of the small compounds) but also their milled powder characteristics (particle size and porosity). From the sieve analysis of the powders obtained from four different plant leaves dried with three different types of drying methods but milled under same conditions showed the particle size distribution was not greatly influenced by the method of drying but varied with the type of the plant material (Table 5.5). Usually with decreasing moisture content, there should be a decrease in bulk density as well as the tap density of the dried powder but we could observe the density values varied according to the method of drying and not just the moisture content (Adhamatika et al., 2022; Çalışkan, 2020). Among all the dried materials, the highest bulk density powder was of *Marsilea minuta* (289.9 kg/m^3) when dried in the microwave oven. However the lowest bulk density powder could be seen for *Centella asiatica* (125.0 kg/m^3) when dried with convective drying at 50ºC (Table 5.6). Also the apparent porosity i.e., the ratio of tapped density to true density of the dried powder from microwave was higher than that of freeze drying and freeze drying porosity values were higher than low temperature convective drying (50ºC) values.

Table 5.5 Particle size distribution of herbal powders

Sample Name	Average particle size (µm) (2000-63)				Average particle size (µm) (250-63)			
	Oven dried (105°C)	Tray dried (50°C)	Microwave dried (720W)	Freeze dried (-40°C)	Oven dried (105°C)	Tray dried (50°C)	Microwave dried (720W)	Freeze dried (-40°C)
CA	652.84±3.39	716.48±6.48	663.76±2.52	735.02±0.39	304.19±2.83	305.33±0.89	276.89±0.53	287.17±0.79
ENF	633.03±12.22	707.65±13.58	676.25±0.97	688.34±0.17	279.18±6.80	309.60±4.28	302.09±0.59	295.19±0.87
EGF	681.46±5.70	641.77±16.59	660.17±2.74	694.13±1.76	312.65±2.97	295.22±5.99	294.51±1.13	301.43±1.13
MN	747±4.30	614.25±5.80	633.16±5.95	661.41±2.01	301.71±1.45	292.11±1.66	292.09±3.21	304.33±0.04

Generally, tapped density is more for regular shaped particles like sphere cubes etc., than irregular shaped particles like needle shaped or fibrous one. In the present study, the tapped density does not follow a specific trend and the lowest and highest tap densities were found to be for *Centella asiatica* and *Enhydra fluctuans*. Owing to the difference in their tissue structure (Appendix E.2) they gave rise to particles of different shapes as well as pore pattern. Also the structural components like lignin, cellulose, hemicellulose and pectin can vary greatly for CA, EGF, ENF, and MN which control the true density of the leaf powder particle specifically in dried form. Since lignin and cellulose have less affinity to moisture than hemicellulose and pectin they influence the drying behaviour greatly (see Chapter 3 polysaccharide chapter). Such difference in composition reflects in the particle size, for all four plants depending on the method of drying 30-50% of the powdered samples are in the range of 250 µm to 106 µm. Etti et al. (2016) and Fitzpatrick et al. (2004) reported that all the pure herbal powders with particle sizes below 100 µm made them cohesive. Hence, the tiny particles will form interparticular binding to make their flow difficult (Li et al., 2004). Since particle size distribution and porosity dictates its functional properties; adsorption-desorption behaviour, extractability of solubles from the particles, enzymatic digestion, shelflife, compaction and flowability etc. microwave drying can be used as a better method than low temperature convective drying or even freeze drying to obtain dried powder with better porosity and smaller particle size.

Table 5.6 Comparative study of different methods of drying

Sample Name	Oven dried (105°C)			Microwave (720W)		
	Bulk Density (kg/m^3)	Tapped Density (kg/m^3)	Apparent Porosity (%)	Bulk Density (kg/m^3)	Tapped Density (kg/m^3)	Apparent Porosity (%)
CA	305.50±7.0	336.16±2.82	37.01±3.67	236.89±7.01	283.70±2.01	34.04±0.24
ENF	305.36±2.33	380.99±3.63	38.10±0.36	272.73±12.99	312.50±0.00	34.38±3.12
EGF	261.54±5.13	307.77±4.73	36.93±0.57	215.08±2.31	253.21±3.21	32.88±2.12
MN	201.01±1.01	235.33±2.77	23.53±0.28	289.92±4.20	305.36±2.33	30.54±0.23
Sample Name	**Tray dried (50°C)**			**Freeze dried (-40°C)**		
	Bulk Density (kg/m^3)	**Tapped Density (kg/m^3)**	**Apparent Porosity (%)**	**Bulk Density (kg/m^3)**	**Tapped Density (kg/m^3)**	**Apparent Porosity (%)**
CA	125.00±00	163.33±3.33	18.00±2.00	217.49±4.73	246.95±3.05	29.63±0.37
ENF	270.47±7.31	313.73±19.61	25.10±1.57	226.0±1.28	266.71±3.56	23.97±2.35
EGF	200.08±4.00	227.74±10.35	24.95±1.14	221.0±1.22	241.0±2.90	26.54±2.73
MN	233.99±4.11	285.95±8.17	22.88±0.65	241.28±8.72	283.82±6.04	22.71±0.48

Results were expressed as mean ± standard error (SE) of triplicate runs.

5.3.3. Effect of three different drying on extractability of alcohol soluble components and antioxidant activity of the resultant extract

In terms of better retention of bioactive compounds in a herb freeze-drying is generally considered as the most reliable method for drying for their processing and analysis. In this study we wanted to confirm two possibilities; whether the drying method can influence the matrix structure and therefore total extractability of a specific soluble (e.g., methanol) fraction in terms of total soluble solids (TSS) and any specific functional property like antioxidant activity of the millieu of molecules in the extract. The TSS of the four-leaf samples listed in the Fig. 5.3 were dried in three different drying methods. For extraction, methanol was used since most primary and secondary metabolites are soluble in methanol and it has good penetration into the cells. All the four leaves dried using microwave and freeze dryer had a 10-20% higher amount of TSS compared to convective oven dried sample at 50ºC. However, there is no significant difference found between freeze-dried and microwave dried samples of EGF, ENF, and MN. In CA we have found 18% higher TSS than freeze-dried samples. Nevertheless, the comparable amount of TSS of the microwave with freeze-dried showed the drying method did not alter the porous matrix of the herbs. Singh et al. (2015) also showed that microwave (0.03-0.78) and freeze (0.03-0.88) dried samples have more or less the same porosity for potato, whereas in the case of convective drying, it is in the range of 0.03 to 0.20. Apart from TSS the so-called total phenol content in terms of gallic acid equivalent of methanolic extract was similar in both microwave and freeze drying on the other hand convective oven dried samples had 25-45% lesser TPC values.

The total flavonoid content of the methanolic extracts from different dried samples of the four plants followed almost same pattern as TPC. However, the antioxidant capacity in terms of Fe^{3+} reduction, free radical scavenging and lipid peroxidation inhibition out of the four herbs, CA and ENF in the same order showed antioxidant potential (Fig. 5.3). Other two plants had significantly lesser antioxidant potential. Additionally, particular antioxidant capacity (e.g., Fe^{3+} reduction or free radical scavenging capacity) of the plants were dependent on both the herb variety and the method of drying.

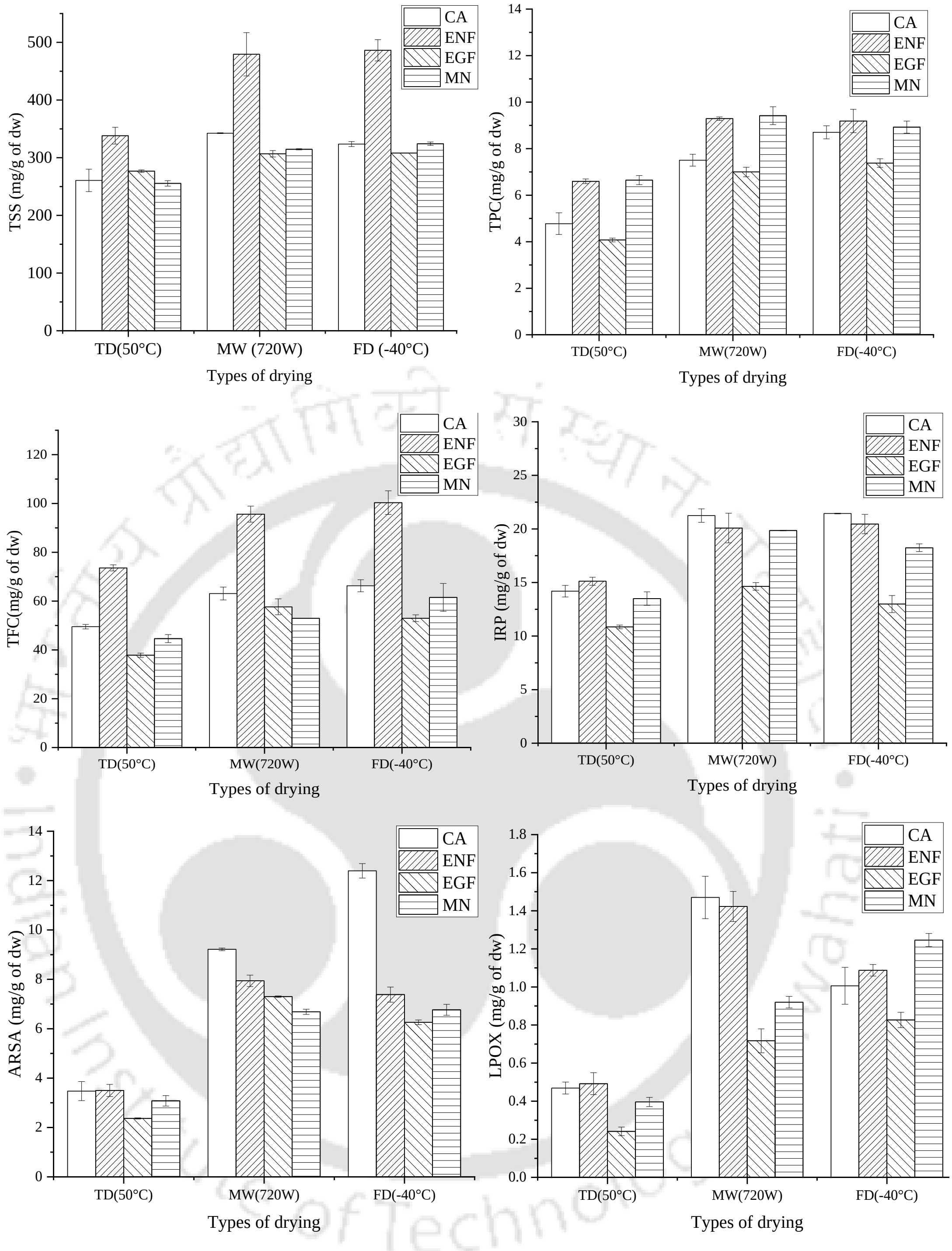

Fig. 5.3 Effect of three different drying on extractability of alcohol soluble components and antioxidant activity. Results were expressed as mean ± standard error (SE) of triplicate runs.

Potisate et al. (2014) reported that approximately 43-62% increase in quercetin and kaempferol levels in the *M. oleifera* leaves after drying in a freeze dryer(-85°C) well as in microwave (150, 450, 900W) compared to dried in a convective dryer at 50°C as well as a reduction in phytochemicals was observed at 60ºC in tray drier due to the fact that multiple of reaction can take place at that high temperature. Similarly, Max industrial microwave did a comparative study on *M. oleifera* leaves and reported an increase in both micronutrients and macronutrients on microwaving. There is an increase in sulphur (0.72%), iron (16.5%), copper (14.7%), manganese (10.2%), vitamin C (46.7%), vitamin E (33.02%), vitamin B2 (47.9%) and folate (14.3%) compared to tray dryer at 40℃ whereas, there is a minimum decrease in phosphorus (5%), potassium (7%), calcium (6.7%), zinc (1.6%) and vitamin A (6.6%) content. Such findings supports that not only both microwave and freeze drying is superior than low temperature convective drying but also quality of microwave dried leaves are closer to freeze dried w.r.t extractability and antioxidant properties of the herbs.

5.3.4. Effect of drying on polyphenol oxidase

To strengthen the conclusion of section 5.3.3 that microwave and freeze-dried herbs had similar TPC and TFC and both values were higher than convective dried condition we assayed the native polyphenol assay for all four leaves. Fig. 5.4 shows out of four types of drying microwave dried samples lost the PPO enzymatic activity similar to that of 105ºC whereas in all four leaves the PPO could survive in significant amount in both freeze-drying and low temperature convective drying at 50ºC. This supports the fact that at a low temperature drying there is enough PPO enzymatic activity that for the long period of drying the oxidative enzyme might degrade some of the phenolic compounds present in the leaves. However, it is important to know the magnitude of oxidase enzymes activity and how it would affect the degradation of phenolics within the leaves. Because during freeze drying the PPOs might not react in subzero condition (-40°C) even if high residual PPO activity is traces in the dried product. Depending on the variety the activity level varied between the drying methods. For example MN showed more PPO activity in freeze dried samples but ENF showed more activity in 50°C dried sample. According to Loh et al. (2018) as polyphenol oxidase activity increased, the percentage loss in TPC also increased; however, there was no obvious trend observed for the peroxidase enzyme. Mujumdar, (2015) also stated that enzymatic activities generally decrease with decreasing water activity. It was observed that all the dried leaves (a_w between 0.1-0.2) have low enzymatic activity. Lin et al. (2012) reported that the release of active oxidative enzymes (PPO and POD) could cause enzymatic degradation and therefore reduce the number of extractable phenolics when leaf tissues were damaged. As PPO enzymes are involved in the production of quinones from monophenols and diphenols, it is logical to expect that high PPO activity would degrade more phenolics in the plant leaf samples (Loh et al., 2018). Moreover most plant tissues contain isoenzymes of PPOs with different substrate affinity and thermal stablity. This is probably the reason in different drying condition specific polyophenols may be present or absent. Microwave dried leaves of *C. roseus, B. citriodora, G. pseudochina, M. communis* contained higher concnetration of gallic acid, caffeic acid, rutin, myricetin 3-o-rhamnoside, quercetin 3-o-glucoside, quercetin 3-o-rhamnoside, myricetin, quercetin, kaempferol, and chlorogenic acid (Kasara et al., 2021; Snoussi et al., 2021; Saifullah et al., 2019; Sukadeetad et al., 2018). In the next section we have also dicussed the differential presence of polyphenols under different drying conditions of the four selected herbs.

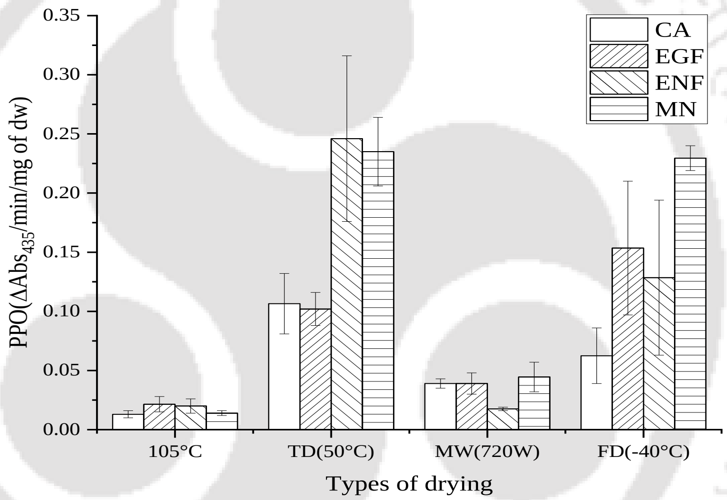

Fig. 5.4 Polyphenol oxidase activity(ΔA435/min/g of dry powder) of different dried samples. Results were expressed as mean ± standard error (SE) of triplicate runs.

5.3.5. Effect of drying on polyphenols of selected four herbs using HPLC

The signature chromatogram profiles of the extracts from CA, EGF, ENF and MN various leaf dried with freeze-drying and microwave and oven drying processes are shown in Table 5.7(a) – 5.7(d). The normalized HPLC chromatogram confirmed that the freeze-dried and the microwave dried samples contained higher amounts of phenolics than those in the oven samples and for most compounds (identified as well as unidentified peaks) the general order of concentration in all four herbs was freeze drying > microwave drying > low temperature convective dried.

Moreover, there was an increased concentration of chlorogenic acid, rutin, ethyl protocatechuate, naringin, and myricetin recorded in the microwave, as well as freeze-dried CA leaves over oven drying. Whereas apigenin was not identified in microwave dried sample of CA but its concentration was much higher in freeze-dried sample than the convective dried one. Others have also reported superiority of microwave and freeze drying for polyphenol extraction/retention in several plant materials (Nahar et al., 2022; Cerretani et al., 2009; Heck et al., 2008). Apart from altering leaf powder particle microstructure and PPO enzyme inactivation, microwave drying can cause releasing of free phenolic compounds from the bound phenolic compounds (Hayat et al., 2020; Lewicka et al., 2015). For example, caffeic acid one of the intermediate in lignification can exist as caffeoyl shikimic acid, caffealdehyde, and caffeoyl alcohol which may not be the extractable. These compounds can be transformed during microwave heating and become extractable (Paciulli et al., 2022; Cerretani et al., 2009). In this study, both freeze-drying and microwave drying could retain more phenolic compounds from the CA, ENF, EGF, and MN. Nevertheless, it is observed that most of the compounds present in the samples are increasing due to microwave drying. Therefore, microwave drying can be a fast-drying method for isolating a good amount of bioactive compounds from these selected plant species.

Table 5.7 Comparative study of HPLC spectra of all the dried samples of four plants

a) *Centella asiatica* (CA)

		CA (height mAU)			
Sl. No.	**Retention time (min)**	**Tray dried (50°C)**	**Microwave dried (720W)**	**Freeze dried (-40°C)**	**Compound Identified**
1.	1.149	91.01	48.85	44.67	
2.	1.55	25.35	4.87	3.86	
3.	3.34	ND	4.11	3.13	
4.	3.60	ND	13.43	10.54	
5.	5.25	ND	7.92	10.97	Chlorogenic acid
6.	14.02	ND	38.04	39.92	Rutin
7.	14.25	ND	5.31	7.18	
8.	14.38	18.90	ND	ND	
9.	14.48	ND	3.08	4.29	
10.	14.73	52.48	ND	ND	
11.	15.09	3.87	68.15	72.72	
12.	15.39	1.84	117.56	91.18	
13.	15.72	ND	5.75	7.10	Ethyl protocatechuate
14.	16.06	ND	9.09	10.31	
15.	16.12	9.64	29.22	34.36	Naringin
16.	16.79	ND	17.23	17.02	Myricetin
17.	17.55	ND	3.49	4.37	
18.	18.37	7.53	4.08	ND	
19.	19.18	11.65	ND	ND	
20.	19.39	27.61	ND	ND	
21.	19.67	1.91	ND	3.64	Apigenin
22.	21.34	ND	ND	4.65	
23.	24.03	2.86	ND	ND	
24.	24.54	ND	ND	ND	
25.	25.95	ND	3.70	4.73	
		274.25	**409.03**	**394.12**	**Total peak height**
		12	**17**	**18**	**No of peaks**

ND: Not detected

b) *Enhydra fluctuans* (ENF)

Sl. No.	Retention time (min)	ENF (height mAU) Tray dried(50°C)	Microwave dried(720W)	Freeze dried (-40°C)	Compound Identified
1.	1.38	ND	ND	107.98	
2.	1.47	28.18	39.99	54.91	
3.	1.63	33.36	28.14	63.90	
4.	1.7	ND	17.82	64.88	
5.	2.03	ND	ND	20.26	
6.	4.48	3.36	ND	9.83	
7.	4.63	ND	10.51	ND	
8.	5.07	ND	ND	6.62	
9.	6.36	26.07	24.41	35.23	Catechin
10.	9.07	ND	ND	7.56	Indole-3-acetic acid
11.	15.22	7.21	ND	ND	
12.	15.34	7.17	18.94	41.94	
13.	15.66	46.63	14.17	ND	
14.	15.86	103.69	61.23	ND	
15.	16.02	ND	155.67	190.97	
16.	16.24	87.55	151.23	166.75	Naringin
17.	16.82	27.91	30.11	9.52	
18.	17.97	15.95	15.72	ND	Trans-resveratrol
19.	18.25	34.10	50.76	14.90	Cinnamic acid
20.	18.53	ND	23.42	35.62	
21.	18.74	9.45	7.92	16.99	Luteolin
22.	19.38	ND	ND	2.73	
23.	19.83	3.33	5.54	4.49	Kaempferol
24.	21.23	12.77	13.49	15.03	
		471.48	**698.30**	**887.94**	**Total peak height**
		15	**17**	**19**	**No of peaks**

ND: Not detected

c) *Eryngium foetidum* (EGF)

Sl. No.	Retention time (min)	EGF (height mAU) Tray dried(50°C)	Microwave dried (720W)	Freeze dried (-40°C)	Compound Identified
1.	1.31	ND	34.41	70.76	
2.	1.40	40.95	ND	8.88	
3.	1.59	18.09	35.42	8.95	
4.	1.67	15.94	ND	14.00	
5.	1.91	ND	2.37	12.91	
6.	2.03	2.98	ND	ND	
7.	2.31	ND	2.30	ND	
8.	2.97	ND	2.06	ND	Protocatechuic acid
9.	4.17	2.07	ND	ND	
10.	4.89	ND	5.32	ND	p-Hydroxybenzoic acid
11.	5.86	14.34	ND	ND	
12.	5.98	ND	28.18	10.74	
13.	15.97	7.82	ND	ND	
14.	16.15	11.05	13.50	13.10	Naringin
15.	16.71	ND	78.26	47.30	Myricetin
16.	16.85	28.27	ND	ND	
17.	17.05	ND	35.46	20.12	
18.	18.16	ND	2.84	1.91	Cinnamic acid
19.	18.90	ND	ND	1.75	Quercetin
20.	19.70	ND	2.97	2.99	
21.	19.83	4.49	ND	ND	Kaempferol
22.	19.94	2.22	2.64	3.83	
23.	24.23	2.70	ND	2.89	
24.	24.96	ND	ND	2.85	
25.	26.42	4.07	7.40	6.30	
26.	26.96	6.87	8.67	8.36	
		163.87	**267.83**	**241.14**	**Total peak height**
		14	**15**	**17**	**No of peaks**

ND: Not detected

d) *Marsilea minuta* (MN)

		MN (height mAU)			
Sl. No.	**Retention time (min)**	**Tray dried(50°C)**	**Microwave dried(720W)**	**Freeze dried (-40°C)**	**Compound Identified**
1.	1.23	34.98	35.03	ND	
2.	1.27	71.57	ND	ND	
3.	1.3	ND	81.24	117.14	
4.	1.45	21.03	31.09	43.04	
5.	1.57	ND	21.08	27.06	
6.	4.10	2.66	2.86	3.20	
7.	5.92	ND	6.75	4.81	
8.	6.25	4.73	ND	ND	Catechin
9.	12.34	ND	6.07	8.58	
10.	12.72	5.39	2.33	3.17	Ferulic acid
11.	13.068	2.25	ND	ND	
12.	15.19	1.75	ND	ND	
13.	16.01	ND	5.24	4.24	Naringin
14.	16.25	4.77	ND	ND	
15.	17.36	ND	ND	2.24	
16.	17.55	7.05	7.44	5.42	
17.	18.62	ND	5.20	3.95	
18.	18.71	6.26	6.64	4.49	Luteolin
		170.66	**221.05**	**242.66**	**Total peak height**
		1764.40	**2151.46**	**2357.79**	**Area under the curve**
		11	**12**	**12**	**No of peaks**

ND: Not detected

5.3.6. Chemical profiling of one of the selected herbs for similarity analysis of drying process

LC-MS analysis was performed for three different drying methods to identify phenolic compounds present in *Centella asiatica* methanolic extracts. A total of 31 compounds were identified in any of the three dried extracts, which belonged to 9 different classes: caffeoylquinic acids, hydrocinnamic acid, tannins, flavonoids, terpenoids, stilbene, and fatty acids (refer to Table 5.8).

The results showed that 19% of these compounds were present in all three types of drying. When compared to freeze-dried *Centella asiatica* extract, the tray-dried sample shared 27% similarity, while microwave-dried samples showed 46% similarity. Furthermore, microwave-dried samples had 38% similarity compared to tray-dried samples. All the identified compounds had been previously reported in different *Centella asiatica* extracts. For instance, the study identified five phenolic acids known as caffeoylquinic acids (CQAs), which had been previously reported in *Centella asiatica* by Long et al. (2012). In addition to phenolics, the flavonoid naringin was detected in all three drying methods, whereas luteolin-7-glucuronide and quercetin were only found in tray drying and microwave drying. A significant group of compounds, including madecassoside, oleuropein, asiaticoside, and madecassic acid, were detected in all three drying processes. However, compounds such as 3,5-di-o-caffeoylquinic acid, piceatannol, p-coumaric acid, ferulic acid derivative, chlorogenic acid, and 3,4-dicaffeoylquinic acid were exclusively found in microwave-dried and freeze-dried *Centella asiatica* extracts. Moreover, tannins like trigalloylquinic acid were detected in all three drying methods. It is important to note that this untargeted metabolomics approach only represents a small fraction of the metabolome, and a collection of chromatographic methods is necessary for a comprehensive understanding of the global metabolome. The results also indicated the preferential distribution of certain compounds in tray-dried, microwave-dried, and freeze-dried *Centella asiatica* methanolic extracts.

Table 5.8 Chemical profiling of *Centella asiatica* methanolic extracts

Sl. No.	Rt (min)	Parent ion (m/z)	MS/MS fragments	Tentative identity of compound	TD	MW	FD	Compound Class
1.	2.46	343	153, 201	Piceatannol	×	✓	✓	Stilbene
2.	2.68	632	128, 341, 539, 632	Oleuropein	✓	✓	✓	Terpenoids
3.	21.76	1033	546, 740, 973	Madecassoside	✓	✓	✓	
4.	22.79	1017	179, 538.3, 740, 957	Asiaticoside	✓	✓	✓	
5.	24.80	713.2	134, 375.2, 585.1	Asiatic acid	✓	✓	×	
6.	27.79	-	503	Madecassic acid	✓	✓	✓	
7.	3.79	180.1	130.2	Caffeic acid	×	✓	×	Hydrocinnamic acid
8.	7.32	-	164.2	P-coumaric acid	×	✓	✓	
9.	28.56	-	143, 293	Cinnamoyl-glucose	✓	×	×	
10.	22.05	1018	193.1, 538.6, 887	Ferulic acid derivative	×	✓	✓	
11.	12.67	-	113, 203.2	Chlorogenic acid	×	✓	✓	Caffeoylquinic Acids
12.	13.36	707	191, 353, 467, 707	1,5-Di-O-Caffeoylquinic acid	×	×	✓	
13.	16.95	515	335, 191.1, 161	3, 4-Dicaffeoylquinic acid	×	✓	✓	
14.	23.94	1060	113, 375.4, 565.5, 740.8, 1000	Neochlorogenic acid	×	✓	×	
15.	18.29	1031.7	161.1, 353, 515.4, 615.4	3, 5-Di-o-caffeoylquinic acid	×	✓	✓	
16.	18.60	-	285, 461.1	Luteolin-7-glucoronide	✓	✓	×	Flavonoids
17.	19.60	565.5	489.3, 511.4, 565.3	Naringin	✓	✓	✓	
18.	21.36	737.6	713, 723	Quercetin derivative	✓	✓	×	
19.	16.07	601	161, 233	Eriodictyol 7-(6-galloylglucoside)	×	×	✓	
20.	20.20	587	187, 429, 489	Catechin derivative 1	✓	×	×	
21.	20.77	713	333.1, 429, 489	Catechin derivative 2	✓	×	×	
22.	25.73	-	285.1	Kaempferol	✓	×	×	
23.	36.97	-	277.2	Myricetin	✓	×	✓	
24.	33.04	-	281	Linoleic acid	×	×	✓	Fatty acid
25.	33.74	837.6	279.2	Linolelaidic acid	✓	×	×	
26.	34.13	695	205, 249.2, 389, 452, 695	Palmitic acid	✓	×	✓	
27.	33.07	737	105, 213, 273, 391, 487	Pelargonidin isomer	✓	✓	×	Anthocyanidin
29.	18.08	613	161, 353, 477, 515, 613	Trigalloylquinic acid	✓	✓	✓	Tannins
30.	25.30	-	127	Pyrogallol	×	×	✓	Other polyphenols
31.	35.09	815	-	Unknown	×	×	✓	

Rt: Retention time; TD: Tray dried (50ºC), MW: Microwave dried (720W); FD: Freeze dried (-40ºC)

5.4. Summary

To convert the herbs into food products and also to assay different bioactives microwave drying was found to be an effective drying process. For leaf kind of product microwave drying was equivalent to 105ºC oven drying for moisture content determination (loss on drying type) as well as quantifying phenolics. Also, this study revealed that hot air oven may have significant variation among samples apart from having longer analysis time. The TPC and TFC content of the four herbs followed the following order ENF>CA>MN>EGF. Trend for *in vitro* antioxidant properties was also similar except CA which showed highest capacity to scavenge free radical and reduce lipid peroxidation. This study also revealed depending on the type of herb the selective extraction can happen when the drying process is switched from convective to microwave or freeze dried. Since, microwave drying is a non-isothermal drying unlike convective drying or specifically conventional tray drying (say 50ºC) the herbs can experience different extent of damage of tissue structure, PPO inactivation and solubilisation of complex polyphenols depending on the heating history which in turn can decide the composition of the biomolecules in solvent extract from the dried herb. While performing microwave drying, the parameters of the sample e.g., size, examination of dielectric parameters and their temperature dependence, penetration depth, the temperature distribution inside the sample, etc. and parameters of the equipment, e.g., power rating of all microwave components, applicator suitable for the intended process, pulse or, forward power, reflected power, single or multimode applicator, temperature control, safety, etc. Therefore, it is important to choose an optimal microwave power for each herb to retain its bioactives and dry it to a desired quality like sensory property, water activity, millability etc.

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Chapter 6

Assessment of four selected leafy vegetables for preparation of herbal drink

Chapter 6

6. Introduction

Wild edible and medicinal plants are primary components of traditional food systems that contribute to food security, nutrition, and human health (Abdullah et al., 2021; Ray et al., 2020). Plant foods used as protective food or for specific health benefits are in great demand due to their perceived safety compared to synthetic drug molecules (Chopra et al., 2022). Herbal beverages are also part of many traditional diets and are known for their therapeutic values (Liu et al., 2023). The present study aimed to develop beverages from four selected plants viz., *Centella asiatica*, *Enhydra fluctuans*, *Eryngium foetidum*, and *Marsilea minuta* and assess their quality. Potential therapeutic effects of these plants have been documented in traditional medicine texts, ethnomedicine repositories, and scientific reports, demonstrating their preventive action against cardiovascular and neurodegenerative disorders, diabetes, cancer, and aging, as supported by previous studies (Kunjumon et al., 2022; Barua et al., 2021; Rodrigues et al., 2022; Arokiyaraj et al., 2018). While non-aqueous extracts of these herbs have been extensively investigated, studies focusing on their beverage form are relatively scarce. However, most of the homemade herbal beverages have poor sensory acceptance due to their high levels of bitterness and astringency. The present study aimed to improve the flavour of an herbal beverage with Khasi mandarin peel to broaden the consumption of the beverage.

Khasi mandarin (*Citrus reticulata*) is the most popular citrus cultivar in the North-Eastern region of India for its exotic taste and flavour as well as for its medicinal values (Gogoi et al., 2020; Bhuyan et al., 2015). The peel of the Khasi mandarin contains certain citrus oil with a refreshing and pleasant sensory characteristic that is appreciated in the food, beverages, pharmaceutical, perfumery and cosmetics industries (Bhuyan et al., 2015).

Fresh herbs like *Centella asiatica* are seasonal and have a very limited shelf life so for yearlong domestic and commercial usage they are stored in dry powder form. The stability of such herbal powders is to be studied to select an appropriate packaging and storage conditions. By studying kinetics of change of the quality parameters, rate of degradation, the most critical quality parameters can be estimated. The constituents in an herbal product, can be affected by the physical and chemical factors like presence of O_2, light, temperature, and humidity. These environmental factors accelerate the rate of oxidation, hydrolysis, enzymatic deterioration, and reactions of the product's constituent with the formulation ingredients like additives present in the herbal formulations (Thakur et al., 2011; Alamgir & Alamgir, 2017). When moisture is absorbed on to the surface of a dry solid product, it increases the rate of decomposition. If active enzymes are present in the product, it may enhance the rate of chemical degradation during storage in the presence of adequate moisture. The changing physicochemical properties can affect not only the sensory quality but also its bioactivity like antioxidative potential. With the increasing moisture absorption, the growth of microorganisms can take place in solid powder and compromise the quality and safety of the product like herbal powder (Thakur et al., 2011; Alamgir & Alamgir, 2017).

Before an elaborated shelf life study often a short stability study under accelerated storage conditions is useful to save time and resources. Stability studies can reveal the changes in the quality of a food or drug product due to various factors such as environmental conditions (temperature, moisture, light), packaging materials, and container-closure systems over a specific period. Conducting a comprehensive long-term study for shelf-life analysis typically requires a significant number of runs. For example, even for observing k-number of environmental factors even at 2-levels $2^k \times 3$ (for triplicates), number of runs is to be done. Each of the runs needs to be performed for the expected shelf life i.e., ≥ 12 months for herbal tea type products. Accelerated Predictive Stability studies (APSs) have emerged as an effective approach to predict the stability of drug/bioactive molecules compared to traditional long stability studies based on International Council on Harmonisation (ICH) (Waterman et al., 2007; González-González et al., 2022). APSs use accelerated product degradation and measure changes in composition and related quality parameters of the drug molecules. The protocol utilizes a moisture-modified Arrhenius equation as a guiding mathematical model for conducting rapid stability studies. By subjecting the products to extreme temperatures and humidity (>30°C, up to 90%) for shorter periods (3-4 weeks), the dominant degradation kinetics can be determined under temperature and relative humidity combinations recommended by ICH (Qiu, 2018a; 2018b). These studies are crucial and useful for evaluating stability at the worst possible storage conditions. Hence for herbal tea products also the protocol can be proposed to reject the worst packing and/or storage conditions (zone IV or worst). This approach offers an efficient and cost-effective solution for assessing herbal product stability, enabling better decision-making and optimization in the development and storage of such products.

The objective of this study was to show a strategy to enhance the flavour of the herbal beverages by incorporating Khasi mandarin peel. Also propose a method to evaluate the stability of medicinal plants with promising property as a beverage. The APS concept was used for the first time for stability analysis of Centella tea. Based on first order kinetics the half-life of the herbal beverages was calculated. The findings have implications for both the food industry and consumers seeking natural remedies with enhanced sensory attributes and prolonged stability.

6.1. Methodology

6.1.1. Dried herb preparation for the herbal drink

Centella asiatica, Enhydra fluctuans, Eryngium foetidum and *Marsilea minuta* were cultivated in a controlled environment. The matured leaves were harvested and washed thoroughly with distilled water to remove any dirt and contaminants. Microwave drying was done within 2-3 h of harvesting to avoid any enzymatic and non-enzymatic degradation. A domestic microwave oven (IFB, 20BCE4, India) at an appropriate power level (720 Watt) was used for the drying. Samples were dried until equilibrium moisture content was reached.

6.1.2. Preparation of herbal drinks

In this study, infusion and decoction types of products were prepared as ready-to-serve beverages. For infusion, 100 mL of boiled distilled water was poured in pre-weighed 4 g of powder and infused for 5 minutes. For decoction, 4 g of sample boiled in 100 mL of distilled water for 5 minutes (Appendix E.6). The beverages were cooled and filtered prior to analysis.

6.1.3. *Centella asiatica* mixed formulation

Two sets of *Centella asiatica* beverage were formulated consisting of 100% *Centella asiatica* powder (unblended) and 90% *Centella asiatica* powder with 10% Khasi mandarin (*Citrus reticulata*) peel powder (blended) (Appendix E.5). To prepare the blended Centella herbal powder, Khasi mandarin peel powders were mixed in different proportions (Centella leaf powder and Citrus peel powder in the ratios of 80:20, 85:15, 90:10, and 95:5. Four different formulations were obtained from these blends. Through sensory analysis, it was determined that the blend with a ratio of 90:10 exhibited highest amount of Citrus peel powder with a favourable flavour profile with reduced bitterness. So, 90:10 ratio of Centella leaf powder and Citrus peel powder was selected for further analysis in the storage stability study.

6.1.4. Sensory evaluation of different beverages

To compare the different sensory attributes of infused and decoction beverages of four herbs 9-point hedonic scale-based scoring was used (Appendix D.6). The sensory quality of beverages was evaluated based on specific quality attributes. The first attribute considered colour and appearance, as a good quality beverage should exhibit a bright and visually appealing colour. Flavour was assessed with a focus on identifying freshness and newness in the beverage. Taste involved assessing the mouthfeel and the sensory experience on the tongue, allowing for the detection of pungency or distinct tastes present in the beverage. Strength of the beverage is the combination of the consistency of the beverage and the intensity of taste or pungency it offers to the tongue was evaluated for the *Centella asiatica* beverages (Yang & Lee, 2020; Roque et al., 2018; Debjani et al., 2013). A commercial green tea was used as a control. A trained panel evaluated the beverages. This panel was composed of 10 persons including five males and five females within 20-40 age group. Each assessor tasted one full cup of the different coded beverage samples (Appendix D.6). Minimum score 1 reflected extreme dislike whereas maximum score of 9 reflected extreme liking. Beverages were evaluated twice by every assessor. Evaluation of each beverages was done by drinking water before and between the testing to clean mouth. The entire sensory analysis was carried out in a single day and the average scores for each attribute were calculated.

6.1.5. Stability study at accelerated storage conditions

In this study, three different combinations of storage conditions were used where condition-A was 45°C with a relative humidity of 82% in addition 6 h of UV exposure every day; condition-B was 45°C+RH 82%, and condition-C was 32°C+RH 61%. 4 g of samples were stored in LDPE (low density polyethylene) packs (63.50 microns) for total 28 days (Appendix E.5). The accelerated predictive stability study conducted in this work utilizes three distinct combinations of storage conditions based on zone IVa and IVb, involving high temperature (>30ºC), relative humidity (>60%), and exposure to ultraviolet (UV) light. In particular, UV radiations can initiate the formation of free radicals and cause chemical changes such as protein, lipid, and vitamin oxidation, development of off-flavours, degradation of antioxidants, and alterations in the colour and texture of food products (Olarte et al., 2009; Lázaro et al., 2014). For the study, the formulation was filled in three set of packs for three different conditions and labeled properly. Three packs were taken out every week from three different storage batches and moisture content, water activity, and colour of the dried powder and quality parameter of the beverage (infusion) prepared from the leave powder were estimated. In the prepared beverages sensory attributes, pH, redox potential (ORP), total extractable solids, and four types of antioxidant assays were done (Appendix E.6).

6.1.5.1. Analytical Methods

6.1.5.1.1. Moisture content and water activity(a_w) determination

The moisture content of the dried powder during storage was determined with AOAC method (AOAC, 2000) (Appendix C.1). Also, water activity (a_w) of the powder was determined using humimeter RH2 water activity meter at 21±1°C.

6.1.5.1.2. Colour determination

Colour properties values were determined as described by Ozmen et al., 2023. The change in L* (lightness of colour (0-100)), a* (redness (+)/greenness (-)), and b* (yellowness (+)/blueness (-)) was determined during storage and difference in colour (ΔE*) was calculated as stated in Appendix D.2.

6.1.5.1.3. Total extractable solids

The total extractable solid content of the beverage from *Centella asiatica* herbal powder was determined using loss on drying method. The herbal powder withdrawn every week of storage was used to prepare the beverage sample. 5 mL of the prepared beverage were dried at 105°C and the difference of weight was used to calculate mg of solids/g of dry weight of the herbal powder (Appendix C.3).

6.1.5.1.4. pH and redox potential

4 grams of *Centella asiatica* (or its blend) pack was collected every week for analysing the changes in quality. Each sample was dispersed in 100 mL of hot water and infused for 5 minutes. The infusion was then cooled to room temperature (21±1°C) and filtered. The pH and redox potential of the filtered solution were measured using a pH meter (Hanna Instruments). The device was calibrated before the sample measurement. If a solution has a lower (more negative) reduction potential, it has a greater tendency to lose electrons to other substances and reduce them.

6.1.5.1.5. *In vitro* Antioxidant activity

The *in vitro* antioxidant activity of beverage during storage was estimated with four different assays. Here, Folin's reducing power (FRP) was determined using the Folin-Ciocalteu method (Singleton & Rossi, 1965). The Ferric reducing power (IRP) was determined with Potassium Ferricyanide Reduction assay (Oyaizu, 1986). The 2,2′-azinobis-3-ethylbenzothiazoline-6-sulfonic acid free radicals scavenging capacity (ARSA) of the beverages was determined with Re et al.'s method (1999). Lipid peroxidation inhibition (LPOX) capacity of the beverages was estimated with Thiobarbituric acid-reactive species assessment method described by Ohkawa et al., 1979 (Appendix B.5, B.6, B.7 and C.9)

6.1.5.1.6. Degradation kinetics of redox potential and antioxidant activity

First order degradation kinetics for both redox potential and antioxidant capacity reduction was validated and the specific rate of degradation was calculated using the following equation

$$lnA = lnA_o - kt \text{ ------------------------ } (1)$$

where t is the storage time (days), k is the first-order rate constant (day^{-1}), A_0 and A are the quality factor (redox potential/FRP/IRP/ARSA/LPOX activity) at time zero and time t, respectively.

The half-life ($t_{1/2}$), the time required for redox potential, FRP, IRP, ARSA and LPOX activity to reduce to 50% of their initial values, was calculated from the rate constant as follows:

$$t_{1/2} = \ln(2)/k \quad \text{---------------------- (2)}$$

where k is the rate constant (day^{-1}).

6.2. Statistical Analysis

All experimental data was expressed as mean ± standard error of triplicate runs. The Origin 9.0 program (2022) was used to analyse the data and mean values were statistically significant ($p < 0.05$).

6.3. Results and Discussion

6.3.1. Evaluation of sensory attributes of infusion and decoction beverages of four selected herbs

For any beverage to be accepted by consumers its sensory appeal and health benefits are the essential properties. Infusion and decoction type beverages were prepared from four selected plants; *Centella asiatica*, *Enhydra fluctuans*, *Eryngium foetidum*, and *Marsilea minuta* to verify if one or more such plants can be used as beverage. Generally, such herbal drinks are popular in many ethnic groups but not common in modern cuisine. However, *Marsilea minuta* showed an unpalatable thick consistency both in case of infusion and decoction beverage (Appendix E.4). The other two plants showed poor overall acceptability score (<7) for their sensory attributes. They had a strong bitter taste and grassy flavour to be accepted as a beverage. Out of all four plants, infused *Centella asiatica* had the highest sensory overall acceptability i.e., 7.4 (Table 6.1).

Table 6.1 Sensory analysis of two types of beverages from four selected herbs

Beverage	Sensory	Commercial green tea	*Centella asiatica*	*Enhydra fluctuans*	*Eryngium foetidum*	*Marsilea minuta*
Infusion	Colour and appearance	8.7±0.22	8.1±0.29	7.8±0.34	7.9±0.29	Not suitable for beverage preparation
	Flavour	8.0±0.35	7.1±0.33	5.9±0.37	6.8±0.47	
	Taste	8.2±0.26	7.1±0.25	5.8±0.38	6.7±0.44	
	Strength	8.2±0.26	7.2±0.26	6.7±0.27	7.0±0.35	
	Overall acceptability	8.3±0.22	7.4±0.11	6.7±0.15	6.9±0.23	
Decoction	Colour and appearance	8.2±0.21	8.0±0.27	7.2±0.44	7.2±0.54	
	Flavour	7.7±0.22	6.9±0.19	6.4±0.48	6.8±0.31	
	Taste	7.6±0.17	6.7±0.27	6.2±0.41	6.2±0.38	
	Strength	8.1±0.28	6.9±0.33	6.5±0.50	6.5±0.42	
	Overall acceptability	7.9±0.12	6.9±0.06	6.4±0.32	6.5±0.21	

Results were expressed as mean ± standard error of triplicate runs.

Centella asiatica is known for its antioxidant, antimicrobial, anti-inflammatory, and anticancer activities (Pokhrel & Neupane, 2021) and our study showed that its sensory properties are near acceptable. In fact, when the sensory scores of *Centella asiatica* and a commercial green tea were compared with the *Centella asiatica* beverage was only slightly inferior than the commercial green tea (Table 6.1). A mean score of 7 was generally considered as an acceptable score for sensory attributes. Hence, the infused *Centella asiatica* beverage was further taken for flavour and taste improvement and stability study.

6.3.2. Improvement of sensory properties of *Centella asiatica* with citrus peel mixed formulation

In this study, it was observed that the infused beverage from Centella herbal powder was acceptable in terms of sensory characteristics. The average score of the sensory attributes of unblended *Centella* herbal beverage indicated it was moderately liked by the panelists (Table 6.2). The sensory quality of commercial green tea/herbal tea consists of three major characteristics; bitterness, astringency, and a persistent sweet aftertaste. Often, addition of flavouring ingredients are needed to increase their sensory scores. The acceptability of citrus peel blended beverages evaluated by a trained panel is presented in Table 6.2.

Table 6.2 Sensory analyses of *Centella asiatica* herbal powder with Khasi mandarin peel powder

Types of Beverage	Colour and appearance	Flavour	Taste	Strength	Overall acceptability
Commercial green tea	8.8±0.14	8.3±0.22	8.2±0.26	8.2±0.26	8.4±0.17
Unblended *Centella asiatica* powder	8.0±0.27	6.9±0.25	6.8±0.14	7.0±0.22	7.3±0.14
Blended *Centella asiatica* powder	8.2±0.21	8.1±0.11	7.9±0.11	7.6±0.17	8.0±0.09

Note: Results were expressed as mean ± standard error of triplicate runs.

The results showed that there was an increase in score for colour and appearance by 2.4%, flavour by 18.5% and taste by 14% in blended *Centella asiatica* beverage over unblended *Centella asiatica* beverage. Moreover, except for flavour, assessors observed a decrease in astringency and an increase in mouthfeel containing sweet and sour taste. It was found that flavouring with Khasi mandarin (*Citrus reticulata*) peel powder not only increased the flavour, colour and taste of the beverage but also imparted an orange like essence to subside the grassy flavour of *Centella asiatica* beverage. This has increased the strength of the beverages by 8% and overall acceptability by 10%. A similar study was reported by Sunarharum et al. (2021) and concluded that different brewing techniques and addition of lemon peel (*Citrus limon*) enhanced the physicochemical characteristics and organoleptic properties of cascara tea. In this study, it was found that blended *Centella asiatica* herbal powder showed good sensory attributes with average overall acceptability score of more than 8 indicating the product was "liked very much" by the panel (Appendix D.6).

6.3.3. Effect of accelerated storage condition on physicochemical and sensory attributes of *Centella asiatica* powder packed with LDPE

Herbal powders are hygroscopic material and tends to change their physicochemical and sensory properties during certain storage conditions. The storage environment could affect their moisture percentage, water activity, colour and other properties. A separate study confirmed hygroscopic nature of the *Centella asiatica* powder at more than 1% moisture by moisture sorption hysteresis (Appendix D.7). That suggests proper packaging is required to retain the quality of the powder over a prolonged storage period, especially in a humid atmosphere. The effect of accelerated storage conditions on physicochemical properties of *Centella* herbal powder was evaluated and tabulated (Table 6.3). *Centella* herbal powder showed negligible increase in the moisture content and water activity in three different storage conditions. After one month of storage, moisture content increased to 0.57% for condition-A, 0.63% for condition-B, and 0.54% for condition-C.

Table 6.3 Effect of accelerated study on moisture content, water activity and colour of *Centella asiatica* powder

Unblended *Centella asiatica* powder										
Sample Name	**Storage Time (days)**	**Moisture (%)**			**Water activity (a_w)**			**Colour difference (ΔE*)**		
		A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
***Centella asiatica* herbal powder**	**0**	0±0.00	0±0.00	0±0.00	0.19±0.00	0.19±0.00	0.19±0.00	0±0.00	0±0.00	0±0.00
	7	0.14±0.00	0.16±0.00	0.12±0.00	0.22±0.00	0.21±0.00	0.20±0.00	11.1±0.01	6.4±0.05	2.9±0.08
	14	0.28±0.00	0.32±0.00	0.26±0.00	0.26±0.01	0.27±0.01	0.22±0.00	18.5±0.02	11.9±0.01	4.8±0.09
	21	0.49±0.00	0.53±0.00	0.46±0.00	0.27±0.01	0.28±0.01	0.23±0.00	20.6±0.06	15.0±0.01	7.3±0.02
	28	0.57±0.00	0.63±0.01	0.54±0.00	0.28±0.00	0.29±0.00	0.24±0.00	24.9±0.01	19.4±0.04	10.5±0.01

Blended *Centella asiatica* powder										
Sample Name	**Storage Time (days)**	**Moisture (%)**			**Water activity (a_w)**			**Colour difference (ΔE*)**		
		A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
***Centella asiatica* herbal powder**	**0**	0±0.00	0±0.00	0±0.00	0.20±0.00	0.20±0.00	0.20±0.00	0±0.00	0±0.00	0±0.00
	7	0.18±0.00	0.20±0.00	0.16±0.00	0.22±0.00	0.23±0.00	0.22±0.00	10.3±0.06	7.2±0.03	4.3±0.05
	14	0.33±0.00	0.36±0.00	0.30±0.00	0.27±0.01	0.27±0.00	0.23±0.00	14.1±0.02	11.5±0.03	7.9±0.06
	21	0.53±0.00	0.56±0.00	0.49±0.00	0.29±0.00	0.28±0.00	0.25±0.00	17.0±0.02	13.8±0.04	9.3±0.02
	28	0.61±0.00	0.64±0.01	0.57±0.00	0.30±0.00	0.29±0.00	0.26±0.00	21.6±0.02	17.3±0.06	10.5±0.06

Note: Results were expressed as mean ± standard error of triplicate runs. A: 45°C+RH 82% +UV (254nm, 6 h); B: 45°C+RH 82%, and C: 32°C+RH 61%.

Since in all three conditions the moisture content was lesser than the prescribed (<12%) limits (WHO, 2018) it can be assumed that the present LDPE (63.50 µm) packaging is good enough to prevent the moisture uptake of the *Centella* herbal powder. UV radiation in Sun light has ionizing power and therefore plays a role in degradation of herbal powders. Kamweru et al. (2014) suggested that the reflection of UV light by LDPE film is lesser than 20% that indicates the major portion of the UV light can be transmitted through and absorbed by LDPE. Hence UV exposure may result in degradation of the herbal powder under accelerated storage conditions, providing insights into the stability of the product when exposed to different ionizing light including Sun light.

Regarding the influence of water activity on chemical reactions, it has been reported that water plays a crucial role in various chemical processes. Water can act as a solvent, facilitating the dissolution and interaction of different compounds, as well as a reactant in certain chemical reactions. Above a critical amount of water in the powdered sample causes hydrolysis of constituents, other biochemical reactions, and growth of bacteria and fungi (Bell, 2020). One or a combination of these reactions can lead to faster deterioration of the product. However, the water activity of the powder in the present study was in the stable range of 0.2 to 0.3 during one month of accelerated storage. Shams et al. (2022) reported that during storage, powders are generally stable with water activity between 0.20 and 0.40 against biochemical reactions like browning, oxidation, and enzymatic reaction. Moreover, a water activity value of more than 0.6 is necessary to provide sufficient moisture for microorganisms to thrive in powders (Tapia et al., 2020). It is worth noting that in this particular study, the water activity of *Centella asiatica* powder was found to be relatively low. This indicates that the powder has a limited amount of available water, which may inhibit microbial growth and contribute to its stability during storage. In addition to the chemical changes, physical properties i.e., colour difference also got affected by environmental conditions such as relative humidity, UV exposure and high temperature (Kulwinder & Singh, 2016). The change in colour were observed as change in a*, L*, and b* parameters during storage. In this study, the colour difference was more observed in case of condition-A (Table 6.3, Fig. 6.1a and 6.1b). As stated by the Ayurvedic Pharmacopoeia of India (2008), alteration in colour also usually occurs not only because of light exposure but also due to change in internal factors like pH. Therefore, the change in pH was evaluated in the beverages prepared for each condition (Table 6.4).

It was found that the initial pH value of *Centella asatica* beverage from unblended and blended *Centella* herbal powder was 5.81 and 5.61 respectively. Table 6.4 shows that during storage, the pH changes of the powder due to high relative humidity, temperature and UV exposure was not more than 0.2 units over one-month period. The rate of increase in pH values in one-month storage were relatively slow for all three conditions which indicates slow chemical degradation. Similarly, insignificant change in total extractable solids was observed for the prepared beverage from the powder stored at different conditions for one month (Appendix D.8).

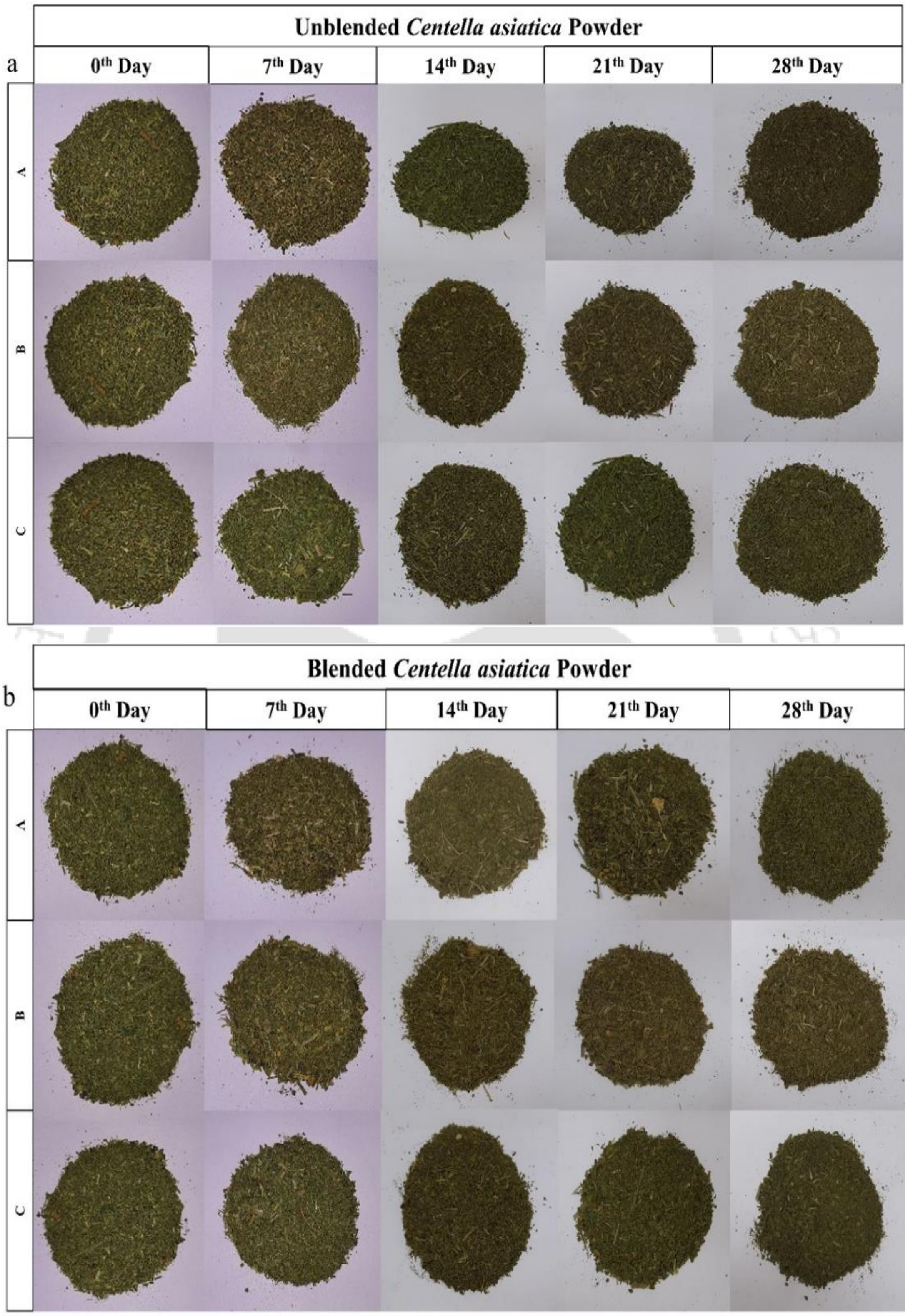

Fig. 6.1 Effect of accelerated storage on (a) unblended and (b) blended *Centella asiatica* powder. A: 45°C+RH 82% +UV (254nm, 6 h); B: 45°C+RH 82%, and C: 32°C+RH 61%.

Other than physicochemical properties, the change in sensory attributes of *Centella asiatica* powder were also estimated during storage. Considering any chemical change will influence the organoleptic properties of the powder, the sensory score of the beverage from the powder were evaluated every week. The colour of the unblended *Centella asiatica* infused beverage showed a light brown colour with a greenish tint and the blended *Centella asiatica* beverage showed a light orange colour with a brown tint. One of the most affected sensory attributes were flavour and taste which decreased during storage. It was found that on 28th day, 80-90% of the panel could recognize a difference in flavour and taste. The sensory attributes were showing similar change to that of the physicochemical properties during accelerated storage. One of reason for such decrease in scores may be due to oxidative damage and browning (Human et al., 2021; Kulwinder & Singh, 2016). The most acceptable storage condition of both blended and unblended *Centella asiatica* powder was condition-C (32°C and RH 61%) where the final sensory score was near acceptable range. This study also recommends light impervious and vacuum packaging pack may further increase the shelf life of such herbal powder (Cheng et al., 2021; Shishir et al., 2017).

Table 6.4 Effect of accelerated storage on pH and sensory properties of *Centella asiatica* powder

Beverage	Storage Time (days)	Unblended *Centella asiatica* powder																	
		pH			Colour and appearance			Flavour			Taste			Strength			Overall acceptability		
		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Infused beverage	0	5.81±0.00	5.81±0.00	5.81±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00
	7	5.81±0.00	5.83±0.00	5.81±0.00	9±0.00	9±0.00	9±0.00	7.4±0.16	7.4±0.16	7.9±0.18	7.6±0.16	7.9±0.10	7.8±0.13	7.4±0.22	7.4±0.16	7.4±0.16	7.2±0.13	7.2±0.13	7.4±0.16
	14	5.83±0.00	5.86±0.01	5.82±0.01	9±0.00	9±0.00	9±0.00	7.3±0.13	7.3±0.15	7.6±0.22	7.2±0.13	7.2±0.13	7.1±0.10	6.9±0.23	6.9±0.18	7.2±0.20	6.8±0.13	6.9±0.10	7.1±0.05
	21	5.84±0.00	5.88±0.00	5.85±0.00	9±0.00	9±0.00	9±0.00	7.0±0.00	7.0±0.15	7.5±0.22	6.6±0.22	6.7±0.15	6.8±0.13	6.6±0.22	6.8±0.13	6.8±0.13	6.7±0.15	6.7±0.15	6.8±0.13
	28	5.87±0.00	5.91±0.00	5.88±0.00	9±0.00	9±0.00	9±0.00	6.5±0.17	6.5±0.17	6.8±0.20	6.3±0.21	6.3±0.15	6.6±0.16	6.1±0.10	6.2±0.13	6.4±0.15	6.2±0.13	6.2±0.11	6.4±0.16
Beverage	**Storage Time (days)**	**Blended *Centella asiatica* powder**																	
		pH			**Colour and appearance**			**Flavour**			**Taste**			**Strength**			**Overall acceptability**		
		A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Infused beverage	0	5.61±0.01	5.61±0.01	5.61±0.01	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00	9±0.00
	7	5.63±0.00	5.65±0.01	5.63±0.00	9±0.00	9±0.00	9±0.00	7.4±0.16	8±0.00	7.9±0.18	7.8±0.13	7.5±0.17	7.6±0.16	7.4±0.16	7.7±0.15	7.8±0.13	7.2±0.13	7.3±0.15	7.4±0.16
	14	5.65±0.01	5.69±0.01	5.67±0.00	9±0.00	9±0.00	9±0.00	7.3±0.15	7.5±0.17	7.6±0.22	7.1±0.10	7.1±0.10	7.2±0.13	6.9±0.23	7.2±0.20	7.4±0.16	6.7±0.21	7±0.00	7±0.00
	21	5.67±0.00	5.72±0.00	5.72±0.00	9±0.00	9±0.00	9±0.00	7±0.15	7±0.00	7.5±0.22	6.4±0.16	6.6±0.22	6.7±0.21	6.6±0.16	6.6±0.16	6.6±0.16	6.7±0.15	6.7±0.13	7±0.02
	28	5.69±0.01	5.81±0.00	5.76±0.00	9±0.00	9±0.00	9±0.00	6.5±0.17	6.7±0.17	6.8±0.20	6±0.00	6.1±0.10	6.5±0.17	6.3±0.15	6±0.15	6.4±0.16	5.9±0.10	6.4±0.13	6.5±0.10

Note: d.w.: dry weight of powder; A: 45°C+RH 82% +UV (254nm, 6 h); B: 45°C+RH 82%, and C: 32°C+RH 61%

6.3.4. Effect of accelerated storage condition on redox potential and antioxidant capacity of *Centella asiatica* powder

For an herbal drink with health benefits, the dried herbs should contain enough amount of antioxidant molecules at the time of preparation. So, during storage of the dried herbs, ORP and antioxidant activity of the beverages prepared from them was monitored. The ORP values of these two types of beverages were decreasing in the range of 9-19% over one-month time. The temperature and humidity had an important effect on the redox status of the dried powder during the storage period. ORP was negatively associated with pH i.e., pH had an increasing trend unlike ORP values that decreased with storage time. The antioxidant potential of the beverages can be measured by several methods and each of them represents antioxidant capacity of milieu of molecules in a natural extract.

In this study, four different antioxidant assays have been studied where FRP was the Folin's reducing power to approximately evaluate the reducing ability of the phenolics present in the beverages (Table 6.5). The IRP assay was done to establish the iron-reducing power and ARSA method for assessing free radical scavenging capacity and LPOX was for finding lipid peroxidation inhibition capacity of the beverages. Though polyphenols are considered as major antioxidants in *Centella* extracts (Kunjumon et al., 2022) but other molecules cannot be ruled out for their physiological antioxidant activity. The reducing power (IRP and FRP) and radical scavenging (ARSA) capacity values showed that even at worst storage conditions (condition-A) in the present study more than 70% of the antioxidant capacity was retained in both blended and unblended *Centella asiatica* powder during accelerated storage (Table 6.5). The minimum change in antioxidant capacity was observed in condition-C which was 10% and 12% in both blended and unblended *Centella asiatica* powder respectively. In case of LPOX assay, the trend of lipid peroxidation was different. From Table 6.5, a maximum of 60% reduction of lipid peroxidation inhibition capacity can be seen in condition-A for both blended and unblended *Centella asiatica* herbal powder. Though a significant decrease in lipid peroxidation inhibition capacity was observed in both the beverages but interestingly, the degradation was less (50%) in the case of blended *Centella asiatica* powder.

In condition, it signifies that irrespective of harsh storage environment the blended *Centella asiatica* powder was less prone to decrease of antioxidant capacity during storage. Similarly, in case of condition-B, 53% reduction of antioxidant capacity in unblended *Centella asiatica* powder and 42% loss in blended *Centella asiatica* powder were observed. The lowest reduction was estimated in condition-C which was 27% in both *Centella asiatica* powders (Table 6.5). Konteles et al. (2022) reported that with an increase in temperature, antioxidant components in green tea powder decreased with time. At high relative humidity, an increase in water activity from 0.11 to 0.58 strongly exhibit the retention of the phenolics (Rocha-Parra et al., 2016). Cheng et al. (2017) reported that even at low moisture content and water activity the antioxidant compounds like catechin could decrease with time. Moreover, to establish the effect of storage, a kinetic model was used to understand the impact of storage conditions on rate of change of critical quality parameters.

In this study, the order of the kinetic model was selected as 1st order which could exhibit R^2 >0.90. The rate of reaction constant k was obtained by plotting $\ln(A/A_0)$ versus time, where A is the concentration/value of reactant or property at any point of storage whereas A_0 is the same quantity at the beginning of the storage. It was clear that k increased with relative humidity (RH%) and temperature. The half-life degradation ($t_{1/2}$, the time by which 50% degradation takes place) were summarized in Table 6.6. The reaction rate constants were affected by both temperature and relative humidity simultaneously. The redox potential was above the acceptable value till 92 days at high temperatures and relative humidity during storage. The reaction rate constant was significantly different for three different accelerated storage conditions (Table 6.6). In a report by Patel et al. (2019) on *Centella asiatica* powder and its formulation, showed concentration change of an important bioactive, asiaticoside followed first-order kinetics. Rao et al. (2021) also confirmed that ayurvedic herbal powder (Shatavari Churna) could be stored for a maximum of six months based on the active component at a low moisture content and packaging. In this study, it was predicted that, with respect to FRP, IRP and ARSA *Centella asiatica* herbal powder stored at ambient temperature (32°C) and relative humidity (61%) was stable for a maximum of 239 days. However, LPOX values should be considered for stringent prediction of best before dates for such herbal products due to its faster degradation rate.

Table 6.5 Effect of accelerated storage on redox potential and antioxidant capacity of *Centella asiatica* powder

Beverage	Storage Time (days)	Unblended *Centella asiatica* powder														
		Redox potential (mV)			FRP (mg GAE/g of d.w.)			IRP (mg AA/g of d.w.)			ARSA (mg TE/g of d.w.)			LPOX (mg MDA/g of d.w.)		
		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Infused beverage	0	42.7±0.05	42.7±0.05	42.7±0.05	4.56±0.01	4.57±0.01	4.56±0.01	11±0.00	11.02±0.00	10.99±0.00	11.54±0.01	11.52±0.01	11.540.00	0.15±0.00	0.15±0.00	0.15±0.00
	7	42.7±0.05	42.1±0.05	42.7±0.00	4.39±0.00	4.46±0.01	4.52±0.01	10.59±0.01	10.70±0.00	10.84±0.00	11.20±0.01	11.30±0.01	11.39±0.01	0.14±0.00	0.14±0.00	0.14±0.00
	14	42.1±0.05	39.5±0.05	42.5±0.05	4.16±0.01	4.26±0.01	4.43±0.01	10.06±0.01	10.26±0.01	10.60±0.00	10.53±0.00	10.78±0.00	11.10±0.00	0.12±0.00	0.12±0.00	0.14±0.00
	21	41.5±0.05	38.1±0.05	40.0±0.05	3.74±0.01	4.02±0.00	4.35±0.01	9.30±0.00	9.78±0.00	10.30±0.00	9.77±0.01	10.27±0.01	10.73±0.00	0.09±0.00	0.10±0.00	0.12±0.00
	28	38.5±0.05	34.5±0.05	38.1±0.05	3.23±0.01	3.76±0.01	4.19±0.01	8.42±0.00	9.09±0.00	9.97±0.01	8.89±0.01	9.65±0.00	10.24±0.01	0.06±0.00	0.07±0.00	0.11±0.00
Beverage	**Storage Time (days)**	**Blended *Centella asiatica* powder**														
		Redox potential (mV)			**FRP (mg GAE/g of d.w.)**			**IRP (mg AA/g of d.w.)**			**ARSA (mg TE/g of d.w.)**			**LPOX (mg MDA/g of d.w.)**		
		A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Infused beverage	0	53.2±0.05	53.2±0.05	53.2±0.05	5.43±0.01	5.43±0.00	5.43±0.00	12.50±0.00	12.53±0.00	12.54±0.00	12.03±0.00	11.98±0.00	11.98±0.00	0.20±0.00	0.21±0.00	0.21±0.00
	7	52.3±0.05	51.4±0.05	52.3±0.05	5.23±0.01	5.33±0.00	5.36±0.01	12.05±0.00	12.15±0.00	12.33±0.00	11.59±0.00	11.74±0.01	11.88±0.00	0.19±0.00	0.20±0.00	0.21±0.00
	14	51.4±0.05	48.1±0.05	49±0.05	4.95±0.00	5.19±0.00	5.26±0.01	11.39±0.00	11.69±0.00	12.06±0.00	10.98±0.00	11.27±0.01	11.54±0.00	0.17±0.00	0.18±0.00	0.19±0.00
	21	49±0.05	46.2±0.05	46.2±0.05	4.59±0.00	4.97±0.00	5.09±0.00	10.56±0.01	10.99±0.00	11.66±0.00	10.17±0.01	10.68±0.00	11.12±0.01	0.14±0.00	0.15±0.00	0.17±0.00
	28	48.1±0.05	42.7±0.05	44.9±0.05	4.13±0.01	4.66±0.01	4.90±0.01	9.58±0.00	10.20±0.01	11.18±0.01	9.26±0.00	10.01±0.01	10.66±0.00	0.10±0.00	0.12±0.00	0.15±0.00

Note: d.w.: dry weight of powder; A: 45°C+RH 82% +UV (254nm, 6 h); B: 45°C+RH 82%; C: 32°C+RH 61%; FRP: Folin's reducing power; IRP: Fe^{3+} reducing power; ARSA: ABTS radical scavenging activity; LPOX: Lipid peroxidation inhibition; GAE: Gallic acid; AA: Ascorbic acid; TE: Trolox; MDA: Malondialdehyde

Table 6.6 Predicted half degradation time for redox potential and different antioxidant capacities of *Centella asiatica* powder during accelerated storage conditions

Unblended *Centella asiatica* powder					
Storage condition	**Redox potential (days)**	**FRP (days)**	**IRP (days)**	**ARSA (days)**	**LPOX (days)**
A	204±0	57±0	73±0	74±0	22±0
B	92±0	99±1	102±0	108±0	28±0
C	165±0	239±8	195±3	161±0	60±0
Blended *Centella asiatica* powder					
Storage condition	**Redox potential (days)**	**FRP (days)**	**IRP (days)**	**ARSA (days)**	**LPOX (days)**
A	182±0	72±1	73±0	74±0	29±0
B	89±0	128±2	95±0	107±0	36±1
C	105±0	190±3	169±0	161±0	59±0

Note: A: 45°C+RH 82% +UV (254nm, 6 h); B: 45°C+RH 82%; C: 32°C+RH 61%; FRP: Folin's reducing power; IRP: Fe^{3+} reducing power; ARSA: ABTS radical scavenging activity; LPOX: Lipid peroxidation inhibition.

6.4. Summary

Centella asiaitica was found to be acceptable as an herbal beverage compared to three other medicinal herbs viz., *Enhydra fluctuans, Eryngium foetidum* and *Marsilea minuta*. Infused Centella powder had better sensory appeal compared to decoction. Use of Khasi Mandarin peel could enhance the overall acceptability of the Centella beverage over the critical hedonic mark of seven. Particularly the flavour perception of the Centella blended beverage was 18.5% higher than the unblended one. Such data supported the novel approach of flavour enhancement of herbal drinks with Mandarin peel blending. The rate of change of sensory acceptability, physicochemical properties, and antioxidant potential of both the unblended and blended beverages was evaluated under accelerated storage conditions. The study showed that the water activity and moisture percentage were stable during one month of storage when packed in LDPE packs. Nevertheless, the pH and total extractable solids of the beverage changed marginally. The redox potential and pH values of herbal powder followed an opposite trend during the storage time irrespective of storage conditions. First-order kinetic model was adequate to predict the loss of antioxidant potential during storage. The antioxidant activity and their half degradation time ($t_{1/2}$) were observed in different storage conditions. For the first time, LPOX assay was reported as a suitable factor to predict the best before values for herbal powders due to its rapid decrease during storage condition. It also showed that both the beverages were fairly stable at normal storage condition in LDPE packs. In terms of sensory and antioxidant capacity blended *Centella asiatica* powder was a promising herbal beverage. Particle characterization of the herbal powder can be done to further enhance its storage, sensory properties and health effect. It is also crucial to consider the effect of long-term consumption patterns of these blended beverages.

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Chapter 7

Antioxidant and prebiotic potential of *Centella asiatica* beverage

Chapter 7

7. Introduction

Consumption of functional beverages with bioactives like polyphenols, amino acids and peptides, oligosaccharides or polysaccharides, etc. are on rise because of their perceived health benefits. Especially after post-COVID-19 pandemic, the global herbal beverages market is projected to grow at 5.1% rate to 2.45 billion USD by 2028 (Globe Newswire, 2021). Herbal beverages are known for their unique aroma and health-promoting properties (Bag et al., 2022). They are often prepared by steeping/brewing (infusion) or boiling (decoction) fresh or dried plant parts like flowers, fruits, leaves, roots, and seeds (Chandrasekara & Shahidi, 2018). The composition of such beverages contains myriad of molecules that interact synergistically with bioactive compounds, increasing the bioactivity (Xiao & Jiang, 2015). The native components of the herbal raw material (plant tissues) undergo drastic changes due to the processing (blanching, drying, extraction, etc.) and digestion in the human body. Hence, the evaluation of their safety and efficacy is more complex than a small synthetic drug molecule. Moreover, with the rising use of such products, it is important to obtain enough scientific evidence to create an appropriate regulatory framework. There are many aspects like antioxidant activity, prebiotic activity, anti-inflammatory etc., of such herbal beverages or their specific constituents that are being studied *in vitro, in vivo* or in clinical trials (Bag et al., 2022).

Though there are many reports on secondary metabolites, including polyphenols from herbal beverages/extracts as therapeutic agents but their acceptance in clinical trials is restricted due to their poor bioavailability, which is a significant concern. The studies on firmicutes/bacteroidetes showed that its ratio could be regulated with the polyphenols like quercetin and apple procyanidins in rat and mouse models (Lyu et al., 2017). Thus, the gut microbiota composition could be modulated by ingesting different dietary polyphenols. Gross et al. (2010) described that black tea and its extract enhance the bifidobacteria, and that certain polyphenols stimulate the growth of beneficial and specific bacterial strains and reduce the occurrence of pathogens.

Herbal beverages prepared by different means share a typical two-compartment structure; a polymeric phase and a true solution phase consisting of small molecules (50 ≤ molecular weight ≤ 1500 Da) and ions in an aqueous solvent. The small molecules can be a wide variety of primary and secondary metabolites. The small molecule fraction of herbal beverages has been studied by many authors (Iftikhar et al., 2022; Chandrasekara & Shahidi, 2018; Bag et al., 2022), but the large molecules (mainly peptide and oligo/polysaccharides) fraction requires more attention.

The rise of improper lifestyle, emerging toxic molecules in food or drugs, pollution, limited health access, and other environmental causes increase intestinal diseases like small intestinal bacterial overgrowth (SIBO), inflammatory bowel diseases (IBD), i.e., crohn's disease, ulcerative colitis and colon cancer (Forgie et al., 2019). The current therapies for these diseases include anti-inflammatory drugs, immune suppressors, and antibiotics in a host of biologics. However, many of these therapies have inconsistent efficacy, impart side effects and are often costly. Hence, there is a growing interest to evaluate various herbal products to prevent or cure such diseases.

This study was focused on the physicochemical and potential antioxidant and prebiotic properties of two ready-to-serve beverages from a medicinal plant, *Centella asiatica*. The plant is a good source of bioactive compounds and is well documented in traditional medicine texts, ethnomedicine repositories, and modern scientific reports for its preventive action on degenerative diseases (Kunjumon et al., 2022). Though there are large number of reports on non-aqueous extracts of many herbs, including *C. asiatica* but fewer studies are available on their beverage form (Junsi & Siripongvutikorn, 2022; Sun et al., 2020). The effect of the processing methods on compositions of small and large molecule fractions of CABs and their antioxidant and prebiotic potential including anti-microbial activity have been studied. Additionally, a hypothetical framework was proposed to highlight the spatio-temporal aspect that needs to be considered when evaluating the potential benefit of such herbal beverages in case of different intestinal diseases.

7.1. Methodology

The work can be categorized into four distinct activities. First, fractionation of prepared *Centella asiatica* beverages from dried powder and fingerprint analysis of their three different fractions. Second, *in vitro* antioxidant activity of characterized fractions of beverages. Third, the physiological antioxidant potential of bioactive compounds of beverages in yeast model. Fourth part of the work is about the effect of CABs on representative gut microbiota. This study aims to develop a schematic for further animal/clinical studies based on conclusions from the current study and the literature available on GI tract motility and spatial distribution of food, beverage, and drug in the gut.

7.1.1. Preparation of beverages

A known variety of *Centella asiatica* (L.) Urb. was cultivated in a controlled environment. The taxonomic identification was done by Dr. Deepu Vijayan (Botanical Survey of India, Shillong). A domestic microwave oven (IFB, 20BC4, India) at an appropriate power level (720 Watt) was used for drying the samples till they reached constant weight. In this study, infusion and decoction types of ready-to-serve beverages were prepared from the leaf powder. Both the preparation methods are traditionally known but in this work the methods were adopted from Guimarães et al. (2010) and Siah et al. (2011) with some minor modifications. For infusion, 100 mL of hot (95 ± 5ºC) distilled water was poured in 4 g powder and incubated for 5 minutes with stirring at 150 rpm in an orbital shaker. For decoction, 4 g of sample was boiled in a glass kettle containing 100 mL of distilled water for 5 minutes. The extracts were clarified with centrifuging at 5000 × *g* for 5 minutes. Both beverages were acceptable in terms of sensory quality.

7.1.2. Fractionation of *Centella asiatica* Beverages

Fractional precipitation method was used for the separation of crude polysaccharides and protein fraction sequentially due to their different solubility. In 50 mL centrifuge tube, a specific amount of absolute ethanol (1:4 v/v) was added in extracts and incubated for 24 h at 4°C. To separate the soluble, the mixture was centrifuged at 4°C, 10,000 × *g* for 10 minutes. The supernatant i.e., ethanol soluble fraction (EF) was separated and residues were washed with ethanol and freeze-dried. The polysaccharide-protein complex residues were separated by incubating with 10% TCA (3.0 pH) and incubated for 24 h at 4°C. The supernatant consists of ethanol precipitated polysaccharide fraction (EPPF) and the residues were TCA precipitated protein fraction (TPPF) (Appendix E.7). These three fractions were freeze-dried and further analyzed.

7.1.3. Analytical Methods

7.1.3.1. Total Solids (TS)

Loss on drying method was used for determining total solids of the crude beverages and their fractions. 5 mL of the samples were dried at 105°C and the difference of weight was used to calculate mg of solids/mL.

7.1.3.2. Total Carbohydrate content (TCC)

Total carbohydrate content of CABs was estimated with Phenol-sulphuric acid method (Pawar & Mello, 2011). Extracts were dissolved in (1:1) 5% Phenol's reagent and 5 mL of concentrated H_2SO_4. The reaction mixtures were mixed and incubated for 20 minutes at 30°C. The absorbance was measured at 490 nm and expressed as mg of glucose equivalent (GE)/mL of extracts (Appendix D.3).

7.1.3.3. Reducing Sugar (RS)

The reducing sugar content was determined with 3,5-dinitrosalicylic acid (DNS) method (Krivorotova & Sereikaite, 2014). 3,5-dinitrosalicylic acid (DNSA) reagent (1 g DNSA and 30 g potassium sodium tartrate in 100 mL 0.25N NaOH) was prepared at 45°C. Extracts were mixed with DNSA reagent (1:1) and kept in a boiling water bath for 5 minutes. After cooling, the absorbance was measured at 540 nm. The reducing sugar contents were expressed as mg glucose equivalent (GE)/mL of extracts (Appendix D.4).

7.1.3.4. Total Soluble Protein (TSP)

The total soluble protein of CABs was estimated by modified Lowry method (Lowry et al., 1951). Extracts were mixed in Lowry reagent (2% Na_2CO_3 in 0.1 N NaOH, 1% $CuSO_4$ and 0.5 mL of 2% potassium sodium tartrate) and incubated for 15 minutes at 37°C. 2N Folin Ciocalteu's reagent (1:2) was added to the reaction mixture and incubated for another 30 minutes at 37°C. The absorbance of the mixture was measured at 660 nm. Total soluble protein was expressed as mg of bovine serum albumin equivalent (BSA)/mL of extracts (Appendix D.5).

7.1.3.5. Spectral analysis of beverages in UV-range

UV-Visible Spectrophotometer is a widely used technique to determine or quantify the diverse analytes or samples through scanning of different wavelengths. In this study, whole beverages and its fraction were solubilized in 1 mg/mL concentration. Each fraction was scanned from 200-500 nm in Shimadzu UV-1900 UV-Vis Spectrophotometer for its characteristic emission spectra.

7.1.3.6. IR signature spectra of the beverages with identification of possible functional groups

Dried powders of whole beverages and fractionated extracts were used to determine the functional group and its emission spectra. Perkin-Elmer Spectrum Two with Universal ATR was used with a scan range from 500-4000 cm^{-1}.

7.1.3.7. Chemical profiling of small molecules (EF) of the two CABs

The phenolic compounds were quantified by using an LC system coupled to a triple quadrupole mass spectrometer (Agilent 6410 Triple Quad MS-MS) equipped with an electrospray ionization (ESI) source. The chromatographic separation of the phenolic compounds was carried out on Eclipse Plus column C18 (100 × 4.6 mm i.d., particle size 3.5 μm). The temperature of the column was set at 40°C and the injection volume of the samples was 5 μL. The positive/negative mode compounds were isolated in mobile phase consists of 0.1% formic acid/0.1% acetic acid in 5 mM ammonium (eluent A) and acetonitrile (eluent B) at a flow rate of 0.40 mL/min. The gradient conditions were as follows: 0–5 min, 2-2% B; 5–20 min, 2-40% B; 20–30 min, 40-90% B; 30–40 min, 90–2% B; 40–45 min, 2-2% B. The capillary voltage was of 135V; nebulizing gas (N_2) flow rate was 15 L/min, and the heat block and de-solvation line temperatures was of 300°C, respectively. Mass spectra was recorded between m/z 15–1650. The main phenolic compounds of *Centella asiatica* were identified by comparing their mass spectrometry fragmentation patterns.

7.1.3.8. Antioxidant capacity of different fractions of *Centella asiatica* beverages

Folin's reducing power (FRP) of CABs was determined using Folin-Ciocalteu method (Singleton and Rossi, 1965). Ferric reducing power (IRP) of CABs was determined with Potassium Ferricyanide Reducing power assay (Oyaizu, 1986). The free radicals scavenging potential (ARSA) of CABs was determined with 2,2′-azinobis-3-ethylbenzothiazoline-6-sulfonic acid assay (Re et al., 1999). Lipid peroxidation inhibition capacity (LPOX) of CABs was estimated with Thiobarbituric acid-reactive species assay (Ohkawa et al., 1979).

7.1.4. Assessment oxidative stress compensation ability of the CABs in a yeast model

7.1.4.1. *Saccharomyces cerevisiae* growth condition

The wild-type *Saccharomyces cerevisiae* strain (EG103) and the isogenic mutant strains sod1Δsod2Δ (EG133) were provided by Dr. Lindsay Kane Barnese (Concordia University, Irvine US) and Dr. E. Gralla (University of California, Los Angeles, CA, USA). One loopful of inoculum of both strains was dissolved in 50 mL of Yeast Extract–Peptone–Dextrose (YPD) broth pH-6.2. The cultures were grown at 30°C and 130 rpm for 12 h (stationary phase that corresponded to approximately 1.5 optical density at 600 nm).

7.1.4.2. Effect of different fractions on the viability of H_2O_2 stressed yeast cell

The protocol for the cell-based antioxidant assay was standardized with sequential pre-treatment with 100 µM quercetin (standard) and 5 mM H_2O_2 stress, respectively. In this assay, aliquots with 2×10^9 CFU/mL of cells were divided into several sub-aliquots for replicates. PBS (pH 7.5) suspended cells were treated with CABs at 30°C for 1 h. The washed cells were stressed with 5 mM of H_2O_2 at same conditions and were grown in YPD agar for 48 h at 30°C (Appendix E.8). The cell viability of both the strains was calculated w.r.t. untreated cells. The specific cell viability data were expressed as % of CFU of untreated yeast cells/concentration of the soluble component (Appendix D.9).

7.1.5. Assessment of change in CFUs of model probiotic and pathogenic bacteria after treatment with CABs and their fractions

Lacticaseibacillus rhamnosus ATCC 53103 was grown in MRS broth at pH 7.2 anaerobically for 36 h and food-borne pathogen *Bacillus cereus* isolated from fermented soybean was grown in nutrient broth at pH 7.2 aerobically for 8 h at 37°C (stationary phase). In this assay, aliquots with 5.8 × 10^7 CFU/mL of cells were suspended in PBS (pH 7.5). The PBS-suspended individual and combined bacterial cells (equal concentration of *L. rhamnosus* and *B. cereus*) were incubated with CABs, their fractions or a standard antioxidant (100 µM quercetin) for 2 h at 37°C at static condition. The cells were grown in all culture agar at 37°C for 48 h (Appendix E.9).

The percentage change in the CFU of *Bacillus cereus* and *Lacticaseibacillus rhamnosus* ATCC 53103 treated with *Centella asiatica* beverages (CABs) were calculated based on corresponding untreated cells CFUs and expressed as percentage of cell viability in individual condition. Similarly, for co-incubation and co-cultured condition, the percentage change in the CFU of each bacterial cell treated with CABs was calculated based on untreated co-culture plates and expressed as percentage of cell viability. A sample calculation is given as below

$$\%\ of\ cell\ viability\ in\ individual\ or\ co-culture = \frac{(IWB \times 100)}{NC^1} = \frac{(126 \times 100)}{494} = 26\%$$

Where, NC^1: Number of CFUs obtained for untreated *Bacillus cereus* or *L. rhamnosus* ATCC 53103 colonies on individually cultured plates or on co-cultured plates; IWB: Number of CFUs obtained after treated with infused whole beverage; similarly, the percentage of cell viability of *Bacillus cereus* and *Lacticaseibacillus rhamnosus* ATCC 53103 treated with ethanol soluble fraction were calculated. Further the specific cell viability data was calculated as % of CFU of untreated bacterial cells/concentration of the soluble component to compare the intrinsic capability to reduce or increase cell viability due to a type of CAB or its fraction since the fractions have different concentrations of solutes.

7.2. Statistical Analysis

Results were expressed as mean ± standard error (SE). The Origin 9.0 program (2022) was used to analyse the data and mean values were statistically significant ($p < 0.05$). Similarity analysis was performed with the Pearson correlation coefficient and Euclidean distance (Appendix D.1). The statistical application Relative antioxidant activity index (RAAI) and Global antioxidant activity index (GAAI) was used to evaluate the antioxidant capacity of CABs (Leporini et al., 2018).

7.3. Results and Discussion

Many authors have studied the bioactivity of the small molecules of different herbal beverages (Bag et al., 2022). However, the soluble polymeric molecules, i.e., the mixture of cell wall polysaccharides, crude protein and other oligomers/polymers that control the rheology bioactivity and stability of the aqueous extracts are inadequately studied (Xiao & Jiang, 2015). Even though the soluble polymers influence gut processing and availability of the small molecules of a (beverage) mixture, these two phases were investigated in an isolated manner. In most studies related to herbal beverages or aqueous extracts, these two phases are investigated in an isolated manner. This work planned to explore the physical and chemical properties including the antioxidant potential, prebiotic activity and all three compartments in two *Centella asiatica* beverages (CABs). The concentration of the soluble/dry products was between the recommended doses as prescribed by the FSSAI.

7.3.1. Effect of two preparation methods on chemical profile of *Centella asiatica* beverage

Among the two beverage preparation methods, the decoction-type beverage could extract about 12% more soluble compounds than the infused one. Faster diffusion of the water solvent within the solid dried plant powder particles and more solubility of the organic molecules in water at boiling condition, might have resulted in higher concentration of solubles in decoction compared to infusion (Zhang et al., 2018). Further, comparing three other components of the CABs i.e., EF, EPPF and TPPF showed that all three fractions were present in higher quantities in the decoction beverage and primarily, EPPF was extracted more than 17% in decoction (Fig. 7.1a and 7.1b). Further, fingerprint spectra for WB (whole beverage) and their fractions (i.e., EF, EPPF, TPPF) were compared to evaluate if the two beverages were different in terms of molecular diversity.

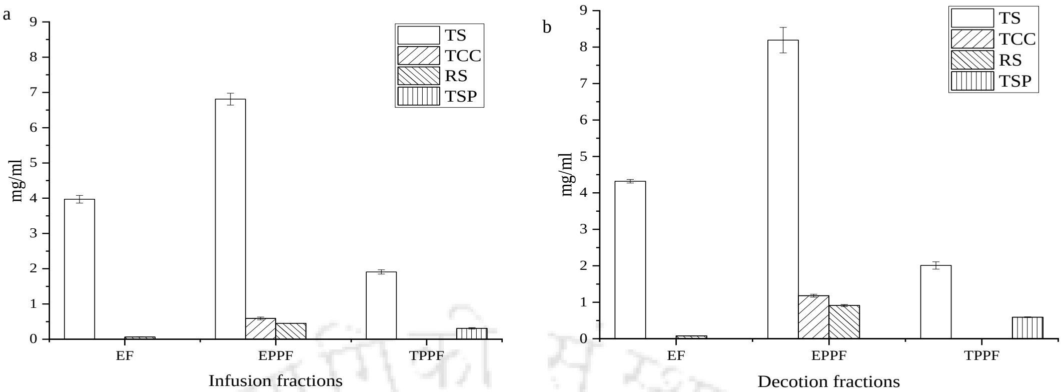

Fig. 7.1 Chemical composition of (a) Infusion and (b) Decoction of CABs. EF: Ethanol soluble fraction, EPPF: Ethanol precipitated polysaccharide fraction; TPPF: TCA precipitated protein fraction. TSS: Total solids; TCC: Total carbohydrate content; RS: Reducing sugar; TSP: Total soluble protein. Results were expressed as mean ± standard error (SE) of triplicate runs.

To develop fingerprint spectra, UV and FTIR spectroscopy were used so that both UV and IR active molecules or functional groups or their complexes could be captured (Kharbach et al., 2020). Also, Pearson correlation and Euclidean distance were calculated to assess the similarity between any two pairs of spectra (Table 7.1). High Pearson correlation coefficient (r) and low Euclidean Distance (d) can complement each other and strengthen the conclusion of similarity between two pairs of data in a quantitative manner.

Table 7.1 Similarity indices of the two types of CABs infused and decoction type present in different fractions

Extract/ fraction	**UV scanning**		**FTIR scanning**	
	Pearson correlation coefficient	**Euclidean Distance**	**Pearson correlation coefficient**	**Euclidean Distance**
WB	0.99	2.08	0.92	5.49
EF	0.96	2.85	0.91	13.55
EPPF	NA	NA	0.71	45.31
TPPF	0.99	0.05	0.96	1.67

Note: NA: Not applicable; WB: Whole Beverage; EF: Ethanol soluble fraction; EPPF: Ethanolic precipitated polysaccharide fraction; TPPF: TCA precipitated protein fraction.

The Pearson correlation of UV spectra of WB and their EF and TPPF of CABs were similar. Further, the Pearson correlation coefficient and Euclidean distance of FTIR spectra of EF and EPPF in each CAB suggested that the beverages presented a different collection of small molecules and oligo/polysaccharides. These results supported that structure–function of individual fractions of different types of beverages will serve as a protective food to set dietary guidelines (Xiao & Jiang, 2015).

7.3.2. Chemical profiling of small molecules (EF) of the two CABs

LC-MS with different separation methods and ionization modes (negative/positive) were done for EF of CABs. About 52 compounds were identified in either of the CABs covering 9 different classes of compounds, viz., caffeoylquinic acids, hydrocinnamic acid, hydroxybenzoic acid, coumarins, tannins, flavonoids, terpenoids, stilbene, and fatty acids (Table 7.2). The present method showed that 80% of these compounds were present in both beverages. All identified compounds were reported earlier in different extracts of *C. asiatica*. For example, the six isomeric phenolic acids identified as caffeoylquinic acids in this study have been reported in *C. asiatica* (Long et al., 2012) (Table 7.2). Apart from phenolics, flavonoids such as epigallocatechin gallate, castilliferol and quercetin derivative were detected in both beverages. Terpenoid saponins were also a major group confirmed by this study such as madecassoside and asiaticoside B. In addition to this, tannins like trigalloylshikimic acid were also detected in both beverages. Such untargeted metabolomics requires a collection of chromatographic methods to elucidate the global metabolome; hence, the compounds detected in the current study represent a small part of the metabolome. However, many compounds like myricetin, quercetin, kaempferol and protocatechuic acid have been reported for their antioxidant, anti-inflammatory, prebiotic and other bioactivity (Bag et al., 2022; Pacheco-Ordaz et al., 2018). Also, the results showed a preferential distribution of some compounds in either of CABs. Some of the glycosides are known to be hydrolysed to their aglycon form during high-temperature processing like boiling (Deng et al., 2011). In the present study, some glycosides, viz., kaempferol-3-glucoside, centellasaponin A, and asiaticoside D were not detected in the harsher preparation method, i.e., decoction. Also, higher aqueous solubility of some phenolics at elevated temperatures brought compounds like chlorogenic acid and piceatannol in decoction beverage but not in infusion. Similarly, oxidative oligomerization with and without metal catalysis can be a reason for identifying C1 procyanidin trimer in decoction beverage. Oleuropein perhaps underwent isomerization in boiling condition in aqueous solvent (Bakhouche et al., 2015). There are separate studies on these individuals (group of) so-called small compounds in many research groups in the context of intestinal antioxidant homeostasis and intestinal microbiota.

Table 7.2 Profiling of the phenolics of the two CABs

Sl. No.	Rt (min)	Parent ion (m/z)	MS/MS fragments	Tentative identity of compound	Infusion	Decoction	Compound Class
1.	2.80	602	601, 539, 439	Irbic acid	✓	✓	Caffeoylquinic Acids
2.	10.4	361	-	Neochlorogenic acid	✓	✓	
3.	13.34	353	203, 115	Chlorogenic acid	x	✓	
4.	13.75	707	467, 353, 191	1,5-Di-O-Caffeoylquinic acid	✓	✓	
5.	15.2	557	515, 353, 278, 161	Dicaffeoylquinic acid derivative	✓	✓	
6.	16.13	707	451, 353,191	Caffeoylquinic acid derivative	✓	✓	
7.	17.14	515	353, 191	3,4-Dicaffeoylquinic acid	✓	✓	
8.	20.25	923	699, 613, 601, 559, 515, 461	1,3,4,5-Tetracaffeoylquinic acid	✓	✓	
9.	20.57	733	613, 515	Dis-trans and mono-cis 3,4 di-caffeoylquinic acid	✓	✓	
10.	20.99	819	699, 687, 601	O-Dimalonyl-O-dicaffeoylquinic acid	✓	✓	
11.	25.61	713	487, 417, 393, 329, 293, 112	Ferulic acid derivative	✓	✓	Hydrocinnamic acid
12.	28.76	623	623, 311	Chicoric acid isomer 1	✓	✓	
13.	28.99	763	623, 311	Chicoric acid isomer 2	✓	✓	
14.	29.62	651	325	P-coumaric acid isomer 1	✓	✓	
15.	29.87	777	651, 325	P-coumaric acid isomer 2	✓	✓	
16.	30.99	325	-	P-coumaric acid	✓	✓	
17.	27.88	751	297	Protocatechuic acid isomer 1	✓	✓	Hydroxybenzoic acid
18.	28.10	750	297	Protocatechuic acid isomer 2	✓	✓	
19.	32.71	299	-	Salicylic acid beta-D-glucoside	✓	✓	
20.	30.52	679	339, 255	Aesculin isomer 1	✓	✓	Coumarins
21.	30.78	791	679, 339, 255	Aesculin isomer 2	✓	✓	
22.	15.67	955	551, 515, 477	Trigalloylquinic acid	✓	✓	Tannins
23.	17.62	855	601, 505, 447, 161	Digalloylquinic acid	✓	✓	
24.	19.62	551	549, 497	Trigalloylshikimic acid	✓	✓	
25.	2.31	456	289, 216, 164	Epigallocatechin gallate	✓	✓	Flavonoids
26.	12.38	601	278, 152	Myricetin-o-(o-galloyl)-pentoside	✓	✓	
27.	13.94	945	601, 515, 395, 161	Eriodictyol 7-(6-galloylglucoside)	✓	✓	
28.	14.5	472	451, 353, 203	Castilliferol	✓	✓	
29.	16.18	923	461	Scutellarein 7-glucuronide	✓	✓	
30.	16.97	511	487, 497	Naringin	✓	✓	
31.	17.4	613	493	Delphinidin 3,5-diglucoside	x	✓	
32.	18.47	923	515, 461, 285	Luteolin-7- glucuronide	✓	✓	
33.	18.64	620	557, 395, 197, 161	Procyanidin B1	✓	✓	
34.	21.37	777	775, 723, 563, 301	Quercetin isomer	✓	✓	
35.	23.65	301	-	Quercetin	✓	✓	
36.	23.72	285	-	Kaempferol	✓	✓	
37.	23.23	1075	1015, 871, 473	Vicenin	✓	✓	
38.	25.87	713	514, 417, 403, 393	Kaempferol-3-O-pentoside	✓	✓	
39.	26.99	447	135	Kaempferol-3-glucoside	✓	x	
40.	27.42	417	-	Kaempferol-3-arabinoside	✓	✓	
41.	34.32	743	695, 250	C1 Procyanidin trimer	x	✓	
42.	2.72	1007	845, 539, 503, 128	Oleuropein	✓	✓	Terpenoids
43.	3.89	1273	725, 563, 503, 113	Oleuropein isomer	x	✓	
44.	20.01	723	546, 507	Hovenidulcigenin B	✓	✓	
45.	21.15	993	957, 713, 538, 473	Asiaticoside	✓	✓	
46.	21.71	1033	974, 546	Madecassoside	✓	✓	
47.	22.23	1017	957, 887, 538, 193	Centellasaponin A	✓	x	
48.	23.00	657	557	Asiaticoside B	✓	✓	
49.	24.12	1059	999, 740, 514	Asiaticoside C	✓	✓	
50.	2516	1059	999, 740, 565, 133	Asiaticoside D	✓	x	
51.	2.46	627	485, 343, 201, 152	Piceatannol	x	✓	Stilbene
52.	33.48	817	279, 205	Linoleic acid	✓	x	Fatty acid
53.	35.17	815	-	Unknown	✓	x	

Rt: Retention time

7.3.3. Chemical profiling of presumptive polysaccharide (EPPF) and protein (TPPF) fractions of the two CABs

Unlike the small molecules, the so-called large molecule fraction from *C. asiatica* aqueous extracts is less known. FTIR scanning of the two major polymeric fractions, EPPF and TPPF obtained from CABs in the present study showed structural heterogeneity (Fig. 7.2a and 7.2b). Between infusion and decoction beverages, the number of peaks was the same in their corresponding FTIR spectra of EPPF and TPPF fractions, but their intensities were different; this indicated that higher concentrations of polymeric compounds were extracted by decoction method. The FTIR spectra of EPPF showed a wide range of weak peaks around 1138 cm^{-1} that could be attributed to mixed polysaccharides. The peaks in the range 1000-800 cm^{-1} represented the presence of glucose and galactose, and the intensity of the peaks was more in decoction. Water-soluble arabinogalactan and pectin from *C. asiatica* have already been reported (Wang et al., 2003; 2005). Apart from that, some aliphatic and aromatic amine groups were present in both polysaccharide fractions of CABs showing the possibility of glycoprotein complexes like arabinoglycan protein. The difference in intensity of the same peaks in both beverages highlights that these presumptive polysaccharide compounds might degrade during brewing due to thermal treatment.

The TPPF of CABs were also studied with a FTIR spectra to detect their functional groups. The infrared spectra of both beverages showed intense characteristic peaks at the region of approximately 1680 cm^{-1} that could be assigned to amide I and 1264 cm^{-1} showing the absorption spectra of primary aromatic amines and amide III. Both beverages have similar peaks for protein fraction and are similar to each other (w.r.t. r = 0.96 and d = 1.96). The samples exhibited a relatively strong absorption band that appeared at 800-640 cm^{-1}, which was assigned to the out-of-plane NH bending (amide V) and was more prevalent in the decoction. Similarly, the peaks at around 625-767 cm^{-1} suggested the presence of OCN bending (amide IV) and had a stronger peak in decoction than infusion.

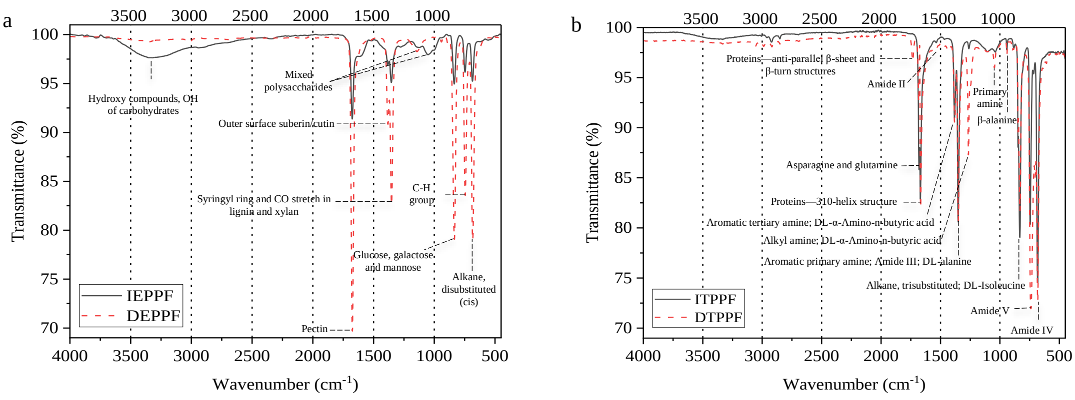

Fig. 7.2 FTIR spectra of (a) Ethanol precipitated polysaccharide fraction and (b) TCA precipitated protein fractions of CABs. IEPPF: Infused ethanol precipitated polysaccharide fraction; DEPPF: Decoction ethanol precipitated polysaccharide fraction; ITPPF: Infused TCA precipitated protein fractions; DTPPF: Decoction TCA precipitated protein fractions.

7.3.4. Antioxidant capacity of different fractions of *Centella asiatica* beverages

To evaluate the antioxidant potential of a variety of food and herbalpreparations of more than one types of so called *in vitro* antioxidant activities like 2,2 azinobis-(3 ethylbenzothiazoline-6-sulfonic acid) radical scavenging (ABTS), Ferric reducing antioxidant power (FRAP), Oxygen radical absorbance capacity (ORAC), Total radical-trapping antioxidant parameter (TRAP), total phenolic content (TPC) and inhibition of auto-oxidation of induced low-density lipoprotein (LDL), 2, 2 diphenyl-l-picrylhydrazyl (DPPH), and cupric reducing antioxidant capacity (CUPRAC)method etc are used. Each *in vitro* antioxidant activity measurement method has its advantages and disadvantages; none of them actually ensure their capacity to restore antioxidant homeostasis at the cell or organism level. Hence, more than one assays are used to find out whether a molecule or a natural extract like CABs can effectively neutralize the oxidative species via electron or proton transfer mechanism, their kinetic features and if they have any specific capability to reverse the oxidative changes in specific biomolecules like lipids, protein or nucleic acids. In the present study, ABTS, FRAP and TPC were done to assess the reduction or radical scavenging capacity of the CABs and their three individual fractions. Decoction beverage was superior in terms of the three antioxidant assays. Also, in both beverages, mainly the small molecule fraction was responsible for their antioxidant capacity which had three to four times more specific antioxidant activity (a standard antioxidant molecule like ascorbic acid, trolox, gallic acid etc. equivalent per unit mass of the mixture) compared to the whole beverage (Table 7.3).

Table 7.3 *In vitro* antioxidant potential of different fraction of two types of CABs

Antioxidant activity	Infusion				Decoction			
	WB	Fractions			WB	Fractions		
		EF	EPPF	TPPF		EF	EPPF	TPPF
FRP (μg GAE/mL)	243.64±9.45	213.42±7.93	ND	ND	255.73 ±10.01	237.15±8.09	ND	ND
IRP (μg AA/mL)	618.25±7.64	475.10±6.52	115.78±1.35	16.67±0.22	713.08 ±9.89	540.72±1.12	145.89±1.80	22.52±0.2
ARSA (μg TE/mL)	603.45±7.73	479±11.82	175.73±9.09	ND	675.73±1.82	579.82±9.55	222.09±13.64	ND
LPOX (μg MDA/mL)	7.53±0.38	14.43±0.19	ND	ND	8.93±0.30	17.62±0.41	ND	ND

ND: Not detectable; EF: Ethanolic soluble fraction; EPPF: Ethanolic precipitated polysaccharide fraction; TPPF: TCA precipitated protein fraction; FRP: Folin's reducing power, IRP: Fe^{3+} reducing power, ARSA: ABTS radical scavenging activity, LPOX: Lipid peroxidation inhibition; GAE: Gallic acid; AA: Ascorbic acid; TE: Trolox; MDA: Malondialdehyde; Concentration expressed in μg standard equivalent/mL. Results were expressed as mean ± standard error (SE) of triplicate runs.

However, the polysaccharide fractions of both beverages showed significant Fe^{3+} reducing power and ABTS radical scavenging activity. Such antioxidant activity in various polysaccharides has been attributed to reducing/radical scavenging ability of phenolic or protein residues as part of the polysaccharide molecules and metal chelating ability of different polysaccharide mixtures (Wang et al., 2016). In the present polysaccharide extracts, the conjugate protein could be traced, which might be the cause of the antioxidant potential however, the exact mechanism of the polysaccharide-based redox reactions requires further investigation. In addition to the three antioxidant assays, the oxidation protection capability of the said fractions against lipid molecules were determined by the Lipid peroxidation (LPOX) assay. Lessening of the formation of lipid peroxidized product (MDA) in the LPOX assay revealed that antioxidant protection of lipid molecules might occur due to the small molecule fraction, which was greater in the decoction beverage. Further, to check how good the extract is as an antioxidant mix it was compared with other known antioxidant rich extracts using two scores viz., Relative antioxidant activity index (RAAI) and Global antioxidant activity index (GAAI) were calculated respectively (Leporini et al., 2018). RAAI uses the antioxidant capacity data estimated by given methods and then calculates a statistical score for the comparison of different antioxidant sources whereas GAAI assigns equal importance to all the assay methods used for assessing net antioxidant potential of a given antioxidant source then statistically calculates a global score for ranking a collection of natural extracts for their potential antioxidant capacity. In terms of GAAI, the CABs were in second (decoction) and third (infusion) position only after *Ginkgo biloba* among twelve well known clinically proven antioxidant extracts (Table 7.4). All three antioxidant activities support the antioxidant potential of the CABs and its different fractions.

Table 7.4 Potential antioxidant capacity of CABs in terms of RAAI and GAAI

Sl. No.	Name of medicinal plants	RAAI			GAAI			T-score	RAAI based on GAAI
		TPC	FRAP	ABTS	TPC	FRAP	ABTS		
1.	*Ginkgo biloba**	2.63	-0.10	0.54	1.00	0.11	0.70	1.80	1.36
2.	*Panax ginseng**	-0.54	0.30	-1.27	0.02	0.24	0.00	0.26	-0.77
3.	*Curcuma longa**	-0.44	-0.88	-1.34	0.06	-0.16	-0.03	-0.13	-1.32
4.	*Moringa oleifera**	0.13	0.23	0.46	0.23	0.22	0.66	1.11	0.41
5.	*Mentha spicata**	1.94	-0.41	-0.48	0.79	0.00	0.30	1.09	0.37
6.	*Azadirachta indica**	-0.52	-0.94	-1.65	0.03	-0.18	-0.15	-0.29	-1.55
7.	*Allium sativum**	-0.30	-0.95	-0.92	0.10	-0.18	0.13	0.05	-1.07
8.	*Cinnamomum zeylanicum**	-0.11	-0.49	0.26	0.16	-0.03	0.59	0.72	-0.14
9.	*Nigella sativa linn**	-0.54	-0.26	1.15	0.03	0.05	0.93	1.01	0.26
10.	*Coriandrum sativum**	-0.55	-0.28	0.83	0.02	0.04	0.81	0.87	0.07
11.	*Trigonella foenum-graecum**	-0.56	-0.30	0.79	0.02	0.04	0.79	0.84	0.03
12.	*Rosmarinus officinalis**	-0.62	-0.23	-0.48	0.00	0.06	0.30	0.36	-0.63
13.	*Centella asiatica* Infusion	-0.30	1.77	0.76	0.10	0.74	0.78	1.62	1.11
14.	*Centella asiatica* Decoction	-0.22	2.54	1.33	0.12	1.00	1.00	2.12	1.81

Note: *Reference literature; RAAI: Relative antioxidant activity index; GAAI: Global antioxidant activity index

7.3.5. Assessment of oxidative stress compensation ability of the CABs in a yeast model

The four *in vitro* antioxidant assays reported in section 7.3.4 suggested that both CABs have notable reducing and radical scavenging ability, but to understand whether they are capable of reversing the oxidative stress condition inside the cell, a separate experiment was done in a yeast model. The yeast cells were treated with CABs and their fractions and then exposed to H_2O_2-induced oxidative stress. Eventually, the yeast cell viability was recorded to check if exposure to CABs or antioxidants could reduce cell death due to oxidative stress. The CFU of untreated cells without the oxidative stress or the antioxidant solutions (ie., none of the CABs or their fractions) were considered as 100% viable cell count. CFUs obtained for all the other treated cells (either of the CABs or their fractions plus 5 mM H_2O_2) were expressed as percentage of untreated cells CFU. It is worth mentioning; no cell viability was observed in 5 mM H_2O_2 treatment alone.

S. cerevisiae is an appropriate eukaryotic model organism for studying various diseases and metabolic processes like aging, gene regulation and expression, metabolism, cell cycle, signal transduction, and degenerative diseases (Cankorur-

Cetinkaya et al., 2013) due to their high gene similarity (~47%) with the human genes (Kachroo et al., 2015). Specifically, it has enzymatic and non-enzymatic ROS detoxification systems consisting of superoxide dismutase, catalase, glutathione peroxidase, glutathione reductase, and mainly glutathione like humans (Shields et al., 2021). Since yeasts are easy and fast to grow compared to animal cells and their genetic modulation is convenient, the *S. cerevisiae* was used as a cell model to study the antioxidant properties of CABs.

In this experiment, the wild type (EG103) and the isogenic mutant sod1Δsod2Δ (EG133) strains of *S. cerevisiae* have been studied. EG133 strain had reduced antioxidant protection due to the deletion of SOD1 and SOD2 genes. It is worth mentioning that CuZnSOD (SOD1) and MnSOD (SOD2) are regarded as primary cellular defences against oxidative stress in yeast and most organisms (O'Brien et al., 2004). Both strains were successfully utilized by other researchers to study the antioxidant properties of different molecules and natural extracts (Dani et al., 2008). In the present study, stationary phase cells of the yeasts were used as they mimic the conditions of postmitotic tissue of higher organisms (MacLean et al., 2001).

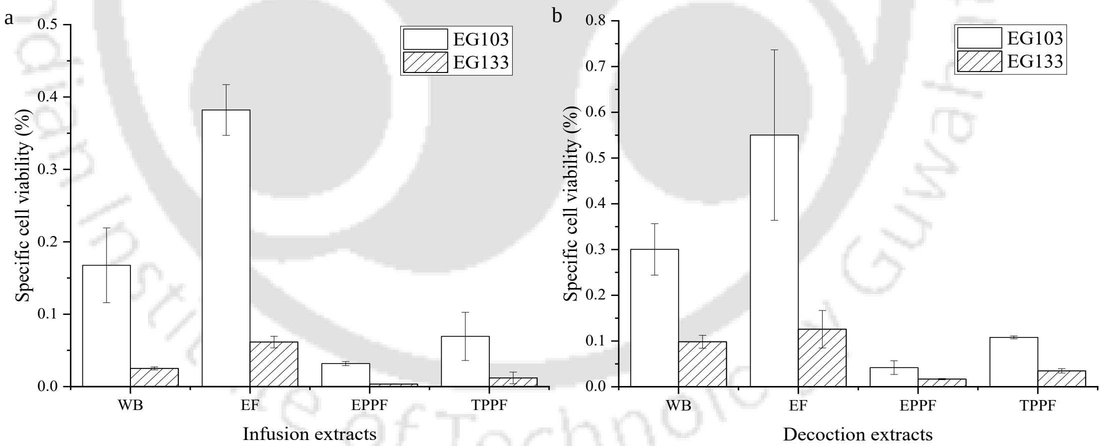

Fig. 7.3 Assessment of oxidative stress reducing ability in a yeast model for (a) Infusion and (b) Decoction of CABs. WB: Whole beverage treated with 5 mM H_2O_2; EF: Ethanol soluble fraction treated with 5 mM H_2O_2; EPPF: Ethanolic precipitated polysaccharide fraction treated with 5 mM H_2O_2; TPPF: TCA precipitated protein fraction treated with 5 mM H_2O_2. Results were expressed as mean ± standard error (SE) of triplicate runs.

The order of specific cell revival was EF>WB>TPPF>EPPF for both beverages (Fig. 7.3a and 7.3b). The specific cell viability data were expressed as % of CFU of untreated yeast cells/concentration of the soluble component (Appendix E.10). In case of EG103, the ethanol soluble fraction of both infusion and decoction had 21% and 25% more oxidative stress-removing capacity than its whole form (Fig. 7.3) and 3% for EG133. The decoction beverage had more than 17% increase in cell viability for EG103 and 7% for EG133 than that of infusion due to more small molecules (ethanol soluble) fraction. The similar result in the wild and antioxidant-compromised yeast cells supports the small molecules in beverages are permeable to the eukaryotic cell membrane and capable of at least reducing oxidants or scavenging radicals inside cells even if it is under oxidative stress and their endogenous antioxidant system is compromised. When the yeast cells were treated with the protein and polysaccharide fractions of CABs, there was slight improvement in cell viability in all cases. It was observed that the effect of EPPF in decoction fraction for oxidative stress removal capacity was 1% more in EG103 and 1.7% in EG133 compared to infusion. However, current knowledge about polymeric antioxidants is limited. And, the current findings suggest that polymers may have the ability to alter the cell membrane porosity and protect against damage due to H_2O_2 exposure. Lin et al. (2020) demonstrated a beneficial effect of three marine organisms derived polysaccharides on the oxidation-stressed *Saccharomyces cerevisiae*. Similarly, the TPPF of decoction increased the resistance about 4% in EG103 and 2% in EG133 than infusion. As shown in Fig. 7.3, EG133 was having no cell viability in stress (5 mM H_2O_2 treatment) due to the absence of SOD1 and SOD2; however, the pretreatment with extract increases the survival rate of EG133 by 7%. This depicts that antioxidant molecules of CABs act independently in EG103 and EG133 depending on the stress response and could induce the transcription of protective genes in EG133 to increase cell survival, similar to the wild strain (Ribeiro, 2015). Moreover, certain amino acids such as methionine and cysteine could scavenge ROS (Luo & Levine, 2009; Bin et al., 2017) identified in the *C. asiatica* extract (Ogunka-Nnoka et al., 2020).

7.3.6. Assessment of change in CFUs of model probiotic and pathogenic bacteria after treatment with CABs and their fractions

Factors such as diet, lifestyle and age can modify the composition and function of gut microbiota. This is termed as intestinal dysbiosis which increases the proliferation of pathogens and reduces the diversity of probiotic bacteria (Varela-Trinidad et al., 2022).

B. cereus secretes both emetic toxins (intoxication caused by ingestion of food containing the toxin cereulide) and enterotoxins i.e., haemolysin BL (Hbl), cytotoxin K and non-haemolytic enterotoxin (Nhe) in GI tract (followed by ingestion of 10^5-10^8 *B. cereus* vegetative cells or spores) (EFSA, 2005). At such enhanced level of the pathogen they can survive in the intestinal environment (Ramarao & Lereclus, 2006; Fagerlund et al., 2008).

This study attempts to determine whether the polyphenols in herbal beverages that remain unavailable for absorption by the human gut epithelia might influence the gut microbiota or intestinal transient pathogens. Hence, two independent experiments were done to determine the effect of two CABs on the growth of a common food pathogen, *B. cereus*, and a proven probiotic strain *L. rhamnosus* ATCC 53103, on treating individually as well as in co-cultured condition. The treatment was performed in a pH medium of 7.2 ± 3 as both strains are able to grow in the selected pH medium and are physiologically acceptable. It will help to eliminate the suppressive effect of *L. rhamnosus* (reduce pH of the medium to 4 on producing lactic acid) on *B. cereus*. In individually grown conditions, it was observed that the WB and IEF showed a significant increase in the growth of *L. rhamnosus* and a decrease in viability of *B. cereus* (Appendix E.11). Specifically, WB showed a 54% increase in *L. rhamnosus* and an 89% decrease in *B. cereus*, while IEF showed a 746% increase in *L. rhamnosus* and a 70% decrease in *B. cereus*. Whereas, in case of WB of decoction, 102% increase in the growth of *L. rhamnosus* and 95% decrease in *B. cereus*. In comparison to infusion, WB of decoction and their EF reduced the growth of *B. cereus* about 6% and 11%, whereas *L. rhamnosus* growth increased by 48% with similar cell viability in EF (Fig. 7.4a).

In contrast, when the two selected microorganisms were exposed together to either of CABs, the cell viability increased by 10% to 13% for *L. rhamnosus* and 92 to 98% decrease in *B. cereus* (Fig. 7.4b). The EF of decoction was found to be the most effective, with more than 28% increase in growth of *L. rhamnosus* compared to the infusion. Correspondingly, in the case of *B. cereus*, the viability loss was 1% more in EF rather than WB (Fig. 7.4b). Though there are earlier reports of antimicrobial activity, including anti-*Bacillus cereus* activity (Arumugam et al., 2011; Wong et al., 2021; Idris & Nadzir, 2021), as far as our knowledge, this is the first report for *C.*

asiatica beverage tested against such pathogen-probiotic couple microorganisms. As expected, decoction beverage had better prebiotic potential for promoting a probiotic strain and restricting a pathogen. The prebiotic effect can be majorly due to the polyphenol-rich small molecule fraction of the beverages and indicates that CABs can modify the microbial composition in the gut to impart health benefits to the host body. Polyphenol-gut microbiota interaction in many *in vivo* studies has substantiated that polyphenols favour the so-called desired bacterial species (Bifidobacteria, Lacticaseibacillus etc.) and inhibit pathogens (Iqbal et al., 2020). However, the polymeric fractions cannot be ignored since it can influence antioxidant balance in the intestine and favour selective growth of some species.

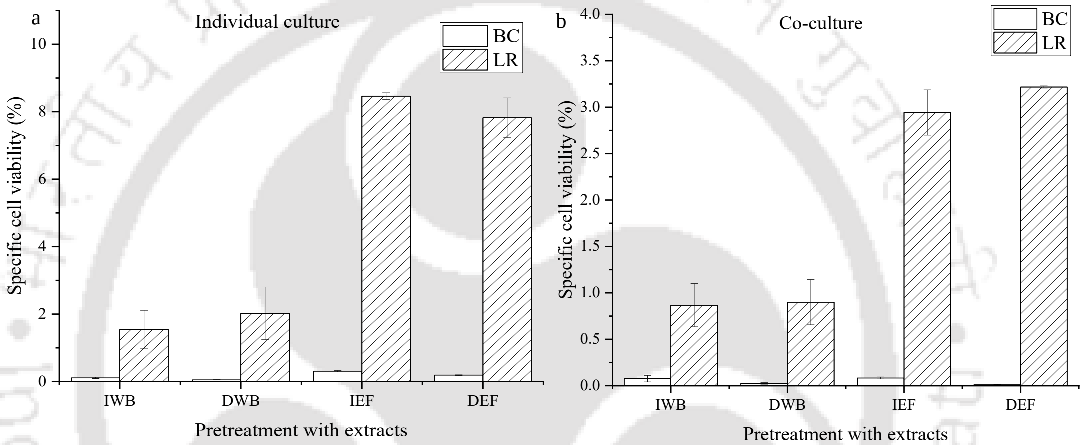

Fig. 7.4 Effect of small molecule fractions and whole beverages on *B. cereus* (BC) and *L. rhamnosus* (LR) (a) Individual culture and (b) Co-culture; IWB: Infused whole beverage; DWB: Decoction whole beverage; IEF: Infused ethanolic fraction; DEF: Decoction ethanolic fraction. Results were expressed as mean ± standard error (SE) of triplicate runs.

7.3.7. A hypothetical framework of action by CABs during intestinal diseases

There are four most common types of intestinal diseases covered; microbial growth imbalance or infections caused by contaminated food, irritable bowel syndrome, inflammatory bowel diseases (IBDs) and cancer. The intestine is under continuous exposure to a host of pathogens viz., Bacteria (E. coli, Salmonella, Shigella, Bacillus, Campylobacter, Clostridium), viruses (Norwalk agent, Rotaviruses), fungal, and parasites (Giardia, Entamoeba, Ascaris) that can cause disease in the intestines. Three layers of barrier in the intestine i.e., chemical, physical and host immunological hurdle prevents any pathogen to spread in the GI tract and/or in the rest of the body via systemic circulation. As part of chemical barrier pathogens and their antigens can be degraded by the gastric acid and pancreatic juice plus the antimicrobial products synthesised by the commensal bacteria can inhibit the colonization of pathogens. The physical barrier in the lumen that consists of epithelial cell layer, unstirred water layer, glycocalyx, and mucus layer to resist colonization of any pathogen. Finally, the antimicrobial peptides and immunomodulating proteins synthesised by Paneth cells and secretory IgA from the enterocytes of epithelium makes the final barrier against the pathogens in the gut (Fig. 7.5a). Any breach of these barrier function can lead to infection and post-infection disorders. IBS is a functional bowel disorder that often happens with abdominal pain and/or diarrhoea and/or change in bowel habit. Out of two types of IBDs in crohn's disease, inflamed areas can emerge in a discontinuous manner across the gastrointestinal tract whereas in ulcerative colitis continuous inflammation of the colon occurs. Ulcerative colitis only affects the inner most lining of the colon while crohn's disease can occur in all the layers of the bowel walls (Bourgonje et al., 2020). Colorectal cancer (CRC) may began as aggregate of noncancerous cells called an adenomatous polyp. A fraction of these polyps can become cancerous slowly. The colonic (often inflamed) mucosa undergo genetic modifications like chromosome instability, microsatellite instability, and DNA hypermethylation to convert into dysplasia or cancer. Pathophysiology of all these four types of diseases are believed to be linked to oxidative stress and depends on a delicate balance between host metabolism, gut microbiota and composition of intestinal content/digesta.

Therefore, it is pertinent to look for dietary options to maintain the homeostasis of ROS in the GI tract in all critical locations over an appropriate time scale. Also, the dietary options should include chemicals that can downplay specific pathogens as well as modulate the diversity (loss) of microbial population in the small and large intestines to prevent *dysbiosis*. The herbal beverages including, the present two CABs, offer great potential as a protective and therapeutic food. In this study, we have successfully carried out *in vitro* and cell level validation of antioxidant ability and also verified *in vitro* prebiotic potential of the CABs. Generally, the *in vitro* studies on antioxidant food and/or prebiotic food does not show its physiological potential and requires *in vivo* efficacy testing in animal or human model. Before going for such animal-level studies or human clinical trials, a critical review of the possible physiological action of the products like CABs is to be done.

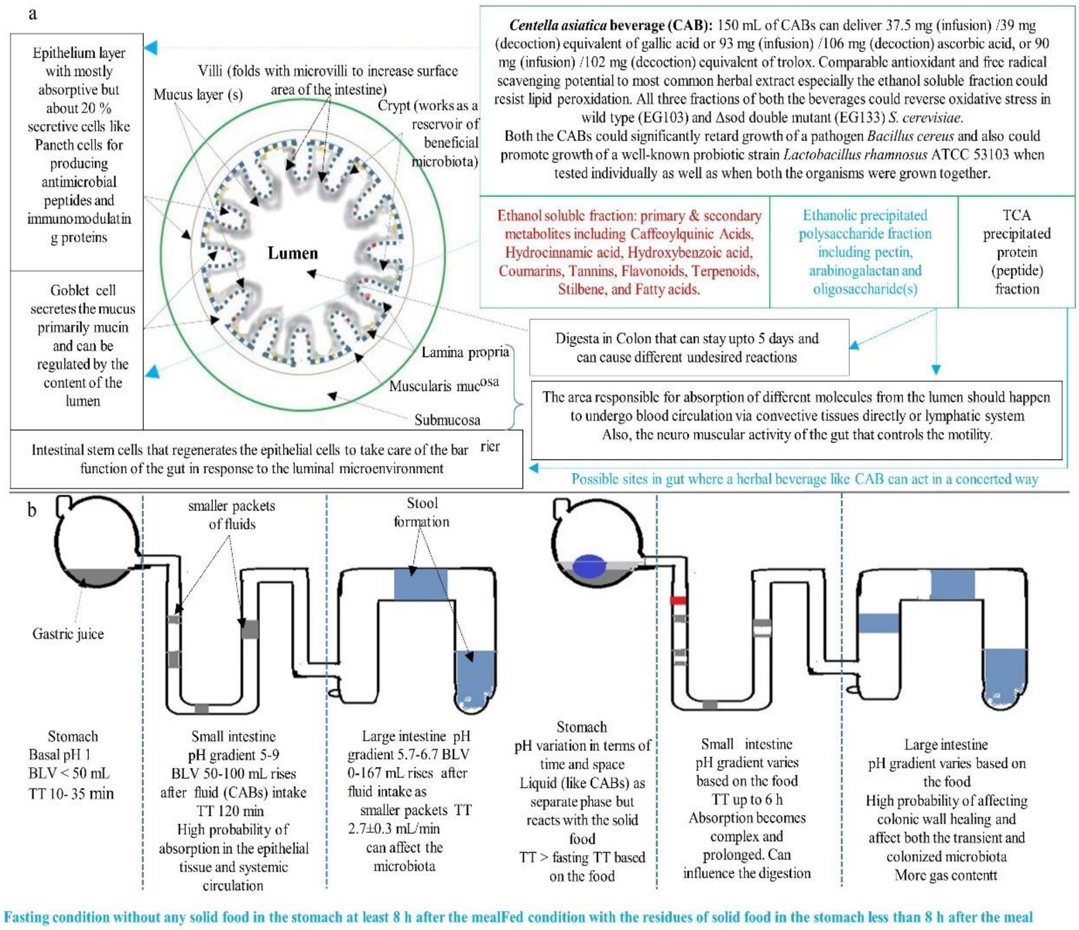

Fig. 7.5 (a) The possible sites of action for *Centella asiatica* herbal beverages. (b) The food regime to be considered for clinical studies of an herbal beverage for intestinal disorders like SIBO, IBS, IBD, colorectal cancer or enteric pathogen infection (Bourgonje et al., 2020; Mudie et al., 2014; Rein et al., 2013; Shimizu et al., 2010; Faizo et al., 2021). TT: Transit time; BLV: Basal liquid volume.

Most drug approval authorities demand the bioavailability studies for a new oral drug molecule to be studied by ingesting 150 – 240 mL of water (Mudie et al., 2014). As per the present study, 150 mL of the CABs can deliver maximum 2.4 g (infusion) or 2.7 g (decoction) of total soluble solids containing 1 g (infusion) /1.2 g (decoction) of polysaccharides, 0.6 g (infusion) /0.65 g (decoction) of small molecules including polyphenols and 0.3 g of protein. Also, the serving will deliver 37.5 mg (infusion) /39 mg (decoction) equivalent of gallic acid or 93 mg (infusion) /106 mg (decoction) ascorbic acid, or 90 mg (infusion) /102 mg (decoction) equivalent of trolox. The biggest advantage of such food system is they contain all water-soluble bioactive components so does not have the solubility hurdles like many of the synthetic drug molecules. How much of these components will be physiologically relevant that depends on multiple factors; the chemical changes the beverages can suffer during digestion and what spatio-temporal distribution it might assume after ingestion in the Gastrointestinal (GI) tract. Fig. 7.5b is a schematic depiction of some qualitative features of fluid distribution inside the Intestinal region. Beverages may have very short half-emptying time from the stomach as low as 8 minutes (for water) but actual time can extend depending on its composition and the time of intake whether in fasting or fed condition (within 8 h of a major meal) (Fig. 7.5b). After the gastric phase (i.e., partially digested proteins and carbohydrates) the chyme may release in the small intestine in small quanta for further digestion and absorption in the body. Bioavailability of dietary antioxidant molecules like polyphenols are low due to their low absorption rate between 0.3% to 43% (Rein et al., 2013). It is also unlikely the individual molecules (e.g., quercetin) can impart any significant metabolic effect in a distant organ like heart or liver at such low plasma concentration (usually reported values are <1 µM). However, in the lumen and in the intestine epithelial tissue they may have significant bioactivity due to much higher (mM range) concentration. It makes sense to analyse the possibility of interaction between the constituents of the beverage with three major components within the intestine; the epithelial cell lining including mucus layer, the intestinal microbiota and the digesta of the previous meal (especially in colon). Once the CABs cross pass gastric processing, firstly it may interact with the mucus layer and the intestinal epithelial tissue consisting of mainly absorptive cells (for absorption of digested products) but some important secretory cells like goblet cells (for secretion of mucus), paneth cells, enterocytes etc. The huge surface area (about 200 m^2) and complex anatomy consisting of circular folds, villi, and microvilli helps the small intestine to effectively absorb host of nutrients and other active molecules. However, this large surface area also makes the organ susceptible to toxins coming through any ingested material. The role of CABs in altering structure and epithelial absorption of these toxins cannot be ruled out (Shimizu, 2010). Often the required immune response of epithelial cells produces excess ROS that may lead to inflammation of the tissue itself. In this study, the oxidative stress relieving ability of the CABs in yeast cell suggest that the small molecule fraction can probably be absorbed by the epithelial tissues and they may restore antioxidant level perturbed by the ROS generated within the intestinal cells or the ROS present in the digested food in the lumen. Additionally, the oxidation of the lipids in cell membrane can distort the cell permeability and cause dysfunction of the cells (Faizo et al., 2021). The inhibitory ability of the CABs for lipid oxidation further supports the CABs might be useful in repairing the oxidative damage of the cell membranes of the epithelial cells. In fact, the mice model studies have revealed that ethanolic extract (similar to the ethanol soluble fraction of the CABs) of *Centella asiatica* could reverse the inflammation of the colon with decreasing activity of Myeloperoxidase (an indicator enzyme for inflammation) and increasing the expression of tight junction protein (to make the mucus layer more porous (Li et al., 2021).

The other important component with which the CAB constituents can interact is intestinal microbiota, especially in the colon phase. The constituents of the beverages can interact with a particular group of microorganisms directly or indirectly. In the GI tract, the redox-potential decreases from the stomach (+ 400 to + 500 mV) to the colon (-200 to -300 mV). In the small intestine, mostly facultative anaerobes such as Proteobacteria and Lacticaseibacillus survives whereas the large intestine is enriched with a large variety of anaerobes like Bacteroidales and Clostridiales. Million and Raoult, (2018) have proposed a Metagenomic Aerotolerant Predominance Index (MAPI) based on a metagenomics study of human faecal matter to predict microbial diversity and reason/remedies of *dysbiosis*.

In the present study, it was clear that CABs can support the growth of a probiotic *Lacticaseibacillus* species but restrict a well-known Intestinal pathogen *Bacillus cereus*, in a mixed culture. Moderately positive redox potential 42 -51 mV of the beverages can promote the favourable environment for a microbial species. Also, we have established the three different components (EF, EPPF and TPPF) of the CABs may work via different mechanisms to promote the microbial diversity since the whole beverages could better restrict the *B. cereus* strain than the EF and the effect was more in presence of *L. rhamnosus*. Aqueous extract of *Centella asiatica* has been already tested for many enteric pathogens with high efficiency (Wong & Ramli et al., 2021) but human trials for such antimicrobial activities are few. Gut microbiota can transform dietary polyphenols into de-glycosylated, oxidized and conjugate forms, which may further modulate the microbial population inside several niches of the small (and large) intestine (Corrêa et al., 2019). Since the spatial distribution of microbial population in the intestine is heterogeneous both axially as well as in transverse direction, the contact pattern between the ingested CAB constituents with these microbial pockets would play a great role in their interaction/modulation with specific species or groups of bacteria (Tropini et al., 2017).

Another hypothesis that can be put forward the (Fig. 7.5) constituents of CABs can alter the motility of the intestine depending on the intake time (fasting/fed condition). Li et al. (2021) have shown *Centella asiatica* enhances c-Kit expression in the colon and 5-HT in the brain to increase intestinal motility. The motility and water phase distribution are different in fasting or fed conditions and alters the unstirred water layer in the intestine (Fig. 7.5b). Therefore, to evaluate the effect of CABs on intestinal diseases not just the intrinsic reaction capacity and reaction rates but spatio-temporal biology of the gut needs to be considered.

7.4. Summary

Centella asiatica beverages contain a myriad of bioactive compounds where nine types of secondary metabolites were identified in this work. These small molecules along with a polymeric phase makes up the CABs. The decoction beverage could extract about 12% more soluble compounds than the infused one, but it was primarily rich in polysaccharide fraction. This study reported that in both CABs, more than 75% of reducing capacity was due to EF and about 3% was due to TPPF. The EPPF had a significant reducing power and radical scavenging ability in both CABs. When both CABs were tested for their oxidative stress reversal efficiency in a yeast model, EF showed maximum efficacy, but TPPF also showed significant oxidative stress reversal. Numerous interactions (non-covalent/covalent) can be anticipated between polyphenols with proteins and/or polysaccharides that impact organoleptic, nutritional or physiological attributes of herbal beverages.

In this work, the CABs and their EF showed a detrimental effect on the pathogen *B. cereus* and a beneficial impact on a probiotic strain *L. rhamnosus* when they were tested individually as well as when they were incubated and cultured together. Therefore, the findings suggest that CABs can potentially prevent both types of imbalances; antioxidant and antimicrobial are typical in many intestinal disorders. If a proper dose strategy is obtained for CABs considering the food regime and motility of GI tract, a promising preventive agent or at least a co-treatment strategy for intestinal diseases or enteric pathogen infection can be developed. The findings and analysis might help in designing mechanistic studies or clinical trials for evaluating the efficacy of herbal beverages like CABs against intestinal disorders.

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Chapter 8

Conclusion and Future Scope of Work

Chapter 8

8. Conclusion and future scope of work

This research work attempted to find out a dietary strategy to fight with lifestyle diseases of digestive tract that are generally linked with oxidative stress and gut microbiota imbalance. The first of objective of this doctoral work produces a repository of 310 leafy vegetables covering their culinary use and ancestral use in medicine. A theoretical analysis of polyphenols of IFCT enlisted 34 leafy vegetables revealed that herbal beverages could be a good way to deliver antioxidant rich polyphenols to the gut. In the second objective, two *Saccharomyces cerevisiae* strains EG103 (wild) and EG133 (sod double mutant) was proposed as a model to study the antioxidant capacity of different compounds or extracts. A standardized method of such assay was developed where resting cells can be stressed with H_2O_2 after exposing to the target molecules or extract. The change in viability and/or antioxidant markers can predict antioxidant capacity of the target molecules extracts.

The third objective of this research revealed that microwave drying was effective to dry four herbs called *Centella asiatica*, *Eryngium foetidum*, *Enhydra fluctuans*, *Marsilea minuta* with respect to their polyphenolic content and antioxidant properties compared to hot air drying. Though freeze drying was best in terms of sensory and antioxidant properties considering its cost and slow drying capacity microwave drying can be an alternative for preparing herbal/culinary powder from the herbs as well as to assess their polyphenols.

In the fourth objective, the four herbs were tested for preparation of herbal beverages, except *Centella asiatica* others did not qualify as a beverage due to their bitter taste and grassy flavor. However, *Centella asiatica* beverages (infusion and decoction) were less appealing to the sensory panel compared to the commercial green tea. 10% Khasi mandarin (*Citrus reticulata*) peel powder improved the sensory property of the *Centella asiatica* beverages. When tested in accelerated storage condition (under UV exposure, high temperature and high relative humidity), the dried herbs showed acceptable change in colour, moisture content, water activity, and product function (i.e., sensory and antioxidant properties). One of the major findings of this study was that the polymeric matrix of the beverages had a functional (antioxidant) role in such herbal beverages. Further, the antioxidant properties of the CABs were confirmed in yeast cell model. Another study showed *Centella asiatica* beverages had prebiotic function when tested with *Bacillus cereus* and *Lacticaseibacillus rhamnosus* mixed population as a gut pathogen-probiotic model system. So, it can be anticipated the developed herbal beverages may have a role in maintaining intestinal health by ROS balance and supporting microbial diversity.

In future scope of work human level trial focusing specific GI disorder/disease (like Inflammatory Bowel Disorder) can be done to recommend the *Centella asiatica* beverages (and their dosages) for prevention and cure of the particular disease/disorder.

Publications

Publications

Published articles in refereed journals

1. Bala, E., Singha, S., & Patra, S. (2019). Polysaccharides from leafy vegetables: chemical, nutritional and medicinal properties. *Natural polysaccharides in drug delivery and biomedical applications*, 567-588.
2. Bala E., Ali, N.A., Singha S., Mitra & S. (2019). Growth modelling and value addition of Roselle (*Hibiscus sabdariffa*) plant. *Journal of Agroecology and Natural Resource Management*, 6(4), pp:196-202.
3. Bala, E., Singha, S. (2023). Protective Role of Leafy Vegetables in Rural Areas: Critical Review of Biology and Processing. *In: Patra, S., Mitra, S., Singha, S., Kalita, P. (eds) Technologies for Rural Development. NERC 2022*. Springer, Singapore.
4. Bala, E., Patra, S., & Singha, S. (2023). Development of *Centella asiatica* beverages with potential antioxidant and prebiotic activity for maintaining intestinal health. *Food Bioscience*, 102751.

Submitted articles in refereed journals

1. Bala, E., Patra, S., & Singha, S. (2023). Flavour enhancement strategy for herbal beverages and kinetic modelling of their antioxidant and sensory properties in accelerated storage conditions. *International Journal of Gastronomy and Food Science*.

Communicated/Under Preparation

1. Bala, E., Patra, S., & Singha, S. Method development for assessing antioxidant potential of polyphenols in yeast model.
2. Bala, E., Patra, S., & Singha, S. Feasibility of microwave drying for analysis and processing of medicinal plants.
3. Bala, E., Patra, S., & Singha, S. Assessment of leafy vegetables and *in silico* study for their antioxidant and prebiotic activity for maintaining Intestinal Health.

National/International conferences

1. Indo-Japan Bilateral Symposium on Future Perspective of Bioresource Utilization in North-Eastern Region (IJBS 17), 2018 Guwahati, India;
   Poster presentation: Nutritional Mapping of Cabbage processing
2. International Symposium on Biodiversity and BioBnaking, Biodiverse 2018, organized by Centre for Environment, IIT Guwahati.
   Poster presentation: Process engineering of germination and malting of grains: a critical analysis
3. 15th World Rural Health Conference organized by Academy of Family Physicians of India, New Delhi.
   Oral presentation: Critical assessment of leafy vegetable consumption for rural nutritional security
4. Workshop: 20th INDO US Flow Cytometry Symposium cum Workshop organized by Bioscience and Bioengineering, IITG.
5. International conference on Recent Trends and Practices in Science, Technology, Management and Humanities for Sustainable Rural Development organized by Development of Rural Development, University of Science and Technology.
   Oral presentation: Growth modelling and value addition of Roselle (*Hibiscus sabdariffa*) plant.
6. 27th Indian Convention of Food Scientists and Technologists (ICFoST -2019) organized by AFST(I) and CSIR-CFTRI, Mysore at Tezpur University.
   Poster Presentation: Effect of enzymatic hydrolysis on *Marsilea minuta* on the bioavailability of flavonoids. Awarded: 1st prize
7. Training through online seminar by Anton Paar: Food Texture as it relates to Processing and Packaging on September 24, 2020.
8. TEQIP III: Recent Trends in Food Processing and Preservation organized by the Department of Food Process Engineering, NIT Rourkela, on 26th -27th September 2020.
9. International Conference on Emerging Techniques in Food Processing (ETFP) organized by Department of Food Processing Technology, Ghani Khan

Choudhury Institute of Engineering and Technology, Malda during March 25-26, 2021.

10. 2-Weeks Comprehensive Online Patent Information Course organized by Turnip Innovations and facilitated by Dr. Rahul Kapoor.

11. North-East Research Conclave on Sustainable Science and Technology, 2022.

    Oral Presentation: Protective role of leafy vegetables in rural areas: critical review of biology & processing.

12. International Seminar on Challenges & Opportunities of Medicinal Plants Based Industries in Bimstec Countries, 2022 organized by School for Agro and Rural Technology, IIT Guwahati.

    Poster presentation: The effect of ethnomedicine and scientific validation of *Centella asiatica* on metabolic diseases: A Systematic Review.

13. International Seminar on Medicinal Plant Production and advancement in herbal medicine, nutraceuticals, cosmetics and other herbal product formulation technologies (MedProRech) conducted at School for Agro and Rural Technology, IIT Guwahati.

    Workshop on Bioprospecting of herbal products in association with Guwahati Biotech Park: Training on advanced chromatographic techniques for herbal products.

14. 7th Northeast Green Summit, 2022.

Appendices

Appendix A

Appendix A.1 Documented List of leafy vegetables

Sl. No.	Regional Name	Scientific Name	Image	Classification	Distribution	Non nutritative Active Ingredients	Nutrient Composition(g/100g d.w.)	Health benefits	Consumption pattern	References
1.	**English:** Indian Pennywort **Assamese:** Baro Manimuni **Bengali:** Thanakuni, **Gujarati:** Brahmi, **Hindi:** Bheki **Kannada:** Brahmi-Soppu **Malayalam:** Kutakam **Manipuri:** Peruk, **Marathi:** Karivana, **Mizo:** Hnahbial, **Oriya:** Manduki, **Sanskrit:** Bhandi, **Tamil:** Kacappi, **Telugu:** Mandukaparni	*Centella asiatica*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Apiales Family Apiaceae Genus Centella Species asiatica	Asia	Triterpenoid(pent acyclic triterpenic acids and their respective glycosides, belonging to ursane or oleanane-type including asiatic acid, asiaticoside, madecassic acid, madecassoside, brahm oside, brahmic acid, brahminoside, thankuniside, isothankuniside, centelloside, madasiatic acid, centic acid, cenellic acid, betulinic acid, indocentic acid and aglycones (asiatic acid and madecassic acid), volatile oil(p-cymol, b-caryophyllene and farnesene), Flavonoids (quercetin and kaempferol, catechin, rutin and naringin)	Moisture(%) 87.2 Carbohydrate 4.8 Protein 1.7 Crude fiber 3.4 Crude Fat 0.7 Ash 2.3 Total carotene 0.04 Vitamin C 0.042 Calcium 0.176 Phosphorus 0.072 Iron 0.012 Energy(kcal) 320	Sedative, Anti-depressant, Anti-inflammatory activity, used in dysentery, fever, Anticancer activity, Brain stimulating effects, medicinal uses including treatment for tuberculosis and leprosy, arthritis and rheumatism, as a blood purifier, treatment of venous hypertension and microangiopathy, effectively applied for anti-bilharzial, antifertility, anti-herpes simplex virus, radioprotection, cosmetics, immunomodulatory and antagonizing liver fibrosis	edible raw, Dried leaves can be ground down into a fine powder for culinary use e.g. in smoothies, nut milks, raw cakes, raw crackers, etc.	Panda et al., 2015; James et al., 2009; Gupta et al., 2005; Perera et al., 2008
2.	**English:** Skunk Vine **Hindi:** Gandhaprasarani **Telugu:** Takkeda **Bengali:** Gandhabhaduliya **Marathi:** Hiran- Vel **Gujrati:** Gandhana **Tamil:** Pinarisangai **Assamese:** Bhedai Lota **Sanskrit:** Gandhadhadhya	*Paederia foetida*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Gentianales Family Rubiaceae Genus Paederia Species foetida	China, Japan, Korea, Indian subcontinent, Myanmar, Thailand, Cambodia, Laos, Vietnam, Malaysia, Indonesia, Philippines	Iridoid glucosides such as asperuloside, scandoside and paederoside; Monoterpenes such as linalool, hentriacontane, hentriacontanol, methylemercaptan, ceryl alcohol, palmitic acid, stigmasterol, campesterol, sitosterol and ursolic acid, Paederoside, Asperuloside, Scandoside (Glycoside), Paederine A and B (Alkaloid) Ursolic acid, oleanolic acid, arachidic acid (Organic Acid)	Moisture(%) 82.55 Crude Protein 2.57 Crude Fat 0.60 Carbohydrate 9.60 TDF 8.47 SDF 1.01 IDF 7.46 Vitamin C 0.271 Calcium 0.20 Natrium 0.027 Potassium 0.844 Iron 0.004	Ulcer reduction, removes bowel travels, antitumor-promoting activity, decoctions of the plant showed significant anti-inflammatory action against arthritis, anticancer activity against human epidermoid carcinoma of the nasopharynx, hepatoprotective potential, reduces abdominal pain, colic, cramps, flatulence and dysentery; and are also used for treating rheumatism and gout, to treat infertility and paralysis, used as a diuretic for inflammation of the urethra, used to treat swellings and bruises, applied for earache, ulcerations of the nose and swollen eyes, treating a swollen belly, distension, herpes or ringworm; and are used in antirheumatic baths, to increase testosterone levels	raw or cooked, eaten raw as a side-dish with rice, steamed and eaten; added to soups; or are mixed with various vegetables and spices,	Panda et al., 2015 Srianta et al.., 2012
3.	**English:** White Goosefoot **Assamese:** Bathuwa Shaak **Bengali:** Betho Shaak **Gujarati:** Bathavo **Hindi:** Bathuwa **Kannada:** Chakravarti **Malayalam:** Parippuchira **Manipuri:** Monshaobi **Marathi:** Chakvat **Oriya:** Bathua Sag **Sanskrit:** Vastuka **Tamil:** Chakravarthi Keerai **Telugu:** Pappukura	*Chenopodium album*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Amaranthaceae Genus Chenopodium Species album	Africa, Europe, Australasia, North America, Oceania	Kaempferol-3-O-(4-β-D-xylopyranosyl)-α-Lrhamnopyranoside-7-O-α-L-rhamno-pyranoside,3-O-(4-β-Dapiofuranosyl)-α-L-rhamnopyranoside-7-O-α-L-rhamnopyranoside, 3,7-di-O-α-L-rhamnopyranoside, 3-Oglucopyranoside and quercetin 3,7-di-O-β-D glucopyranoside, 3-O glucosylglucuronide, 3-O-α-L-rhamnopyranosyl-(1→6)-β-D-glucopyranoside, 3-O-β-D-glucopyranoside, β-carotene and lutein	Moisture (%) 92.8 Carbohydrates 7.0 Protein 29.2 Dietary fibre 36.5 Ash 16.7 Calcium 1.82 Potassium 4.90 Magnesium 1.38 Copper 0.001 Iron 0.012 Zinc 0.0023 Energy(KJ) 800	Laxative and anthelmintic, reduces skin problems, anti-inflammatory, anorexia, cough, dysentery, diarrhoea, oedema, piles, small worms, properties like antiphlogistic, antirheumatic, contraceptive, laxative, odontalgic, rheumatism, bug bites, sunstroke, urinary problems, have sedative and refrigerant properties, used the poultice leaves to soothe burns, prevents piles if taken often as cooked, fresh leaves are cooked as vegetable and eaten raw for Constipation, intestinal worms; Fresh leaves are grinded and mixed with water and sugar and this juice is taken orally for Jaundice, urinary disorder	used in dishes such as soups, curries, and paratha	Poonia et al., 2015 Panda et al., 2015; Abbas et al.i, 2013; Gqaza et al., 2013

4.	**English:** Elephant Foot Yam **Hindi:** Oal **Bengali:** Kachu Shak **Kannada:** Gandira **Malayalam:** Cinapavu, **Marathi:** Suran **Sanskrit:** Arsaghna **Tamil:** Anaittantu **Telugu:** Daradakandagadda **Urdu:** Zamin-Kand	*Amorphophallus paeoniifolius*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytin Class Magnoliopsida Superorder Lilianae Order Alismatales Family Araceae Genus Amorphophallus Species paeoniifolius	Africa, South Asia, Southeast Asia and the tropical Pacific islands	Omega 3 fatty acids, Diosgenin, amblyone, 3, 5-diacetylambulin	Moisture (%) 92.7 Carbohydrates 70.75 Protein 11.53 Crude Fibre 14.32 Crude Fat 3.52 Ash 6.9 Potassium 3.81 Magnesium 11.9 Phosphorus 0.453 Iron 34.02 Copper 3.26 Zinc 2.31 Manganese 0.66 Energy(kcal) 359.08	Reduces gastrointestinal disturbance, constipation and hemorroids, reduce the bad cholesterol, prevent the blood from clotting, maintain hormonal balance, provide relief from pre-menstrual syndrome, reduce irregular bowel movements & cure constipation, very low glycemic index, treatment for piles, cure for Hypertension	Cooked as curries, fry, boiling	Koni et al., 2017 Panda et al., 2015
5.	**English:** Water Morning Glory **Hindi:** Nali **Manipuri:** Kolamni **Marathi:** Nalichi-Bhaji **Tamil:** Sarkaraivalli **Telugu:** Tutikura **Kannada:** Chanthion **Bengali:** Kulmi Sag **Oriya:** Kalama Saga **Sanskrit:** Kalambi	*Ipomoea aquatic*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Solanales Family Convolvulaceae Genus Ipomoea Species aquatica	Africa, Asia, Southeast Pacific Island such as Vietnam, China, India, Hong Kong, and Taiwan	Nortropane alkaloids, calystegines B1, phenolic compounds N-cis-Feruloyltyramine, N-trans-feruloyltyramine, 3α,7β-O-D-di glycopyranosyl-dihydroquercetin and Isochlorogenic a, b, c	Moisture(%) 72.83 Carbohydrate 54.20 Crude protein 6.30 Crude Fiber 17.67 Crude Fat 11.0 Ash 10.83 Calcium 0.416 Magnesium 0.301 Manganese 0.002 Phosphorus 0.109 Potassium 5.46 Sodium 0.135 Iron 0.21 Energy(kcal) 300.94	Cancer, heart disease, stroke, high blood pressure, cataracts, osteoporosis and urinary tract infection. Alkaloids have analgesic effects, pain relievers and narcotics, protect the body against allergies, inflammation, free radicals, platelet aggregation, microbes, ulcers, hepatoxins, viruses and tumors	Fried, bolied, steamed and eaten with rice, used in soup	Thi et al, 2015 Panda et al., 2015; Umar et al., 2007
6.	**English:** Hygrophila **Bengali:** Kuliakhara **Hindi:** Talimakhana	*Asteracantha longifolia*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Angiospermae Subdivision Spermatophytina Class Equisetopsida Subclass Magnoliidae Superorder Asteranae Order Lamiales Family Acanthaceae Genus Asteracantha Species longifolia	Asia and Africa	Acetaldehyde, Methylhydrazone, 2-propanone, 7-O-B-D-glucopyronosyl-dihydromquercetin-3-O-a-D-glucopyranoside, β-sitosterol, lupeol	Moisture(%) 86.93 Protein 18.41 Crude Fiber 22.77 Calcium 1.17 Cobalt 0.09 Copper 0.07 Zinc 0.01 Sodium 0.09 Potassium 2.6 Magnesium 0.24 Phosphorus 0.51 Iron 0.041	Used in dropsy, rheumatism, jaundice and diseases of the urinogenital system, inflammations, hyperdipsia, strangury, jaundice and vesical calculi. It is also used in flatulence and dysentery. Leaves are haemopoictic, hepatoprotective, anti-inflammatory, antioxidant, analgesic, antidiabetic, stomachic, ophthalmic, diuretic and liver tonic. It is used in hepatic obstruction, jaundice, arthritis, rheumatism and diseases of urinogenital tract. It is useful in anemia and for treating blood diseases. It is used to lower the blood sugar level. It is used in burning sensation, fever and headaches. It is also used in diarrhoea and dysentery.	Cooked as vegetables	Chauhan et al., 2010 Amin et al., 2012 Rukshana et al., 2017 Sunita et al., 2008 Dash et al., 2012; Saple et al., 2021
7.	**English:** Bottle Gourd Greens **Hindi:** Lauki **Manipuri:** Khongdrum **Marathi:** Dudhi **Tamil:** Surakkai **Malayalam:** Pechura **Telugu:** Sorakkaya **Kannada:** Sorekayi **Bengali:** Lau Shak **Urdu:** Lauki **Gujarati:** Tumada **Sanskrit:** Tiktalabu	*Lagenaria siceraria*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Cucurbitales Family Cucurbitaceae Genus Lagenaria Species siceraria	India, China, Eurpoean countries, Brazil Hawaiian	4-C-glycosylflavone, 7-0-glucosyl-6-C-glucoside apigenin, 6-C-glucoside apigenin, 6-C-glucoside luteolin, and 7,4'-O-diglucosyl-6-C-glucoside, apigenin	Moisture(%) 83.7 Carbohydrate 8.3 Protein 4.4 Fibre 1.8 Fat 0.3 Calcium 0.560 Phosphorus 0.088 Iron 0.007 Energy(kcal) 43	Used for baldness, cardiotonic general tonic, dieretic, antihepatotoxic, analgesic, and anti-inflammatory, hypolipidemic, antihyperglycemic, immunomodulatory and antioxidant activities, used as a vermifuge purgative diuretic for increasing lactating women, jaundice, diabetes, ulcer, piles, colitis, insanity, hypertension, congestive cardiac failure (CCF), and skin diseases (Leaves with salt or coconut oil are often used as poultices for skin irritation, and tumours)	Cooked as vegetables and curry	Tyagi et al., 2012 Tirumalasetty et al., 2014 Prajapati et al., 2010; Lim et al., 2011

8.	**English:** Chinese Spinach **Assamese:** Bishalya Karani **Bengali:** Dengua **Hindi:** Lal Sag **Kannada:** Dantina Soppu **Manipuri:** Chengkruk Tingkhang **Marathi:** Ranmaath **Oriya:** Bajjisag **Sanskrit:** Alpamarisa **Tamil:** Thandukkeerai **Telugu:** Thotakoora	*Amaranthus gangeticus/ tricolor*		Kingdom Plantae Subkingdom Tracheobionta Superdivision Spermatophyta Division Magnoliophyta Class Magnoliopsida Subclass Caryophyllidae Order Caryophyllales Family Amaranthaceae Genus Amaranthus Species gangeticus	Asia, Africa, Mediterr-anean	Betacyanins and betaxanthins, Isoqercetin and rutin, Salicylic acid, syringic acid, gallic acid, vanilic acid, ferulic acid, p-coumaric acid and sinapic acid were the most common phenolic acids, α,β,γ tocopherols, phytosterols	Moisture(%) 92.65 Carbohydrates 5.21 Crude Protein 0.56 Ash 0.62 Crude Fiber 0.92 Crude Fat 0.12 Calcium 0.003 Potassium 0.123 Sodium 0.2	Astringent, diuretic, improves vision, strength liver, Provides energy, Improves digestion, Reduces bad cholesterol, Good for anaemic patients, Decreases risk of cardiovascular disease, controls hypertension, contains amino acids which fight against free radicals that result in aging, boost the body's immune system, higher levels of calcium which develops bone strength, cures arthritis, gout, and other inflammation-related issues, treating premature greying, treating sore throat, treating mouth sores-mouth ulcers	Cooked as vegetables	Khanam et al., 2013 Shukla et al., 2006 Sheela et al, 2004 Amin et al., 2015
9.	**English:** Ivy Gourd **Hindi:** Kunduru **Marathi:** Tondli **Tamil:** Kovai **Malayalam:** Kova **Telugu:** Donda Kaya **Kannada:** Tondikay **Bengali:** Telakucha **Oriya:** Ban-Kundri **Sanskrit:** Bimbika	*Coccinia grandis*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Cucurbitales Family Cucurbitaceae Genus Coccinia Species grandi	tropical Africa from Senegal to Somalia; Arabian Peninsula to India, Sri Lanka, China, Indo-China to Indonesia, New Guinea, Australia	Cephalandrol, lupeol, sigma-7-en-3- one, taraxerone and taraxerol, Bcarotene, lycopene, cryptoxanthin, β- Amyrin acetate, β-Sitosterol, β- Carotene, Cucurbitacin B, Lycopene	Moisture(%) 91 Carbohydrates 3.9 Crude Fibre 2.7 Crude Protein 3.6 Crude Fat 0.2 Ash 1.4 β carotene 4.036 Vitamin A 0.673 Thiamin 0.0001 Vitamin C 0.013 Calcium 0.057 Zinc 0.0005 Iron 0.001 Energy(Kcal) 32	Good for liver, effective against bilious affections, as an appetizer, taken after stomach upsets, Anti-inflammatory, analgesic and antipyretic activity, for treatment of number of ailments including diabetes, wounds, ulcers, inflammation, in eruptions of skin, fever, asthma and cough, antinociceptive, antidiabetic, hypolipidemic, anti-bacterial, and anti-tussive activities	Cooked as vegetables, added to soups	J et al., 2017 Attanayake et al., 2016 Pekamwar et al., 2013 http://tropical.theferns.info/viewtropical.php?id=Coccinia+grandis; Lim et al., 2011
10.	**English:** Dwarf Waterclove **Bengali:** Sushni **Hindi:** Chopatiya **Tamil:** Aalaik Keerai	*Marsilea quadrifolia*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Polypodiophytina Class Polypodiopsida Subclass Polypodiidae Order Salviniales Family Marsileaceae Genus Marsilea Species quadrifolia	Central and southerm Europe, Caucasia, western Siberia, Afghanistan, Southwest India, China, Japan, North Amirica	β-carotene, Thiaminase, L – arginine monohydrochloride; DL-β Phenylalanine, kaempferol 3-O-(2″-O-E-caffeoyl)-β-d-glucopyranoside, kaempferol 3-O-(3″-O-E-caffeoyl)-α-l-arabinopyranoside, 4-methy-3′-hydroxypsilotinin and (±)-(E)-4b-methoxy-3b,5b-dihydroxyscirpusin A, phytoestrogens, Hexadecanoic acid, ethyl ester, Phytol, 9,12-Octadecadienoic acid (Z,Z)-, Marsilin (1-triacontanol-cerotate), 3-hydoxy-tri-acontan-11-one,hentriacontan-6-ol, methylamine, beta-sitosterol, marsileagenin A, flavonol-O-mono-and-diglycoside, C-glucoylflavones and Cglucosylxanthones	Moisture(%) 90.8 Crude Protein 35 Ash 8.9 Beta Carotene 0.003 Calcium 0.005 Sodium 0.001 Potassium 0.002 Phosphorus 0.005	Treat snakebite and applied to abscesses, bipolar disorder treatment, Dysphasia, Phlegm, strangury, bronchitis, eye diseases, piles, insomnia, anti-inflammatory, diuretic, depurative, febrifuge and refrigerant, antioxidant, antinociceptive, and anti-inflammatory	Cooked as vegetables	https://herbpathy.com/Uses-and-Benefits-of-Marsilea-Quadrifolia-Cid5865 Ashwini et al., 2012; Nahar et al., 2011; Soni et al., 2012 Mandal et al., 2012; Zhang et al., 2016; K et al., 2015
11.	**English:** Green Taro **Hindi:** Arvi **Manipuri:** Pan **Marathi:** Ran Aalu **Tamil:** Sempu **Malayalam:** Chempu **Telugu:** Chamadumpa **Kannada:** Kesavedantu **Bengali:** Alti Kachu **Oriya:** Jongal Saaru **Mizo:** Bal **Sanskrit:** Aaluki,	*Colocasia esculenta*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Lilianae Order Alismatales Family Araceae Genus Colocasia Species esculenta	Bangladesh, India, Brazil, China, Taiwan, Egypt, Europe, East Africa, Greece, Spain, Hawaii	Thiamine, riboflavin, niacin, oxalic acid, calcium oxalate, anthocyanins, cryptoxanthin, beta-carotene	Moisture(%) 83 Carbohydrate 2.3 Crude Fiber 2.2 Ash 9 Crude Protein 2.9 Crude Fat 0.6 Calcium 0.0002 Potassium 0.0004 Sodium 0.0001 Magnesium 0.0002 Energy(Kcal) 20.3	Anticancer, antihyperlipidemic/ antihypercholesterolaemic, anxiolytic, wound healing, antimelanogenic, anti-inflammatory, probiotic, antihypertensive, antidiabetic, antioxidant, hepatoprotective, anti-inflammatory, antimicrobial, anti-helminthic, proliferative and hypolipidaemic properties, Reduce Symptoms of Rheumatoid Arthritis, Blood Pressure and Heart Health, Immune System Health, Cramps, Digestive Health, Enhances Learning, Helps Maintain Dental Health, Boosts Vision, Thickens Hair, Diabetes, Skin Health, Prevent Bone Loss, Circulation Stimulation	Cooked as vegetables	Nutritional Freshwater Life By Ramasamy Santhanam https://www.healthbenefitstimes.com/taro/ Pereira et al., 2015 Kumar et al, 2017; Azubuike et al., 2018

12.	**English:** Water Sprite, Indian Fern, Sumatra Fern, Oriental Water Fern	*Ceratopteris thalictroides*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Polypodiophytina Class Polypodiopsida Subclass Polypodiidae Order Polypodiales Family Pteridaceae Genus Ceratopteris Species thalictroides	Asia, Australia, America	Ascorbic acid, α and γ-tocopherol, thiamine,	Moisture(%) 86.61 Carbohydrate 54.34 Fiber 5.54 Protein 13.36 Fat 3.21 Ash 10.18 Vitamin C 0.006 Calcium 0.434 Sodium 0.085 Potassium 1.341 Phosphorus 0.215 Magnesium 0.107 Manganese 0.006 Iron 0.0584 Zinc 0.003 Copper 0.001 Energy(kCal) 299.69	Used as styptic to stop bleeding, as medicine for foetal toxin and accumulation of phlegm, used as poultice against skin problems, highly effective against acid reflux, high blood pressure, bleeding problem, high blood pressure, carbuncle, gastric catarrh, styptic, poultice, prevents tooth decay, heart disease, fight against bowel issue, stroke, digestive health	Cooked as vegetables	Nutritional Freshwater Life By Ramasamy Santhanam https://herbpathy.com/Uses-and-Benefits-of-Water-Sprite-Cid5413; Adedeji Olayinka Adebiyi et al., 2019
13.	**English:** Vegetable Fern **Bengali:** Dhenkir Shaak **Assamese:** Dhekia	*Diplazium esculentum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Polypodiophytina Class Polypodiopsida Subclass Polypodiidae Order Polypodiales Family Woodsiaceae Genus Diplazium Species esculentum	Asia, Oceania	alpha-glucosidase, β-carotene, vitamin E, alpha-tocopherol, Beta-carotene: low; vitamin E: medium; riboflavin: low; ascorbic acid: low; calcium: low; iron: low; protein: 3.2%, antioxidative activities higher than alpha-tocopherol.	Moisture(%) 91.82 ± 0.43 Protein 0.87 ± 0.004 Fiber 0.72 ± 0.05	Good appetizer and effective against constipation and leprosy, coronary heart disease, neurodegenerative disorders, diabetes, arthritis, inflammatory diseases, lung damage, aging, and cancer, antimalarial effects, treat jaundice, constipation, earache, to treat fever, measles and dermatitis, treatment of skin infections such as dermatitis and measles	Tender leaves are cooked with fruit of Dilleniaindica and fish and taken as vegetable; Whole plant is used as insecticides	https://www.revolvy.com/main/index.php?s=Diplazium%20esculentum Mitra et al, 2015 Tongco et al., 2014
14.	**English:** Tapioca **Hindi:** Shakarkand **Manipuri:** Umangra **Marathi:** Prochugaali Chine **Tamil:** Maravallikkilanku, **Malayalam:** Kollikkilannu, **Telugu:** Karrapendalamu **Kannada:** Kanagale **Oriya:** Kaato Konda **Mizo:** Pangbal **Sanskrit:** Tarukandah, **Tangkhul:** Thingpai	*Manihot Esculenta Crantz*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Malpighiales Family Euphorbiaceae Genus Manihot Species esculenta Crantz	Indonesia, Brazil, Nigeria, Thailand, India	Anthocyanins, identified 3-rutinosides of kaempferol and quercetin; the cyanogenic glycosides, lotaustralin and linamarin	Moisture(%) 89.1±0.6 Carbohydrate 45.8±0.9 Fibre 8.3±0.8 Protein 38.1±1.5 Fat 3.8±0.5 Calcium 0.43±0.006 Potassium 2.26±0.03 Magnesium 0.37±0.004 Phosphorus 0.23±0.004 Sodium 0.08±0.002	Potential therapeutic role related to some cardiovascular diseases, cancer treatment, inhibition of certain types of virus including Human Immunodeficiency Virus type 1 (HIV-1) and improvement of visual acuity, protect against oxidative damages, controlling oxidative stress during pregnancies complicated by intrauterine growth retardation	Leaves are cooked as vegetables	Suresh et al, 2011 Ravindranet al., 1988
15.	**English:** Indian Patchouli **Assamese:** Xukloti **Gujarati:** Sugandhi Panadi **Konkani:** Paat **Marathi:** Pach **Tamil:** Katir-P-Paccai	*Pogostemon cablin*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Lamiaceae Genus Pogostemon Species cablin	Asia	Patchouli alcohol, α-patchoulene, β-patchoulene, α-bulnesene, seychellene, norpatchoulenol, pogostone, eugenol and pogostol, Limonene, Spathulenol, α- and β-Selinene, Heptanal, Longipinanol, Myrtenol, Nonanal, Norpatchoulenol, 1-Octen-3-ol, Epifriedelinol, cis-Farnesol, 7-Epi-α-selinene, Globulol, Aciphyllene, Alloaromadendrene, (+)-Camphene, (−)-Camphor, δ-Cardinene, α and β-Caryophyllene, Caryophyllene oxide, Elemol, Epiglobulol, Eucalyptol, α-Elemenone, Valencene	Moisture(%) 85 Carbohydrate 265.6 Protein 24.54	Treat colds, headaches, fever, nausea, vomiting, diarrhea, abdominal pain, insect and snake bites. In aromatherapy, patchouli oil is used to relieve depression, stress, calm nerves, control appetite and to improve sexual interest, activities such as antioxidant, analgesic, anti-inflammatory, antiplatelet, antithrombotic, aphrodisiac, antidepressant, antimutagenic, antiemetic, fibrinolytic and cytotoxic activities	Tender leaves are cooked	Swamy et al., 2015 Beek et al., 2017

16.	**English**: Chameleon Plant, Lizard Tail, Heartleaf, Fishwort **Assamese:** Musundari, **Hindi:** Simdalu **Khasi:** Ja Mardoh **Manipuri:** Tokningkhok **Nepali:** Gane **Tangkhul:** Ngayung	*Houttuynia cordata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Magnolianae Order Piperales Family Saururaceae Genus Houttuynia Species cordata	Japan, Korea, southern China, and Southeast Asia	Quercetin, Rutin, Hyperin, Afzelin, Isoquercitrin, Apigenin, Quercetin-3-O-β-D-galactoside-7-O-β-D-glucoside, Kaempferol 3-O-[α-L-rhamnopyranosyl-(1→6)-β-D-glucopyranoside], Quercetin 3-O-α-L-rhamnopyranosyl-7-O-β-D-glucopyranoside, Quercetin hexoside, Kaempferol, Isorhamnetin, Phloridzin, Avicularin, Protocatechuic acid, Chlorogenic acid, Vanillic acid, p-Hydroxy-benzoic acid methyl ester, Chlorogenic acid methyl ester, Caffeic acid, Quinic acid, Catechin, Procyanidin B, Neochlorogenic acid, Cryptochlorogenic acid	Moisture(%) 67.170±0.050 Carbohydrate 24.551±0.106 Fibre 4.610±0.019 Protein 5.444±0.040 Calcium 55.427±0.932 Magnesium 49.040±0.560 Manganese 0.079±0.008 Copper 0.155±0.034 Zinc 0.108±0.007 Iron 1.883±0.027	Against allergies, asthma, bacterial infection, removes free radicals, strong antioxidant properties, such as cancer, coronary heart disese diabetes, and infection, treat, the measles, dysentery and gonorrhoea, antipyretics, diuretics, pus removal, constipation, colds, detoxification, swelling, hypertension, tuberculosis and para-nasal sinusitis	Cooked as vegetable	Fu et al., 2013 Kumar et al., 2014 Rathi et al., 2013 Dai et al., 2015 Oh et al., 2015 Ahongshangbam et al., 2017
17.	**English:** Ground Cherry **Hindi:** Rasbhari **Marathi:** Chirboti **Tamil:** Kupanti **Malayalam:** Notinotta **Telugu:** Kupanti **Kannada:** Gadde Hannu **Bengali:** Bantepariya **Gujarati:** Popti	*Physalis philadelphica*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Solanales Family Solanaceae Genus Physalis Species philadelphica	America, Mexico, India	α-Carotene, β-Carotene, Lutein-zeaxanthin, Lycopene	Moisture(%) 92 Carbohydrates 5.84 Dietary Fiber 1.9 Protein 0.96 Calcium(mg) 7 Copper 0.079 Iron 0.62 Magnesium 20 Manganese 0.153 Phosphorus 39 Zinc 0.22	Treat constipation, gas & gastritis and bloating, beneficial for colon health and ulcers, Diabetes control, Prevents cancer, boosts the immune system, Good for weight loss, Improves vision, Increases the energy level, low down blood pressure, play an important role against melanomas, and cancers like thyroid, breast, pancreas and oesophagus, treatment of gastrointestinal disorders in Guatemala[1] and for treating leprosy, purifying the blood, and as a poison antidote	Cooked as vegetables	NingSu et al., 2002 http://www.gyanunlimited.com/health/amazing-health-benefits-and-medicinal-uses-of-tomatillo-physalis-philadelphica/10928/
18.	**English:** Black/True Mustard **Bengali:** Kalo Rai Shak **Hindi:** Banarasi Rai Sag **Malayalam:** Kadugu **Telugu:** Avalu **Kannada:** Sasive	*Brassica nigra*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Brassicales Family Brassicaceae Genus Brassica Species nigra	North Africa, Asia, Europe	A-amyrin; L-proline, 5-oxo-, methyl ester; 1,2-Benzenedicarboxylic acid, diisooctyl ester; 1,4-dichloro-Benzene, oleic acid, sinigrin, ferulic acid, glycoside, stearic acid, isothiocyanate, sinapinic acid, vanillic acid, protocatechuic acid, gluconasturtiin, P coumaric acid	Moisture(%) 95.84 Carbohydrate 5.6 Fiber 1.1 Protein 3 Sodium(mg) 32 Phosphorus 52 Calcium 183 Iron 3	Treating alopecia, epilepsy, snakebite, and toothache, treat carcinoma, throat tumours, and imposthumes, rheumatism, reduces allergy, arthritis, asthma, Bronchitis, Scurvy, Heart Disese, Fatigue, Diabetes, Cough, Phlegm, Lung Cancer, Ringworm, small pox, fever, cold, Cramps, headache, migraine, pneumonia, scorpion sting, sciatica, joint pain, menses scanty, piles, baldness, hiccups	Raw or cooked as vegetables	Rajamurugan et al, 2012 http://www.mpbd.info/plants/brassica-nigra.php https://herbpathy.com/Uses-and-Benefits-of-Black-Mustard-Cid108
19.	**English:** Sesban **Bengali:** Dhaincha **Hindi:** Jayanti **Kannada:** Jeenangi **Oriya:** Thaitimul **Marathi:** Shewarie **Telugu:** Samintha **Sanskrit:** Jayantika **Tangkhul:**Chuchurangmei **Tamil:** Chittakatti **Tribal:** Dhoineyekeng (Khumi)	*Sesbania sesban*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Fabales Family Fabaceae Genus Sesbania Species sesban	Africa, Australia, Hawaii, and Asia	Cycloartenol (9,19 cyclo-9β-lanost-24 – en-3β-), stigmasta-5, 22-dien3-ol, acetate (3β), stigmasterol, campesterol, squalene, phytol, steroidal and triterpenoid aglycone, diosgenin	Moisture(%) 88 Fibre 12.9 Protein 2.44 Calcium 1.59 Phosphorus 0.33 Sodium 0.03 Magnesium 0.35	Significant anti-implantation activity, astringent, anti-inflammatory, antimicrobial, antifertility, demulcent and purgative	Raw leaves added to singju, fruit cooked eaten as eromba	DANDE et al., 2013 Dande et al., 2014 Mythili et al., 2013 https://www.feedipedia.org/node/253

20.	**English:** Malabar Spinach **Bengali:** Pui Shak In **Gujarati:** Poi Ni Bhaji **Kannada:** Basale Soppu In **Konkani:** Valchi Bhaji **Malayalam:** Vallicheera **Marathi:** Mayalu **Odia:** Poi Saaga **Sinhalese:** Vel Niviti **Tamil:** Kodip Pasali **Telugu:** Bachhali **Tulu:** Basale	*Basella alba L. var. rubra (L.) stewart*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Basellaceae Genus Basella Species alba	China, tropical Africa, Brazil, Belize, Colombia, West Indies, Fiji and French Polynesia	betacyanin, oxalic acid ,flavonoid like acacetin, 4,7-dihydroxy kempferol and 4'-methoxyisovitexin, phenolic acids like vanilla, syringic and ferulic acid, Rutin, Quercetin, Scopoletin, Coumarin, β-xanthin and β-cyanin pigments and Caffeic, Homo-protocatechuic-, Chlorogenic, trans- and cis-p-coumaric, p-hydroxybenzoic, phloretic, trans- and cis-sinapic, cinnamic-acids; and the fruit consists of β-cyanin, gomphrenin I, gomphrenin II, and gomphrenin III	Moisture(%) 93 Carbohydrates 3.0 Fiber 0.9 Protein 2.0 Fat 0.3 Calcium (mg) 128 Phosphorous 40 Iron 4.9	Demulcent, a diuretic and an emollient action, reduce fever and neutralize poison, significantly increased red blood cell count, white blood cell count, packed cell volume, haemoglobin concentration and platelet count, daily diet may reduce anemia and maintain good health, directly stimulated testosterone, estradiol and aromatase mRNA levels in isolated Leydig cells, significant membrane stabilizing action on human red blood cell membrane, Anti ulcer activity, CNS depressant activity, Cytotoxic and antibacterial activity, Antioxidant activity, Wound healing activity, Nephroprotective effect,	Cooked as vegetables	Kumar et al., 2013 Singh et al., 2016 Suganthi et al.,2015 Vimala et al., 2014 Adegoke et al., 2017 https://www.nutrition-and-you.com/basella.html
21.	**English:** Giant Taro **Hindi:** Mankanda **Kannada:** Baalaraaksha **Bengali:** Mankachu **Manipuri:** Hongoo **Marathi:** Kaasaalu **Sanskrit:** Alooka, **Tamil:** Merukan **Tangkhul:** Paankhot	*Alocasia acuminata Schott*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Lilianae Order Alismatales Family Araceae Genus Alocasia Species acuminata Schott	Asia	cyanogenetic glycosides, alocasin, gallic acid, mallic acid, ascorbic acid, succinic acid, betalectins, triglochinin, isotriglochinin, β-glucosidases, phytosterol like compound, ceramide, ergosterol , campesterol, stigmasterol, β- sitosterol and clionasterol	Moisture(%) 80 Crude fiber 1.40 Protein 26.8 Calcium 0.12 Phosphorus 0.09	Antidiarrheal, antifungal, anti-inflammatory, anthelmintic, antihyperglycemic, laxative antimicrobial, antinociceptive, diuretic, antitumour, hepatoprotective, hepatorenal, antioxidant activities	tender leaf and caudex are eaten cooked with acidic fruit	Singh et al., 2017 Mubeen et al., 2012 Srivastava et al., 2012 Karim et al., 2015
22.	**English:** Spinach Dock, Garden Sorrel **Hindi:** Chuk **Kannada:** Pundi **Nepali:** Amile Ghans **Sanskrit:** Chutrika **Telugu:** Chukkakura	*Rumex acetosa*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Polygonaceae Genus Rumex Species acetosella	northern Mediter-ranean, Central Asia, North America.	flavan-3-ols,proanthocyanidins, oxalic acid, 2''-O-Acetylisoorientin, 2'',6''-Di-O-acetylisoorientin	Moisture(%) 87.47±0.42 Ash 10.18 ± 0.01 Crude protein 3.70 ± 0.19 Crude lipid 9.78 ± 0.75 Crude fiber 12.53 ± 0.01 Carbohydrate 63.81 ± 0.18 Energy value 350.66 ± 0.27 (Kcal)	Treat constipation, bronchitis, scurvy, arthritis, gastric ulcer, cramp, diarrhea, sore throat and water retention while seeds are used as astringent in hemorrhages, presence of anticancer, anti-ulcerogenic and anti-inflammatory activities, treat emesis and gastrointestinal ailments	garnish, flavouring agent, a salad green, and a curdling agent for cheese,	http://eol.org/pages/485385/overview; Kathi J. Kemper et al., 1999 https://www.henriettesherb.com/eclectic/kings/rumex-acet.html Shmuel Yannai, Idris et al., 2011
23.	**English:** Nalta Jute **Hindi:** Pat-Sag **Manipuri:** Limon **Marathi:** Motichhunchh **Tamil:** Punaku, **Telugu:** Parinta **Bengali:** Bhungipat **Oriya:** Kaunria **Sanskrit:** Mahachanchu	*Corchorus olitorius*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Malvales Family Malvaceae Genus Corchorus L. Species olitorius	Africa and Asia	phytol (3,7,11,15-tetramethyl-2-hexadecen-1-ol) and monogalactosyldiacylglycerol (1,2-di-O--linolenoyl-3-O--D-galactopyranosyl-sn-glycerol), α-tocopherol, caffeic acid, chlorogenic acid and isorhamnetin, 3,5-dicaffeoylquinic acid, quercetin 3-galactoside, quercetin 3-glucoside, quercetin 3-(6-malonylglucoside), and quercetin 3-(6-malonylgalactoside)	Moisture(%) 86.1 Carbohydrate 6.34 Dietary Fiber 1.7 Protein 3.2 Calcium(mg) 184 Magnesium 54 Phosphorus 63 Potassium 478 Sodium 10 Zinc 0.69 Iron 2.73 Copper 0.222 Manganese 0.107 Selenium(μg) 0.8	Treats ascites, pain, piles, and tumours, used for cystitis, dysuria, fever, and gonorrhoea. The cold infusion is said to restore the appetite and strength, demulcent, deobstruent, diuretic, lactagogue, purgative, and tonic, folk remedy for aches and pains, enteritis, fever, pectoral pains	Cooked as vegetables	https://www.healthbenefitstimes.com/jute/ Furumoto et al., 2002 Oboh et al., 2012 Azuma et al., 1999 Batran et al., 2013

24.	**English:** Common Leucas **Hindi:** Chhota Halkusa, **Manipuri:** Mayanglambum **Marathi:** Tamba **Tamil:** Thumbai **Malayalam:** Tumba **Telugu:** Tummachettu **Kannada:** Tumbe Guda **Bengali:** Ghal Ghase **Oriya:** Bhutamari **Konkani:** Tumbo **Sanskrit:** Dronapushpi **Nepali:** Gummaa	*Leucas aspera*		Kingdom Plantae Subkingdom Tracheobionta Superdivision Spermatophyta Division Angiosperma Class Dicotyledonae Subclass Gamopetalae Series Bicarpellatae Order Tubiflorae Family Labiatae Genus Leucas Species aspera	Africa, E. Asia, China, Pakistan, India, Nepal, Bangladesh, Myanmar, Thailand, Vietnam, Malaysia, Indonesia, Philippines to New Guinea	stylopine, protopine, fumaritine, fumaricine, fumarophycine, fumariline, fumarofine, galactose, oleanolic acid, ursolic acid and Beta-sitosterol . Aerial parts contain alpha - sitosterol, beta-sitosterol. Shoots contain long chain compounds -l-hydroxytetratriacontan-4-one and 32-methyl- tetratriacontan-8-ol, dotriacontanol, 9, 12, 15-Octadecatrienoic acid, methyl ester (z, z, z), n-Hexadecanoic acid, Squalene and 1, 2-Benzenedicarboxylic acid, bis (2-methylpropyl) ester	Moisture (%) 12.51-26.7 Crude protein 8.65-48.09 Crude fibre 2.69-12.66 Crude fat 2.65-18.10 Ash 3.26-11.45 Carbohydrate 16.79-59.38 Calcium 40 Iron 2.19 Phosphorous 12	Antiviral, anti-fungal, antioxidant, anti-inflammatory, antiallergenic, antithrombic, anticarcinogenic, hepatoprotective, and cytotoxic activities, beneficial effects on some diseases involving lipid peroxidation, rheumatism, psoriasis and chronic skin eruptions, traditionally as an antipyretic and insecticide	cooked and eaten as a pot herb	Das et al., 2010 Latha et al., 2013http://tropical.theferns.info/viewtropical.php?Id=Leucas+aspera Singh et al., 2016 Anandan et al., 2012 Kumar et al., 2016, V et al., 2016 Srinivasan et al., 2014
25.	**English:** Spreading Hog-Weed **Assamese:** Pananua **Bengali:** Gadapushpa **Gujarati:** Satodi **Hindi:** Shothagni **Kannada:** Komme **Malayalam:** Tharana **Marathi:** Punarnava **Sanskrit:** Shothagni **Tamil:** Mookkaratti **Telugu:** Atakamamidi	*Boerhavia diffusa*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Nyctaginaceae Genus Boerhavia Species diffusa	Africa, Asia, North America, South America,	Punarnavoside, Borhaavone, 2'-O-Methyl abronisoflavone, Quercetin, kaempferol, 3,4-Dihydroxy-5-methoxycinnamoyl rhamnoside, Quercetin 3-O-rhamnosyl $(1 \rightarrow 6)$ galactoside (quercetin 3-O-robinobioside), Eupalitin 3-O-galactosyl $(1 \rightarrow 2)$ glucoside, Kaempferol 3-O-robinobioside, Eupalitin-3-O-β-D-galactopyranoside, trans-caftaric acid, Boerhavisterol	Moisture (%) 86.91 Carbohydrates 30.90 Proteins 15.20 Fat 1.61 Magnesium(mg) 142.9 Sodium 75.9 Potassium 52.7 Lead 1.25 Copper 3.9 Cadmium 0.28	Reduces diuretic, jaundice, Wound healing, Insect/scorpion/snake bite, Ophthalmia, Skin disorders, Rheumatism, Cardiovascular problems, Inflammationedema/arthritis, anticonvulsant, diuretic, anti-inflammatory, antifibrinolytic, antibacterial, anti-hepatotoxic, anthelmintic, febrifuge, anti-leprosy, antiasthmatic, antiurethritis, antilymphoproliferative, antimetastatic, immunosuppressive, antidiabetic, antioxidant, immune-modulation, hepatoprotective, anti-nociceptive, nephroprotective, bacteria induced ulcer & diarrhea and antiurolithiatic activities	Cooked and eaten as curry	Mishra et al., 2014 Beegum et al., 2014 Nayak et al, 2017 R et al., 2017
26.	**English:** Spinach **Sanskrit:** Chhurika **Hindi:** Paalak **Tamil:** Pasali **Kashmiri:** Palakh **Bengali:** Palang	*Spinacia oleracea*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Amaranthaceae Genus Spinacia Species oleracea	Asia, Europe	omega-3 fatty acids, coumarins, anthroquinones, querecetin; myricetin; kampeferol; apigenin; luteolin; patuletin; spinacetin; jaceidin; 5,4'-dihydroxy-3.3'-dimethoxy-6:7-methylene dioxyflavone-4'-glu-curonide, 5,4'-dihydroxi-3,3'-dimithoxi-6,7-methylene-dioxiflavone ($C_{18}H_{14}O_8$.); 3,5,7,3',4'pentahydroxi-6-methoxiflavone; lutein, β-carotene, violaxanthin and 9'-(Z)-neoxanhin; monogalactosyl diacylglycerol, digalactosyl diacylglycerol, and sulfoquinovosyl diacylglycerol; alpha- and beta-basrubrins	Moisture (%) 94.04 Carbohydrate 40 Fibre 8 Protein 28 Fat 5.5 Calcium(mg) 800 Phosphorus 415 Sodium 650 Iron 80 Potassium 4500	Urinary calculi, treatment of difficulty in breathing, inflammation of liver and lungs, leucorrhoea, useful in diseases of blood and brain, asthma, leprosy, biliousness, useful in urinary concretion, inflammation of the lungs and the bowels, sore throat, pain in joints, thirst, lumbago, cold and sneezing, sore eye, ring worm scabies, leucoderma, soalding urine, arrest vomiting, biliousness, flatulence	Cooked as vegetables	Singh et al, 2016 Roberts et al., 2016
27.	**English:** Long Coriander, Wild Coriander **Hindi:** Ban Dhania **Manipuri:** Awa Phadigom **Bengali:** Bon Dhonia **Assamese:** Jongali Memedo **Tangkhul:** Lam Sachikom **Nepali:** Ban Dhania	*Eryngium foetidum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Apiales Family Apiaceae Genus Eryngium Species foetidum	Europe, Western Asia and North Africa	β-sitosterol, stigmasterol, campesterol, brassicasterol, 3α-cholesterol, (-)-clerosterol, avenosterol, avenasterol, stigmastadienol, α–pinene, p-cymene, 2,3,6 Trimethyl benzaldehyde, E(2) Dodecenal, Dodecenoic acid, E(2) Tridedecenal, Duraldehyde, Formyl1,1,5trimethyl cyclohexa 2,4 den 6-ol, Eryngiol, Dimethyl acetophenine, Lauric acid, Capric acid	Moisture(%) 74.19 Carbohydrate 2.841 Crude fibre 7.1 Protein 11.3 Fat 2.597 Ash 9.073 Calcium 0.473 Magnesium 0.054 Iron 0.001 Zinc 0.0001 Manganese 0.0003 Copper 0.00024 Energy(Kcal) 46.9	Anti-inflammatory and antinociceptive activity, treatment for burns, earache, fever, hypertension, constipation, fits, asthma, stomach ache, worms, infertility complications, snake bites, diarrhoea and malaria	Cooked as vegetables, seasoning	Wang et al., 2012 Dutta et al., 2017, M et al., 2014 http://tropical.theferns.info/viewtropical.php?id=Eryngium+foetidum Swargiary et al., 2016; Narzary et al., 2015

28.	**Common Name:** Kala Chana	*Cicer arietinum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Fabales Family Fabaceae Genus Cicer Species arietinum	Asia	1,3,12, nonadecatriene-5, 14-diol, hexadecanoic acid, 3,7,11,15, tetramethyl-2-hexadecen-1-ol and octadecanoic acid, 9,5,11 octadecatrienoic acid, methyl ester, tetracosane, vitamin e acetate and phenol, 2, 5-bis [1,1- dimethyl ethyl], folate, phylloquinone, ascorbate, β-carotene, hexadecanoic acid (6.02%) and 9H – fluorene	Moisture (%) 94.04 ± 0.54 Carbohydrate 56.00 ± 0.15 Fiber 11.37 ± 0.51 Protein 24.84 ± 0.12 Calcium(mg) 2.679 ± 0.08 Phosphorus 368 ± 0.04 Iron 514 ± 0.05	Antioxidant, antimicrobial, anticancer, antitumor, antiproliferative, anti-inflammatory and hypolipidemic activity	Cooked as vegetables	Islam et al., 2004 GATADE et al., 2013 Gupta et al., 1988 Ibrikci et al, 2003
29.	**English:** Cabbage **Assamese:** Bandha Kobi **Bengali:** Bandhakopi **Gujarati:** Kobi **Hindi:** Band Gobhi **Kannada:** Elekosu, **Konkani:** Kale **Manipuri:** Kobiful **Marathi:** Kobi **Nepali:** Gob **Oriya:** Bandha Kobi **Sanskrit:** Kapikam **Tamil:** Kovicu **Telugu:** Kosu **Urdu:** Gobhi	*Brassica oleracea var. capitata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Brassicales Family Brassicaceae Genus Brassica Species oleracea	Asia	Allyl isothiocyanate, iberin, indol-3-carbinol, Iberin, iberin nitrile, allyl cyanide, sulforaphane, ascorbigen, quercetin, kaempferol, apigenin, rutin, sinapinic acid, caffeic acid, p-coumaric acid, ferulic acid, α and β-carotene, α and β-amyrins, S methyl-L-cysteine sulfoxide	Moisture(%) 87.93±0.54 Carbohydrate 4.52±0.22 Fiber 3.77±0.11 Protein 1.94±0.10 Calcium 28.9±1.51 Sodium(mg) 176±1.16 Potassium 678±2.65 Manganese 0.67±0.02 Copper 0.05±0.003 Iron 2.15±0.10 Zinc 2.11±0.04 Phosphorus 26.92±0.47	Antioxidant property; vitamin A necessary for healthy skin, bones, gastrointestinal and respiratory system; vitamin C enhance immune system; vitamin E has neurological function, regulates enzyme activity and gene expression; lowers risk of cancer progression, treat bed sores, inflammation in skin and joints, polysaccharides shows anti-inflammatory activity, decrease breast engorgement, antiulcerogenic activity, anticholesterol, hipoglicemic and anticoagulant effect	Cooked as vegetables	Ogbede et al., 2015 Dunja et al., 2017
30.	**English:** Bearded Knotweed **Bengali:** Bekh-Unjubaz **Kannada:** Konde Malle **Malayalam:** Belutta **Manipuri:** Yelang **Marathi:** Dhaktasheral **Mizo:** Anbawng **Nepali:** Bish **Tamil:** Niralari **Telugu:** Kondamalle	*Polygonum barbatum*		Kingdom Plantae Subkingdom Tracheobionta Superdivision Spermatophyta Division Magnoliophyta Class Magnoliopsida Subclass Caryophyllidae Order Polygonales Family Polygonaceae Genus Polygonum Species barbatum	South China, Bhutan, India, Indonesia, Malaysia, Myanmar, Nepal, New Guinea, Philippines, Sri Lanka, Thailand and Viet Nam	5, 7, 2', 5'-tetrahydroxy-6-methoxyflavanone; 7-methoxy-3, 5, 8- trihydroxyflavanone; sitosterol, viscozulenic acid and acetophenone; (-)-2-methoxy-2-butenolide-3-cinnamate (1) along with six known compounds, β-hydroxyfriedalanol (2), 3-hydroxy-5-methoxystilbene (3), (-) pinocembrin (4), sitosterol-(6'-O-palmitoyl)-3-O-β-D-glucopyranoside (5), (-) pinocembrin-5-methyl ether (6) and sitosterol-3-O-β-D-glucopyranoside	Moisture (%) 45.13 Total ash 11.96 Water soluble ash 20.00 Water insoluble ash 80.00 Acid soluble ash 70.00 Acid insoluble ash 30.00 Sulphated ash 75.67 Carbohydrate 53.04 Crude protein 7.63	Anti-ulcer, wound-healing, antimicrobial, antinociceptive, anti-inflammatory, diuretic	Cooked as vegetables	Thongam et al., 2016, X et al., 2011 Loganathan et al., 2014 http://www.stuartxchange.com/Subsuban.html, M. Abdul Mazid et al., 2009, Said et al, 2015
31.	**English:** Water Celery, Water Parsley **Manipuri:** Komprek **Tangkhul:** Hanchamhan	*Oenanthe javanica*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Apiales Family Apiaceae Genus Oenanthe Species javanica	E. Asia, China, Japan, Korea to Australia	Persicarin, isorhamnetin, afzelin, hyperoside	Moisture (%) 88 Carbohydrate 62.8 Fibre 12.8 Protein 19.9 Calcium(mg) 1202 Phosphorus 585 Iron 32 Sodium 192 Potassium 4713	Depurative, febrifuge and styptic, used in the treatment of epidemic influenza, fever and discomfort, jaundice, haematuria and metrorrhagia	Cooked as vegetables	https://pfaf.org/user/Plant.aspx?LatinName=Oenanthe+javanica Choong-Hyun Lee et al., 2015 Bhaigyabati et al., 2017 Ma et al., 2009

32.	**English:** Night-Flowering Jasmine Greens **Bengali:** Shefali **Hindi:** Har Singar, **Manipuri:** Singarei **Tamil:** Pavizhamalli **Malayalam:** Paarijatam **Sanskrit:** Parijat	*Nyctanthes Arbor-tristis*		Kingdom Plantae Division Angiosperms Class Dicotyledonae Subclass Gamopetalae Series Bicarpellatae Order Gentiales Family Oleaceae Genus Nyctanthes Species arbor-tristis	South Asia and Southeast Asia	flavanol glycosides (astragaline and Nicotiflorin), Triterpenoid (Nyctanthic acid and oleanolic acid), iridoid glycosides (arborside A,B,C) and Iridoid glucoside (arborside D), β-monogentiobioside ester of α-Crocetin, D-mannitol, β-sitosterol, astragalin, nicotiflorin, oleanolic acid, nyctanthic acid, methyl salicylate, an amorphous glycoside, an amorphous resin, trace of volatile oil, carotene, friedeline, lupeol, mannitol, glucose, fructose , iridoid glycosides, and benzoic acid	Moisture(%) 50.01 Carbohydrate 9.48 Crude fibre 9.41 Protein 15.02	Treatment of sciatica, arthritis and malaria besides this it is also used as tonic and laxative. This plant holds a promising role in expelling worms, wound healing, Immunomodulation. It is also used as anti-helminthic, anti-amoebic, anti-trypanosomal and larvicidal	Cooked as vegetables	S et al, 2015 Desai et al, 2016 RAHMAN et al., 2011
34.	**English:** Sessile Joyweed **Assamese:** Ha-Galdeb **Hindi:** Garundi **Manipuri:** Phakchet **Marathi:** Kanchari **Tamil:** Ponnanganni **Malayalam:** Ponnankannikkira **Telugu:** Ponnagantikura **Kannada:** Honagonne **Oriya:** Madaranga **Konkani:** Koypa **S** **Anskrit:** Matsyaksi **Nepali:** Bhiringi Jhaar	*Alternanthera sessilis*		Kingdom Plantae Subkingdom Tracheobionta Super division Spermatophyta Division Magnoliophyta Class Magnoliopsida Subclass Caryophyllidae Order Caryophyllales Family Amaranthaceae Genus Alternanthera Species sessilis	Bangladesh and other parts of Asia	ß-sitosterol, stigmasterol, campesterol, lupeol, α- Spinasterol, β- carotene, essential oil [1,1,1,5,5,5-hexamethyl-3,3-bis [trimethylsilyl)oxy]trisiloxane (15.43%); S,S-dioxide trans-2-methyl-4-N-pentylthiane (11.27%); didodecylphthalate (10.62%) and tetrahydro-2,5-dimethoxy furan (10.01%)] Riboflavin(mg)- 0.14	Moisture(%) 77.4 Carbohydrate 11.6 Fibre 2.8 Proteins 5 Fat 0.7 Vitamin 17 Calcium (mg) 510 Phosphorus 60 Iron 16.7	Used as galactogogue, cholagogue, febrifuge and in indigestion problems, eye diseases, cuts, wounds and antidote to snake bite; skin diseases, analgesic (non-narcotic) property, to relive tiredness, laziness, and sleeps, antidiabetic potential	Cooked as vegetables	T et al., 2010, R et al., 2012 Hossain et al., 2014, Unni et al., 2009, Mondal et al., 2014 Walter et al., 2014, Tan et al., 2013, Khan et al., 2016, SK et al., 2017
35.	**English:** Hound's Berry **Manipuri:** Leipungkhangga **Tamil:** Manatakkali **Hindi:** Mokoi **Malayalam:** Mulaku-Thakkali **Telugu:** Kasaka **Marathi:** Laghukavali **Urdu:** Makoya **Tangkhul:** Hantehan **Nepali:** Kaalo Biheen,	*Solanum nigrum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Solanales Family Solanaceae Genus Solanum Species nigrum	Southeast Asia, Americas, Australasia, and South Africa.	Anthocyanidin, Gallic acid, catechin, protocatechuic acid (PCA), caffeic acid, epicatechin, rutin, and naringenin, hydrocyanic acid, phytic acid, gentisic acid, luteolin, apigenin, kaempferol, and m-coumaric acid	Moisture(%) 59 Carbohydrate 9.10 Fibre 1.65 Protein 3.52 Calcium (mg) 410 Iron 13.04	Prevent oxidant cell damage having anticancer activity due to water soluble antioxidant and free radical scavengers, used for the treatment of wounds, burn and ulcers, cure several infectious and non-infectious diseases, prevents liver toxicity & cytotoxicity, useful remedy to treat breast cancer; Leaves are crushed and mixed in water. This extract is applied topically for Washing painful eyes	Cooked as vegetables	Zebish et al, 2016, Gqaza et al., 2013; Ashrafudoulla et al., 2015; Kumar et al., 2016; Saleem et al., 2009 Chauhan et al., 2012; Abbasi et al., 2013
36.	**English:** Arrowhead **Manipuri:** Koukha **Bengali:** Chhotokut	*Sagittaria sagittifolia*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Lilianae Order Alismatales Family Alismataceae Genus Sagittaria Species sagittifolia	Most of Europe, including Britain, temperate Asia and N. America.	labda-7,14- dien- 13(S),17-diol, 17-hydroxymanool, 19-O-R-L-arabinofuranosyl-ent-rosa-5,15- diene, 13-epi-manoyl oxide-19-O-R-L-2′,5′-diacetoxyarabinofuranoside	Moisture(%) 70.6 Protein 5 Carbohydrate 22.4 Fibre 0.9 Calcium(mg) 13 Phosphorus 165 Iron 2.6 Potassium 729	Antiscorbutic; Diuretic; Galactofuge, infected sores, wounds and skin eruptions, used as an antidote for snakebites, Immunomodulatory Activity, Antimicrobial Activity, antiscorbutic, laxative, tonic and diuretic, Proteinase Inhibitory Activity	Cooked as vegetables	http://www.iucngisd.org/gisd/species.php?sc=858 http://tropical.theferns.info/viewtropical.php?id=Celosia+argentea Lim et al., 2015 Liu et al., 2006

37.	**English:** Plumed Cockscomb **Bengali**: Moragaphool **Hindi**: Lalmurga **Manipuri**: Haolei **Marathi**: Mayurashikha, **Sanskrit**: Mayurachuda, **Tamil**: Cavarcuttuppannai, **Telugu**: Mayurasikhi	*Celosia argentia*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Amaranthaceae Genus Celosia Species argentea	India and China	4-hydroxycinnamic acid (p-coumaric acid), 4-hydroxybenzoic acid, protocatechuic acid, caffeic acid, m-coumaric acid, gallic acid, 4-hydroxybenzaldehyde, hydroxybenzaldehyde, 2,4-dihydroxybenzoic acid, pyrogallol, 3,5-dihydroxybenzoic acid	Moisture(%) 91.16±0.07 Fibre 3.53±0.42 Protein 5.17±0.06 Calcium 178.08±0.50 Chromium 1.98±0.01 Copper 3.75±0.30 Iron 15.25±0.23 Lead 0.83±0.01 Magnesium 39.64±0.08 Manganese 1.73±0.04 Nickel 1.03±0.04 Phosphorus 38.01±0.42 Potassium 62.34±0.38 Sodium 35.25±0.30 Zinc 7.25±0.25	Treatment of sores, ulcers and skin eruptions and possesses laxative, antioxidant, and anti-inflammatory activities, investigated for anti-inflammatory, antipyretic, antidiabetic, antibacterial and diuretic properties, treatment of inflammations, fever and itching, antidiarrhoeal, anti-apoptosis, antiaging,anti-carcinogen, cardiovascular protection and improvement of endothelial function and cell proliferation activities, antioxidant, antidiabetic, tonic, immune stimulatory, antitumor, antibacterial, anti-inflammatory, antiosteoporosis, antiulcer, hypolipidemic, diuretic, larvicidal, antihypertensive, hypoglycemic and analgesic activity	Cooked as vegetables	Kumar et al., 2014; Okpako et al., 2015; A et al., 2016; Varadharaj et al., 2017; Ayodele et al., 2011
38.	**English:** Spiny Amaranth **Hindi:** Kanta Chaulai **Manipuri:** Chengkruk **Marathi:** Kante Bhaji **Tamil:** Mullukkeerai **Malayalam:** Kattumullenkeera **Tangkhul:** Somchan **Telugu:** Mullatotakura **Kannada:** Mulluharive **Bengali:** Kantanotya **Sanskrit:** Tanduliuyah **Nepali:** Kaande Lunde	*Amaranthus spinosus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Amaranthaceae Genus Amaranthus Species spinosus	America and Asia	Hentriacontane, ß-sitosterol, campesterol, cholesterol and stearic, oleic and linoleic acids, quercetin and rutin, a-spinasterol, octacosanoate, oleanolic acid, 7-p-coumaroyl apigenin 4-o-beta-D-glucopyranoside, a new coumaroyl, flavone glycoside called spinoside, xylofuranosl uracil, beta – D-ribofuranosyl adenine, beta-sitosterol glucoside, hydroxycinnamates, quercetin and kemferol glycoside, betalins, betaxanthin, betacyanin, amaranthine and isomaranthine, gomphrenin, betanin, stigmasterol, linoleic acid	Moisture(%) 86.26 Carbohydrate 28.48 Fibre 3.34 Protein 35.39	Used as a mouth-wash for toothache, as a laxative; applied as an emollient poultice to abscessess, boils and burns, Bronchodilator and spasmolytic activity, Diuretic activity, Antibacterial activity, Antitumor activity, Antimicrobial activity, Antigenic and allergenic activity, Gastrointestinal activity, Immunomodulatory activity, Anti-pepticulcer activity, Haematological activity, Anti-nociceptive activity, Anti-malarial activity, Anti-helmintic activity, Anti-inflammatory activity, Anti-diabetic activity, Antioxidant and Hepatoprotective activity	Cooked as Vegetables	http://www.mpbd.info/plants/amaranthus-spinosus.php Asha et al., 2016 Choudhury et al., 2013 Amabye et al., 2015 Rjeibi et al., 2017 AGBEDE et al., 2012
39.	**English:** Little Hogweed **Hindi:** Lunia **Manipuri:** Leibak Kundo **Tamil:** Paruppu Keerai **Malayalam:** Koluppa **Kannada:** Dudagorai **Bengali:** Nunia Sag	*Portulaca oleracea*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Portulacaceae Genus Portulaca Species oleracea	North Africa, Southern Europe through the Middle East and the Indian Subcontinent to Malesia and Australasia	Omega-3-fatty acids, kaempferol, myricetin, luteolin, apigenin, quercetin, genistein, and genistin, dopa, dopamine, and noradrenalin, Oleraceins A, B, C, D, and E are cyclodopa alkaloids, monoterpenes such as portulosides A and B, diterpenes such as portulene, and β-amyrin type triterpenoids	Moisture(%) 91.18±0.113 Carbohydrate 42.41±0.262 Protein 17.53±0.106 Calcium 183.63±0.247 (mg) Iron 3.79+0.014 Magnesium 124.77±0.042 Phosphorus 156.87±0.050 Potassium 274.70+0.141 Sodium 68.67±0.050	Treat insect or snake bites on the skin, boils, sores, pain from bee stings, bacillary dysentery, diarrhoea, hemorrhoids, postpartum bleeding and intestinal bleeding, reported to have anti-hyperglycemic, anaesthetic and analgesic properties, anti-allergic, anti-oxidative, antimicrobial, anti-diarrhoea and anticancer activities, possess antinematicidal, molluscicidal, insecticidal and antioxidant, anti-cancer, aphrodisiac, anti-protozoal, antibiotic, antifungal, antiviral, hepatoprotective, anti-ulcer properties, antiviral, antibacterial and anti-parasitic and anti-diarrhoeal agent, antineoplastic functions	Cooked as vegetables	Ezeabara et al., 2014 Zhou et al., 2015
40.	**English:** Tropical Spiderwort **Hindi:** Kana **Kannada:** Hittagani **Malayalam:** Kanankolai, **Manipuri:** Wangden Khoibi **Marathi:** Kena **Nepali:** Kane **Sanskrit:** Kanchata, **Tamil:** Kanangkozai, **Telugu:** Neerukaassuvu	*Commelina benghalensis*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Superorder Lilianae Order Commelinales Family Commelinaceae Genus Commelina Species benghalensis	Asia and Africa	3-dodecene, 1-hexodeconol, 9- eicosene and Tetratriacontane, Phenol 2,4 bis(1,1dimethyl ethyl), Hexadecen1ol,trans 9, 9eicosene, 9,10 anthracenedione, tetracosane, 1,4 Benzenedicarboxylic acid, bis (2ethylhexyl) ester, 13Docosenamide, Tetracosane 11 decyl	Moisture(%) 95.56 Fiber 10±0.69 Protein 3.125±0.0312 Fat 0.8±0.3	Mouth thrush, inflammation of the conjunctiva, psychosis, epilepsy, nose blockage in children, insanity and exophthalmia, used medicinally as a diuretic, febrifuge and anti-inflammatory agent, hypotensive and cardio depressant properties, potential of antihyperglycemic,	Cooked as vegetables	https://www.flowersofindia.net/catalog/slides/Bengal%20Dayflower.html Tiwari et al., 2013 Sumithra et al., 2017 Tadesse et al., 2016 Shivprasad et al, 2016

41.	**English:** Bitter Gourd Greens **Assamese:** Karela **Bengali:** Karala **Gujarati:** Karelu **Hindi:** Karela **Kannada:** Haagalakaay **Konkani:** Kaaraate **Malayalam:** Kayppa, **Manipuri:** Karon Akhabi **Marathi:** Ambalem **Mizo:** Changkha **Nepali:** Amala **Oriya:** Changkha **Sanskrit:** Kaarvellakah **Tamil:** Iraca-Valli **Telugu:** Kakara **Urdu:** Karela	*Momordica charantia*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Cucurbitales Family Cucurbitaceae Genus Momordica Species charantia	Asia, the Caribbean, Africa, and the Amazon	Momorcharins, momordenol, momordicilin, momordicins, momordicinin, momordin, momordolol, charantin, charine, cryptoxanthin, cucurbitins, cucurbitacins, cucurbitanes, cycloartenols, diosgenin, elaeostearic acids, erythrodiol, galacturonic acids, gentisic acid, goyaglycosides, goyasaponins and multiflorenol	Moisture(%) 86.92 ± 0.05 Carbohydrate 57.92 ± 0.04 Fibre 6.01 ± 0.01 Protein 2.46 ± 0.03 Calcium 22.36 phosphorus 24.36 (mg) Potassium 32.84 Sodium 6.58 Magnesium 5.88	Antioxidant, antimicrobial, antiviral, antihepatotoxic and antiulcerogenic activities, to exhibit anti-inflammatory, anti-angionic, analgesic, anti-allergic, cytostatic, used in the treatment of infections such as respiratory tract, urinary tract and diarrheal disease	Cooked as vegetables	Mada et al, 2013 Santhi et al.,2011 Daniel et al., 2014 Ayeni et al., 2015
42.	**English:** Arrowleaf Sida **Hindi:** Sahadeva **Manipuri:** Uhal Ukabi **Tamil:** Kurundotti **Malayalam:** Vankuruntotti **Bengali:** Svetbarela **Guajarati:** Baladana **Marathi:** Sadeda **Assamese:** Boriala	*Sida rhombifolia*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Malvales Family Malvaceae Genus Sida Species rhombifolia	Asia	Sitosterol and stigmasterol, sitosterol-3-O-β-D-glucopyranoside and stigmasterol-3-O-β-Dglucopyranoside, phaeophytin A, 17^3-ethoxypheophorbide A, 13^2-hydroxy phaeophytin B, 17^3-ethoxypheophorbide B, 5,7-dihydroxy-4'-methoxyflavone, cryptolepinone and a salt of cryptolepine, ecdysteroids, quinazoline alkaloids, besides β-phenylethylamines and carboxylated tryptamines	Moisture(%) 93.44 Total ash 16 Water soluble ash 1.2 Acid insoluble ash 8 Sulphated ash 22.5 Carbohydrates 94,000-475,000 (ppm) Fiber 33,000-167,000 Protein 74,000-347,000 Fat 14,000 -71,000	Hypertension, diabetes, treatment of gout, good for rheumatism, flatulence, colic, haemothermia, and emaciation, vitiated conditions of tridosa, seminal weakness, arthritis and diarrhea, cures vata ulcers, disorders due to morbid pitta and skin diseases, demulcent, diaphoretic, diuretic, emollient, stomachic, tonic, sudorific, appetite and stimulant	Cooked as vegetables	Chaves et al., 2013 Sharma et al., 2013 Rahman et al, 2011 Woldeyes et al.,2012 https://herbpathy.com/Uses-and-Benefits-of-Sida-Rhombifolia-Cid4563
43.	**English:** False Daisy **Hindi:** Bhringaraj, **Manipuri:** Uchi-Sumbal **Tamil:** Karisilanganni, **Malayalam:** Kannunni **Telugu:** Galagara **Kannada:** Ajagara **Oriya:** Kesarda **Sanskrit:** Bhringaraj **Nepali:** Bhringaraaj	*Eclipta prostrata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Asterales Family Asteraceae Genus Eclipta Species prostrata	India, Nepal, China, Thailand, and Brazil	Wedelolactone, 2-formyl-alpha-terthienyl;alpha-terthienyl-methanol; thlophene acetylenes; diisovalerate; Stigmasterol; sitosterol; coumarin and its derivatives dimethylewedelolactone-7-glucoside and nor-wedelolactone, 10-Octadecenoic acid, methyl ester, 9,19-Cyclocholestan-3-ol-7-one,4a-dimethly-[20R], Dodecanoic acid, 10 methyl, methyl ester, Tridecanol, 2-ethyl-2-methyl, 1,2 Benzenedicarboxylic acid, butyl octy ester, 1-Heptatriacotanol, Oleic acid, eicosyl ester	NF	Analgesic, antiseptic, antiviral, antibacterial, antioxidant, antihaemorrhagic and anti-hyperglycemic, antidiabetic activities, shows immunomodulatory action, shows immunomodulatory action, used as a tonic and diuretic in hepatic and spleen enlargement, catarrhal jaundice and for skin diseases	Cooked as vegetables	Sharma et al., 2017 https://www.pharmatutor.org/articles/phytochemical-and-pharmacological-profile-of-eclipta-albacl Anand et al, 2014 Chokotiaet al., 2013, Lin et al., 2010
44.	**English:** Fenugreek Greens	*Trigonella foenum-graecum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Fabales Family Fabaceae Genus Trigonella Species foenum-graecum	Asia	Anthocyanin, leucoanthocyanidines, campesterol, stigmasterol, phytols, Propanoic acid, 2-methyl, Oxime-, methoxy-phenyl-4-Ethylbenzoic acid, 2-Hexadecene, 3,7,11,15-tetramethyl-, [R-[R*,R*-(E)]], Hexadecanoic acid, methyl ester, n-Hexadecanoic acid, 9,12-Octadecadienoic acid (Z,Z)-, methyl ester, Octadecanoic acid), 9,12,15-Octadecatrienoic acid, ethyl ester, E,Z-1,3,12-Nonadecatriene, Nonanoic acid, Glycerine	Moisture(%) 86.1 Carbohydrates 6 Fiber 1.1 Protein 4.4 Minerals 1.5	Antidiabetic, anticholesterolemic, anti-fertility, anticancer, antimicrobial, antistress, antipsoriatic, anti-parasitic and potential immunomodulators, hypocholesterolaemic effects, anti-thrombotic anti-allergic, immune stimulating, estrogenic and vasodilatory actions, restorative and uterine tonic, and useful in burning sensation, treating arthritis, asthma, sore throat	Cooked as vegetables	Jabeen et al., 2017 Mishra et al.,2016 Sumayya et al., 2012 Pasricha et al, 2014

45.	**English:** Tree Onion	*Allium fistulosum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Lilianae Order Asparagales Family Amaryllidaceae Genus Allium Species fistulosum	Japan, korea, Russia, India, China	Caffeic acid, Citric acid, Ferulic acid, Malic acid, Oxalic acid, Para-coumaric acid Para-hydroxybenzoic acid, Propionaldehyde, Protocatechuic acid, Raffinose Sinapic acid, Succinic acid	Carbohydrates(g) 7.34 Dietary Fiber 2.6 Protein 1.83 Calcium(mg) 72 Copper 0.083 Iron 1.48 Magnesium 20 Manganese 0.160 Phosphorus 37 Zinc 0.39 Selenium(µg) 0.6	Anticholesterolemic, anticlastogenic, anticonvulsant, anticrustacean, antifilaria antihelmintic antispasmodic, antiradiation effect, anti-implantation, antihypertriglyceridemic, antihyperglycemic, antihypercholesterolemic, antihistamine, aphrodisiac, carminative, emmenagogue, expectorant, and tonic , and for the treatment of bruises, bronchitis, cholera, colic, earache, fevers, high blood pressure, jaundice, pimples, and sores	Cooked as vegetables	VLASE et al., 2013 https://www.nutrition-and-you.com/scallions.html Tocmo et al, 2015 SHARMA et al, 2014
46.	**English:** Devil's Backbone **Assamese:** Harjora **Bengali:** Harbhanga, **Hindi:** Hadjod **Kannada:** Asthi Samhaara **Malayalam:** Cannalamparanta **Marathi:** Chaudhari **Oriya:** Hadasinkuda **Sanskrit:** Asthisamhari, **Tamil:** Perandai **Telugu:** Gudametige	*Cissus qudrangularis*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Vitales Family Vitaceae Genus Cissus Species quadrangularis	Africa, Arabia, and Southeast Asia	Onocer-7-ene-3b-21a diol & Onocer-7ene 3a, 2,1 diol, resveratrol, piceatannol, pallidol perthenocissin and phytosterols, ascorbic acid, triterpene, β-sitosterol, ketosteroid	Moisture(%) 86.9 Carbohydrate 36.6 Fiber 15.6 Protein 12.8 Potassium(mg) 67.5 Calcium 39.5 Zinc 3 Sodium 22.5 Iron 7.5 Lead 3.5 Cadmium 0.25 Copper 0.5 Magnesium 1.15	Anthelmintic, dyspeptic, digestive, tonic, analgesic in eye and ear diseases, in the treatment of irregular menstruation and asthma, and in complaints of the back and spine, Gastro protective activity, medicinal uses in gout, syphilis, venereal diseases, piles, leucorrhoea	Cooked by boiling with potatoes and dry fish	TEWARE et al., 2011 M et al., 2016 Kumar et al., 2012 Yadav et al, 2016
47.	**English:** Creat **Bengali:** Kalmegh **Hindi:** Kirayat **Manipuri:** Vubati **Marathi:** Oli-Kiryata, **Tamil:** Nilavembu **Malayalam:** Nelavepu, **Telugu:** Nilavembu **Kannada:** Nelaberu **Oriya:** Bhuinimba **Konkani:** Vhadlem Kiratyem **Urdu:** Naine-Havandi **Assamese:** Kalmegh **Gujarati:** Kariyatu **Sanskrit:** Kalmegha, **Mizo:** Hnakhapui	*Andrographis paniculata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Acanthaceae Genus Andrographis Species paniculata	Taiwan, China, India	14-deoxy-11,12-didehydroandrographolide, 14-deoxyandrographolide, 14-deoxy-14,15-dehydroandrographolide, isoandrographolide, 3,19-isopropylideneandrographolide and 14-acetylandrographolide, arabinogalactan proteins, 7-Omethylwogonin, apigenin, onysilin and 3,4-dicaffeoylquinic acid, hydroxybenzoic acids, hydroxycinnamic acids, p-coumaric, caffeic, ferulic and sinapic acids, quinic, shikimic or tartaric acid, squalene, polyprenol, lutein, chlorophyll a, β-sitosterol, and stigmasterol from the stems; and α-amyrin acetate, triacylglycerols, lupeol, α-amyrin, and β-amyrin,	Moisture(%) 71.65+0.04 Carbohydrate 65.04+0.04 Fibre 6.22+0.01 Crude Protein 14.88+0.01 Fat 9.71+0.00 Calcium (mg) 8.02 Magnesium 10.02 Sodium 5.05 Potassium 1.44 Phosphorus 4.2 Copper 2.53 Zinc 1.28 Manganese 3.75 Iron 33.76	Appetizer, anthelmintic and very effective against ailments of liver, treat liver disorders, bowel complaints of children, common cold and respiratory infection, properties like antidiarrhoeal, immunostimulant, anticancer, antihuman immunodeficiency virus (HIV), antisnakebite activity, act against upper respiratory tract infections, antimalarial, filaricidal, antidiarrhoeal, and cardiovascular activities, fertility effects and protective effects on liver and gall bladder, possess anti-inflammatory, hepatoprotective, astringent, anodyne, tonic, alexipharmic and anti-pyretic properties and helps in arresting dysentery, cholera, diabetes, influenza, bronchitis, swellings and itches, piles and gonorrhea	Cooked as vegetables	Dwivedi et al., 2015 Divya et al.,2011 Chao et al., 2010, 2012 Rajalakshmi et al., 2016 Roy et al., 2010 Das et al., 2014 Praveen et al., 2014 Carmen et al., 2016 Abasiekong et al., 2017
48.	**English:** Muyna **Hindi:** Muyna **Manipuri:** Heibi **Marathi:** Huloo **Tamil:** Manakkarai **Telugu:** Visikilamu, **Kannada:** Mullakare, **Oriya:** Gurbeli **Konkani:** Helu **Sanskrit:** Pindituka	*Vangueria spinosa*		Kingdom Plantae Phylum Tracheophyta Class Magnoliopsida Order Gentianales Family Rubiaceae Genus Vangueria Species spinosa	topical Asia to South East Asia, Nepal, Bangladesh, Myanmar, Thailand, Cambodia, Laos, Vietnam	Proanthocyanidin, (−)-epicatechin-3-O-β-glucopyranoside, 2-[3-cyclopropyl-4-hydroxyphenyl]-5,7-dihydroxy-4-oxo-4H-chromen-3-yl acetate, 19 α-hydroxyasiatic acid, oleanolic acid, myricyl alcohol, β-sitosterol, and 3-O-β-D-glucopyranosyl-bsitosterol, 19α-hydroxyursane-type triterpenes, (2α,3α,19α,24,28-pentahydroxyurs-12-ene), meyanthic acid (3β-acetoxy-2β,19α,23-trihydroxyurs-12-en-28-oic, myricyl pentadecanoate	NF	Treatment of skin infection, peptic ulcer, headache, diabetes, hepatic disorder, dysentery, indigestion, intestinal worm, and painful urination, important for its abortifacient activity, antioxidant, antimicrobial, antidiabetic, cytotoxic, hepatoprotective, and nephroprotective activity, Treatment of Cough, Scorpion-Sting and as Refrigerant, Nutrients, Hepatoprotective, Nephroprotective, and antidiabetic	Added raw in singju	Sen et al., 2017

49.	**English:** Balloon Vine, **Hindi:** Kanphata **Marathi:** Kanphuti, **Tamil:** Kottavan, **Malayalam:** Jyotishmati, **Telugu:** Buddakakara, **Kannada:** Agniballi, **Bengali:** Lataphatkari **Oriya:** Sakralata **Assamese:** Kapal Phuta **Sanskrit:** Bunu-Uchchhe, **Nepali:** Jyotismati	*Cardiospermum halicacabum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Sapindales Family Sapindaceae Genus Cardiospermum Species halicacabum	Central America, South America, Hawaii, Taiwan, the Philippines, Malaysia, Polynesia, India, Sri Lanka, Africa, Malta, Europe	Cyclohexane-1, 4, 5-triol-3-one1-carboxylic acid, benzene acetic acid, caryophyllene, phytol and neophytadiene, Beta-phenethylphenyl acetate, Hexadeconoic acid, Octadeconoic acid, 9-octadecenoic acid, N-methyl tomatidine, 3-methylbutanamide, Alpha-octadecene, Neophytadiene, Hexadecene, 14-methyl-8-hexadecyne, 1-tert-butyl-2-methoxy-4-methyl-3, 5-dinitrobenzene, N-methyl tomatidine, 3-methylbutanamide, 1,2-benzenedi carboxylic acid, Apigenin and luteolin	Moisture(%) 83.3 Carbohydrate 9 Protein 4.7 Calcium(mg) 61	Analgesic, anti-inflammatory and vaso-depressant activity, used for the treatment of skeletal fractures, used to cure ear-ache and to reduce hardened tumours, treatment of hyperthermia, reduce hyperglycaemia, hypersensitivity, immune-suppression and allergic reactions	Young leaves can be cooked as vegetables black pea or making chutney	http://www.eattheweeds.com/tag/cardiospermum-halicacabum/ Jeyadevi et al., 2013 Veeramani et al.,2008 Viji et al., 2010 Kumaran, et al., 2008
50.	**English:** Purple Granadilla **Kannada:** Gadiyaarada Hoo **Nepali:** Jhumke Laharo **Tangkhul:** Sadapor Won	*Passiflora edulis*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Malpighiales Family Passifloraceae Genus Passiflora Species edulis	Asia, Australia, and tropical Africa	Dodecanoic acid,10-methyl-,methyl ester, E,E,Z-1,3,12-Nonadecatriene-5,14-diol, 9,12,15-Octadecatrienoic acid, 2,3-dihydroxypropyl ester (Z,Z,Z), S.Hexadecenoic acid,9-octadecenyl ester(Z,Z) and Docosanoc acid,1,2,3 propanetriyl ester	NF	Used as a sedative, diuretic, anthelmintic, anti-diarrhoeal, stimulant and also in the treatment of hypertension, menopausal symptoms and colic of infants, for the treatment of dysentery and hypertension, possess anti-helmentic activity	Cooked as vegetables; added to meat curry	Razia et al., 2014 Phamiwon ZAS, 2017
51.	**English:** Sneeze Wort, **Marathi:** Harandodi, **Tamil:** Koti-P-Palai **Malayalam:** Velipparuthi **Telugu:** Dudipalatiga **Kannada:** Dugdhive **Oriya:** Dudghika **Assamese:** Khamal Lata **Gujarati:** Kadvo Kharkhodo **Sanskrit:** Hemajivanti **Bengali:** Titakunga Shak **Hindi:** Nak-Chhikni Sag	*Dregea volubilis*		Kingdom: Plantae (unranked) Asterids Order: Gentianales Family Apocynaceae Subfamily Asclepiadoideae Genus Dregea Species volubilis	India, Sri Lanka, Myanmar, Indonesia, Thailand and China	1,3-Diazacyclooctane-2-thione, 2-Undecanol, Vitamin d3, 1,3-Propanediol,2-ethyl-2-(hydroxymethyl), Myo-Inositol, 4-C-methyl, Hexadecanoic acid, methyl ester, 2-Acetylamino-3-hydroxy-propionic acid, Linoleic acid, Trimethylsilyl ester, Undecanal,2-methyl, Hexadecanal, 2-methyl, Phen-1,4,-diol,2,3-dimethyl-5-trifluoromethyl, Oxirane, (hexadecyloxy)methyl	NF	Treatment of infectious diseases and various ailments, used to treat rheumatic pain, cough, fever and severe cold, treat dyspepsia, treating urinary infections, used to treat inflammation, piles, leucoderma, asthma, tumors, urinary discharge, significant antifungal activities against ringworm causing fungus	Cooked as vegetables	Natarajan et al., 2013 Sandhya et al., 2013 Hossain et al., 2011
52.	**English Name:** Marsh Herb **Bengali:** Hingcha Shak **Hindi:** Harkuch Sag	*Enhydra fluctuans*		Kingdom Plantae Subkingdom Tracheobionta Superdivision Spermatophyta Division Magnoliophyta Class Magnoliopsida Subclass Asteridae Order Asterales Family Asteraceae Genus Enhydra Species fluctuans	Southern Africa, tropical Asia to Australia	β-carotene. myricyl alcohol, kaurol, cholesterol, sitosterol, glucoside, sesquiterpene lactones including germacranolide, enhydrin, fluctuanin and fluctuandin, a number of diterpenoid acids and their isovalerate and angelate derivatives, stigmasterol, cholesterol, sitosterol, glucoside, other steroids and gibberellins A9 and A13	Moisture(%) 87.60 ± 0.57 Carbohydrate 61.61 ± 1.10 Crude Fiber 11.95 ± 0.18 Protein 16.69 ± 0.36 Fat 2.66 ± 0.20 Calcium 902.46 ± 0.85 Sodium 135.86 ± 0.27 Potassium 253.37 ± 1.11 Magnesium 57.38 ± 1.16 Iron 23.34 ± 0.45 Zinc 4.38 ± 0.20 Copper 1.32 ± 0.06	Good blood purifier and appetizer, Antioxidant activity, Antimicrobial and cytotoxic activity, Hepatoprotective activity, CNS Depressant Activity, Antidiarrheal activity, Antimicrobial activity, Leaves are laxative and antibilious; cure inflammation, leucoderma, bronchitis and biliousness; useful in skin and nervous affections; also useful in tropidity of the live	Cooked as vegetables	http://www.mpbd.info/plants/enhydra-fluctuans.php Ramjan Ali et al., 2013 http://www.stuartxchange.org/Kangkong-kalabau.html

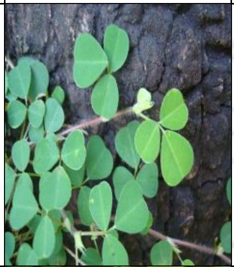
53.	**English:** Red Gourd Greens **Bengali:** Kumra Shak **Hindi:** Mithakaddu Sag **Assamese:** Ranga **Gujarati:** Lal Kolu **Hindi:** Lal Kaddu, **Kannada**: Kandu Gumbala **Kashmiri:** Tumbi **Malayalam:** Vellarimathan **Manipuri:** Mairen **Marathi:** Lal Bhopala **Mizo:** Mai **Punjabi:** Halwa Kaddu **Oriya:** Kumda **Sanskrit:** Kusmandakah **Tamil:** Carkkarai-P-Pucani, **Telugu:** Gummadi	*Cucurbita maxima*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Cucurbitales Family Cucurbitaceae Genus Cucurbita Species maxima	China, Argentina, India, Mexico, Brazil, and Korea	β-carotene, lutein, rutin, quercetin	Moisture(%) 74.41 Carbohydrates 69.22 Fibre 11.21 Protein 14.21	Used as nervous disorder, cancer, helminthiasis, cooling effectin the body, gastrointestinal problem, joint pain, cold, piles,dysentery, oedema, skin disorder, leprosy, rheumatoid arthritis, chicken pox, anaemia, malaria, anti-HIV, diabetic, hypertensive, inflammation, immunomodulatory, antibacterial, burns, scalds, inflammation, abscesses, boils, migraine, neuralgia, haemoptysis, heamarroch, diuretic, refrigerants, prostate problem, ascarisis, aerial parts are used for hypoglycaemic, antioxidant, hepatoprotectivity, antidiabetic, anti-cancer	Cooked as vegetables	Godwin et al., 2014 Neelamma et al., 2016 Periyanayagam et al., 2015 **Vegetables** By G. J. H. Grubben
54.	**English:** Five Leaved Carpetweed **Hindi:** Jharasi **Marathi:** Sarsalida **Tamil:** Turapoondu **Malayalam:** Parpadakapullu **Telugu:** Chetarasi **Bengali:** Khet Papra **Oriya:** Malagoso **Bengali:** Ghora Gima Shak	*Mollugo pentaphylla*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Molluginaceae Genus Mollugo Species pentaphylla	Asia	Mollugogenol A and mollugogenol B, oppositifolone, spinasterol, squalene and lutein, sapogenol, 3 ,16 ,22-trihydroxyisohopane	NF	Treat whooping cough and jaundice, anti-diabetic activity, used for sprue and mouth infections, used as aperient, antiseptic, emmenagogue, and stomachic; also, used as mild laxative. Infusion of the plant is used to promote menstrual discharges, to improve digestion and to stimulate the liver. Also used as diuretic, anthelmintic, antioxidant and spermicidal, used to treat eye diseases, used as anticancer, antitoxic, and diuretic, treatment of fever, diarrhoea, dysentery, skin problems, jaundice and rheumatism	Cooked as vegetables	http://www.stuartxchange.org/Malagoso.html Sahu et al., 2012 Sharma et al., 2012 Valarmathi et al., 2010 MAHARANA et al., 2012
55.	**English:** Green Amaranth **Hindi:** Jungali Chaulayi **Konkani:** Ranbhaji **Malayalam:** Kuppacheera **Marathi:** Math **Sanskrit:** Tanduliya **Tamil:** Kuppai-K-Kirai **Telugu:** Chilaka-Thotakoora **Nepali:** Lunde Saag	*Amaranthus hybridus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Amaranthaceae Genus Amaranthus Species hybridus	Asia and Africa	Allantoic acid, Benzofuran, 2,3-dihydro, Tridecanoic acid, 3-hydroxy-, ethyl ester, 2-Methoxy-4-vinylphenol, 1-Dodecanol, 2-Thiophenecarboxylic acid, 5-nonyl, Octadecanoic acid, 3-Chloropropionic acid, Tetradecanoic acid, Heptanoic acid, 3-Octadecenoic acid, Propanoic acid, 3-mercapto-, dodecylester, Phytol, 9,12,15-Octadecatrienoic acid, (Z,Z,Z)-, Octadecanoic acid, Oleic acid, Propanoic acid, Benzofuran,	Moisture(%) 85.7 Carbohydrates 44.1 Protein 34.2 Fibre 6.6 Fat 5.3 Calcium(mg) 2243 Phosphorous 500 Iron 27 Sodium 336 Potassium 2910	Used curatively for diarrhea, dysentery, excessive menstrual flow, ulcers and intestinal haemorrhaging, For the treatment of intestinal bleeding, excessive menstruation, diarrhea and other related problems, Hepatoprotective Activity, Anthelmintic Activity, Antidiabetic and Antihyperlipidaemic Activities, Anti-inflammatory Activity	Cooked as vegetables	Ahmed et al., 2013 Pulipati et al., 2014 Salvamani et al., 2016
56.	**English:** Horse Radish Tree **Bengali:** Sajina Shak **Hindi:** Saijan Sag **Kannada:** Guggala, **Malayalam:** Muringai **Marathi:** Shevga **Tamil:** Murungai **Telugu:** Mochakamu,	*Moringa oleifera*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Brassicales Family Moringaceae Genus Moringa Species oleifera	Asia and Africa	Myrecytin, quercetin and kaempferol, iso-quercetin or isotrifolin, Gallic acid, caffeic acids, Chlorogenic acid (CGA), N,α-L-rhamnopyranosyl vincosamide, phenylacetonitrile pyrrolemarumine,40 -hydroxyphenylethanamide-α-L-rhamnopyranoside, 3-hydroxymethyl glutaryl CoA,	Moisture(%) 77.2 Carbohydrate 8.4 Fibre 0.8 Protein 8.4 Calcium 523 Iron(mg) 9.6	Antiproliferation, hepatoprotective, anti-inflammatory, antinociceptive, antiatherosclerotic, oxidative DNA damage protective, antiperoxidative, cardioprotective, Antibacterial, Antineoplastic and other Pharmaceutical function, anticarcinogenic, immunomodulatory, reduce gastric ulcers, hypotensive, antidiabetic, anti-cancer, antiatherosclerotic, antiatherogenic, and hepatoprotective functions	Cooked as vegetables	Zebish et al., 2016 Sain et al., 2016 PATEL et al., 2014 Solana et al., 2015 Jimenez et al., 2017 FERREIRA et al.,2008

57.	**English:** Indian Sorrel Greens **Bengali:** Amrul Shak **Hindi:** Amboti Sag **Manipuri:** Yensil **Tamil:** Paliakiri **Malayalam:** Poliyarala	*Oxalis corniculata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Oxalidales Family Oxalidaceae Genus Oxalis Species corniculata	Asia	Carotene, Tartaric acid , Citric acid ,Mallic acid, Isoorietin, Isovitexin, Swertsin ,2'-O(Beta-D-glucopyranosyl), 5-Hydroxy-6,7,8, 4'-tetramethoxyflavone, 5,7,4'-Trihydroxy-6,8-dimethoxyflavone, squalene, , 7-Oxabicyclo [4.1.0]heptanes,1-methyl-4-(2-methyloxiranyl), 1b, 5, 5, 6a-Tetramethyl-octahydro-1-oxa-cyclopropa[a]inden-6-one, 9,12-Octadecadienoic acid (Z,Z)-, phenyl, methyl ester, D-Glucose, 4-o-α-D-glucopyranosyl, α-D-glucopyranoside, O-α-D-glucopyranosyl (1.fwdarw.3) -α-Dfructofuranosyl, Hexadecanoic acid, methyl ester, n-Hexadecanoic acid, 9,12-Octadecadienoic acid, methyl ester, (E,E), 9,12-Octadecadienoic acid (Z,Z)	Moisture(%) 82.42±0.5 Carbohydrate 24.67±0.4 Crude protein 22.28± 0.5 Crude lipid 23.7±0.5 Sodium 1.12±0.02 Potassium 2.17± 0.31 Calcium 2.5± 0.08 Magnesium 0.25±0.03	AntiAmoebic, Anti-Giardia, Cardio protective, Antibacterial Cream Formulation, Antitumor, Antioxidant, Anti-Epileptic, Antifungal, Abortifacient, Anti-fertility, Anti-Urolithiasis, Antibacterial activity, good appetizer, removes kapha, vata, and piles; astringent cures dysentery and diarrhoeas, skin diseases and quarten fevers, used for curing of anthelmintic, styptic, astringent, diarrhea, dysentery, dysmenorrhoea, hepatitis, amenorrhoea and burning sensation, antimicrobial activity, Fresh leaves are crushed and paste is applied topically for Worms and scorpion sting	Cooked as vegetables	Kumar et al., 2013 Singh et al., 2017 Rehman et al., 2015 Durgawale et al., 2015, Kaur et al., 2017, Jain et al., 2010, Abbasi et al., 2013
58.	**English:** Lined Elatostema **Tangkhul:** Hantekhan	*Elatostema lineolatum*		Kingdom Plantae Phylum Tracheophyta Class Magnoliopsida Order Rosales Family Urticaceae Genus Elatostema Species lineolatum	Asia	NF	NF	Ulcers, carbuncle, dysentery, urinary infectious and itching	Cooked eaten by simply boiling or with rice and other vegetables	THAPA et al., 2009 Thongam et al., 2016
59.	**English:** Pointed Gourd Greens **Punjabi**: Parwal **Gujrat:** Patal **Oryia:** Patal **Tamil:** Kombu-Pudalai **Kannada:** Kaadu-Padavala **Malayalam:** Patolam **Bengali:** Potol Shak **Hindi:** Parwal Sag	*Trichosanthes dioica*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Cucurbitales Family Cucurbitaceae Genus Trichosanthes Species dioica	Asia	Beta-carotene, anthraquinone, catechin, coumarin, quinine, catechin, xanthoproteins,	Moisture(%) 92.89 Fiber 35.67±1.12	Purgative and as tonic, febrifuge, in treatment of jaundice, anasarca and ascites, anthelmintic effects, used as antipyretic, diuretic, cardiotonic, laxative, antiulcer, anti-inflammatory, antimicrobial, anti allergic, antibiotic, hypoglycaemic, overcoming problems like constipation, fever, skin infection and wound, maintain healthy heart and brain	Cooked as vegetables	Deka et al., 2015 Banerjee et al., 2015 Kavitha et al., 2017
60.	**English:** Coriander **Hindi:** Dhaniya **Bengali:** Dhane **Manipuri:** Phadigom **Tamil:** Kotthu Malli **Gujarati:** Dhana **Sanskrit:** Dhanika **Kashmiri:** Dhaniwal **Oddiya:** Dhania **Punjabi:** Dhania **Marathi:** Dhaue, **Telagu:** Dhaniyalu	*Coriandrum sativum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Apiales Family Apiaceae Genus Coriandrum Species sativum	Asia	α-pinene,limpnene,γ-terpinene,p-cymene, borneol, citronellol, camphor, geraniol and geraniol acetate, heterocyclic components like pyrazine, pyridine, thiazole, furan and tetrahudrofuran derivatives, isocoumarins, coriandrin, dihydrocoriandrin, coriandronsA-E, flavonoids, pthlides, neochidilide, digustilide phenolic acids and sterols, linalool, linalyl acetate, geranial, camphor, limonene,geranyl acetate, γ-terpinene	Moisture(%) 88.63 Crude protein 11.49 Crude fibre 28.43 Starch 10.53 Sugar 1.92 Ash 4.98	Diuretic, antioxidant activity, antidiabetic activity, anti-convulsant activity, sedative hypnotic activity, anti-microbial activity, anti mutagenic activity, anthelmentic activity, postcoital and diuretic, carminative/stimulant properties, stomach complaints, ophthalmia, conjunctivitis, elephantiasis, and urinary bladder stone	Used as vegetables and garnishing	Pathak et al., 2011 Gayathri et al., 2016 THANGA VE et al., 2015

61.	**English:** Bengal Clock Vine **Hindi:** Neel Lata **Gujarati:** Tumakhlung **Bengali:** Neel Lota **Assamese:** Kukua Loti **Mizo:** Vakohrui **Khasi:** Jermi Khnong, **Nepali:** Kaagchuchche	*Thunbergia grandiflora*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Acanthaceae Genus Thunbergia Species grandiflora	Asia	Iridoid glycosides, isounedoside, and grandifloric acid, α-3-octanol, 3,7 dimethyl 1,6-octadien-3-ol and 2- methoxy-3-(2-propenyl) phenol, Caffeic acid, Quercetin-3-O-rutinoside-7-O-α-Lrhamnopyranoside, Kaempferol-3-O-α-L-rhamnopyranosyl-7-O-β-D4C1-arabinopyranoside-4'-methyl ether, Kaempferol-6-C-sophoroside Kaempferide 3-O- α-L-arabinofuranoside, Kaempferol-3-O-α-L-rhamnopyranoside, isoquercetrin, Quercetrin, Quercetin and Kaempferol	NF	Used for the treatment of blood dysentery, cataract, diabetes, gout, hydrocele, hysteria, malaria, marasmus, post eclampsia, pre-eclampsia, rheumatism, spermatorrhoea	Cooked as vegetables	Uddin et al., 2016 Mbachu et al., 2017 Ibrahim et al., 2017 Olaoluwa et al., 2016
62.	**English:** Sweet Flag **Hindi:** Bach **Manipuri:** Okhidak **Marathi:** Vekhand **Tamil:** Vashambu **Malayalam:** Vaembu **Kannada:** Baje **Bengali:** Bach **Assamese:** Bach **Mizo:** Hnim-Rimtui **Sanskrit:** Bacha **Nepali:** Bojho	*Acoras calamus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Lilianae Order Acorales Family Acoraceae Genus Acorus Species calamus	Asia	A- and B-asarones	Moisture(%) 91.94 Total starch 2.4	Enhance the cognitive abilities, has ability to treat neuropathic pain, antibiotic, cephalic, circulatory, memory boosting, tranquilizing substance, anti-rheumatic, nervine, stimulant anti-spasmodic, circulatory, and memory boosting properties, cures psychological disorders like depression, gives relief from arthritis, gout, and rheumatism, hormone secretion in the body, prevents epileptic fits, prevents hysteric attacks, relieve from nervous spasms, stimulation of blood circulation, stimulation of metabolism, treatment of headache, insomnia	Cooked as vegetables	https://bodynutrition.org/calamus/ Bisht et al., 2013 Saxena et al., 2012
63.	**English:** Spreading Sneeze Weed **Arabic:** Kundush **Bengali:** Nakchikni **Assamese:** Hansia Bon **Chinese:** E Bu Shi Cao **French:** D's Aigrettes **German:** Kleine Centipede **Gujarati:** Chhikani **Hindi:** Kundush **Marathi:** Nakasinkani **Persian:** Bekhe Gazran **Sanskrit:** Chikkana' **Urdu:** Nakchikni	*Centipeda minima*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Asterales Family Asteraceae Genus Centipeda Species minima	Asia	Myriogynic acid, 2β-(Isobutyryloxy)florilenalin, palmitic acid, (Z,Z)-9-,12-octadecatrienoic acid, (Z,Z,Z)-9-,12-octadecatrienoic acid, phytol, naptho[2.3-b]furan-2-(3H)-on, 1-(1,2,3,4,7,7a-hexahydro1,4,4,5-tetramethyl-1,3a-ethano-3aH-inden-6-yl)etanon, 1,3,5-tri-tertbutyl-benzene, (3Z)-2-methyl-3-octen-2-ol and artemisia ketone	NF	Treatment of paralysis and pain in the joints, and also against malaria, hepatitis, diabetes mellitus, eczema, insect or snake bites, and opium poisoning, Anodyne, antitussive, depurative, diuretic, stimulates blood circulation. When the aroma of the squeezed flower heads is inhaled it induces sneezing and so is used to relieve nasal conjestion, especially during coughs and colds. A paste made from the flower heads is applied externally in the treatment of swellings and skin inflammations.	Cooked as vegetables	Vishwanath et al., 2012 Sarkar et al., 2017 Miaoxian et al., 2009
64.	**English:** Spanish Needle **Gujarati:** Phutium **Hindi:** Kumra **Nepali:** Tikhe Kuro **Oriya:** Samara Kodaki **Assamese:** Daomeoai	*Bidens pilosa*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Asterales Family Asteraceae Genus Bidens Species pilos	Asia and Africa	Sulfuretin, Myristic acid, Palmitic acid, Stearic acid, Arachidic acid, Behenic acid, Oleic acid, Elaidic acid, Linolic acid, Ethyl linoleate, Methyl linolenate, Ethyl linolenate, 2-Butoxyethyl oleate, 2-Butoxyethyl linoleate, Pentayneene, Pilosol A, 1-Phenylhepta-1,3-diyn-5en, Butein, Okanin, Apigenin, Luteolin, 5-O-Methylhosludin, Luteolin 7-O*β*-Dglucopyranoside, Axillaroside, Centaureidin, Centaurein, Luteoside, Quercetin	Moisture(%) 80.48 Fibre 18.13 Protein 15.86 Fat 7.49 Sodium (mg) 0.54 Calcium 0.39 Phosphorus 0.31 Potassiu 1.21 Manganese 2.2 Copper 1.26 Zinc 4.53 Magnesium 0.023 Iron 78.9	Treat a wide variety of ailments, have antitumor, antiinflammatory, antidiabetic and antihyperglycemic, antioxidant, immunomodulatory, antimalarial, antibacterial, antifungal, antihypertensive, vasodilatory, and antiulcerative activities	Cooked as vegetables	http://www.db.weedyconnection.com/cobblers-peg-bidens-pilosa/ Bartolome et al., 2013 Ezeonwumelu et al., 2011 Falowo et al., 2016 Alikwe et al., 2014

65.	**English:** Burnweed, Fireweed, Pilewort	*Erechtites hieracifolia*		Kingdom Plantae Division Magnoliophyta Class Magnoliopsida Order Asterales Family Asteraceae Genus Erechtites Species hieracifolia	Hawaii, China, and Southeast Asia	Phellandrene, p-cymene, cis-ascaridol and (E)-caryophyllene, a- and b-Paederine, embelin, and friedelanol, entriacontane, hentriacontanol, ceryl alcohol, sitosterol, stigmasterol, campesterol, urosolic acid, and epifriedelinol, friedelan-3-1, beta-sitosterol, iridoid glycosides, asperuloside, paederoside and scandoside; sitosterol, stigmasterol, campesterol, ursolic acid, palmitic acid and methyl mercaptan	Moisture(%) 87.14±1.42 Carbohydrate 6.96±0.44 Crude Protein 1.94±0.11 Crude Fat 0.80±0.01 Calcium 99.54±1.51 Natrium 5.30±0.27 Potassium 529.72±2.70 Iron 3.04±0.02	Antidiarrheal, Antiinflammatory, Antispasmodic, antitussive Activity, Antioxidant Activity, Anticancer Activity, Antithrombolytic / Antidiabetic, Antibacterial, Antiulcer, Antihyperlipidemic, Anthelmintic, Anti-Inflammatory in Experimentally Induced Colitis, Increased Testosterone Level, Hepatoprotective	Cooked as vegetables	Daniel Lorenzo, 2001 http://www.stuartxchange.org/Kantutan.html
66.	**English:** Neem **Hindi:** Neem **Manipuri:** Neem **Marathi:** Nimbay **Tamil:** Veppai, **Malayalam:** Ariyaveppu **Telugu:** Vepa **Kannada:** Turakabevu **Bengali:** Neem **Urdu:** Neem **Assamese:** Neem **Gujarati:** Dhanujhada **Sanskrit:** Pakvakrita	*Azadirachta indica*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Sapindales Family Meliaceae Genus Azadirachta Species indica	Asia	Gamm.-elemenet, (2E)-3,7,11,15-Tetramethyl-2-hexadecen-1-ol, Methyl petroselinate, Phytol, Methyl isoheptadecanoate, Hexadecamethylcyclooctasiloxane, Butyl palmitate, 2,6,10,14-Tetramethylheptadecane, Nonadecane, Isobutyl stearate, Oxalic acid, 2-ethylhexyl tetradecyl ester, Heptacosane, Eicosane, Heptacosane, Octacosane, kaempferol, quercetin, myricetin and apigeni-7-O-glucoside	Moisture(%) 90.50±0.24 Carbohydrate 78.12±0.35 Fibre 5.92±0.47 Protein 1.58±0.34 Fat 2.07±0.35	Anti-inflammatory, anti-allergic, antioxidant, anti-diabetic, anti-viral and anti-cancer activities, anti-leprosy activities, antimicrobial activity, curative activity against several human problems such as ulcers, swollen liver, malaria, dysentery, diarrhea	Cooked as vegetables	Kutum et al., 2011 Dash et al., 2017 Hossain et al., 2013 Madaki et al., 2016
67.	**English:** Brahmi, Herb Of Grace, Indian Pennywort, Moneywort, Monnier's **Assamese:** Brahmi **Bengali:** Brahmisaka **Gujarati:** Brahmi, **Hindi:** Brahmi **Kannada:** Brahmi Brahmi, **Konkani:** Brahmi **Malayalam:** Brahmi **Manipuri:** Brahmi-Sak **Marathi:** Brahmi, **Oriya:** Brahmi **Sanskrit:** Brahmi, **Tamil:** Nir-P-Pirami, **Telugu:** Sambrani Aku	*Bacopa monnieri*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Plantaginaceae Genus Bacopa Species monnieri	Asia	luteolin-7-glucoside, glucoronyl-7-apigenin, Phytosterol, Anthraquinone, Dodecane, Phenol, 2-methoxy-4-(2-Propenyl), Tridecane, N-Hexadecanoic acid, Octadec-9-enoic acid, 3,7,11,15-Tetramethyl-2-Hexadecen-1-ol, Phytol, Cis-9-Hexadecenal, Heneicosane, Icosanoic acid, Nonacosane, Stigmasterol, Stigmast-5-en-3-ol, 2,6,10-trimethyl,14-ethylene-14-Pentadecne, Cholesta-4,6-dien-3-ol, 2-Cyclohexen-1-one	Moisture(%) 85.5 Protein 32.55 Fat 2.90 Ash 7.20 Fibre 4.80	Used for controllingasthma, rheumatism, hoarseness and fever, used in generalized weakness, lethargy, fatigue and exhaustion, treat anxiety, anger, nerve pain, insomnia, learning problems and concentration difficulties, used in the treatment of epilepsy and asthma, used as a cardio tonic, digestive aid and to improve respiratory function, protection from free radical damage in cardiovascular diseases, certain types of cancer and helps to prevent induced lipid peroxidation, antioxidant, antiaging, antidepressant, anticancer and antibacterial activity	Cooked as vegetables	Kutum et al., 2011 Singh et al., 2012 Pawar et al., 2016 Jain et al., 2017 Ramadas et al., 2016
68.	**English:** Indian Bay Leaf, Indian Cassia **Hindi:** Tejpatta **Manipuri:** Tejpat **Tamil:** Talishappattiri **Malayalam:** Tamalapatram **Telugu:** Talisapatri, **Kannada:** Patraka **Bengali:** Tejpat **Urdu:** Tezpat **Assamese:** Mahpat, **Gujarati:** Tamaal Patra **Sanskrit:** Tamalapattra **Tangkhul:** Sakomna	*Cinnamomum tamala*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Magnolianae Order Laurales Family Lauraceae Genus Cinnamomum Species tamala	India, Nepal, and Bhutan	Eugenol (66.1%), spathulenol(4.8%), viridiflorene (2.4%), methyleugenol (1.9%), aromadendrene, furanogermenone (59.5%), β-caryophyllene (6.6%), sabinene (4.8%), germacrene D (4.6%) and curcumenol (2.3%), Sesquiterpenoids (96.8%), dominated mainly by furanosesquiterpenoids (79.3%) viz. furanodienone (46.6%), curzerenone (17.6%), furanodiene (1.8%) and curzerene (1.2%)	Moisture(%) 50.5 Carbohydrates 9.5 ± 0.5 Dietar fibre 30.5 ± 0.6 Protein 6 ± 0.5 Fat 8.5 ± 1.8	Used in traditional medicines as an astringent, stimulant, diuretic, carminative and in cardiac disorders, antidiarrheal, hypoglycemic activity, anorexia, dryness of mouth, bladder disorders, acaricidal, hepatoprotective, anti-inflammatory, anti-hyperlipidemic and antioxidant etc., are antihelminthic, diuretic and are good for spleen and lever as well as useful in inflammation, uses also include as an antiflatulent, carminative and in the treatment of cardiac disorders	Cooked as vegetables	Kutum et al., 2011 Hassan et al., 2016 Dandapat et al., 2014 Gill et al., 2015 Shah et al., 2010 Deb et al., 2013 Dandapat et al., 2015

69.	**English:** East Indian Glory Bower **Assamese:** Nephaphu **Khasi:** Dieng Jakangum, **Mizo:** Phuihnam **Nepali:** Anpui **Tangkhul:** Nareihan	*Clerodendrum colebrookianu m*		Kingdom: Plantae Phylum: Tracheophyta Class: Magnoliopsida Order: Lamiales Family: Lamiaceae Genus: Clerodendrum L. Species: colebrookianum	Asia	Sterol glycoside (clerosterol 3β-o-[β-d-glucoside]) along with clerosterol, sitosterol, octacosanol, colebrin A-E, β-sitosterol and sterol compounds	Moisture(%) 77.90 Carbohydrate 44.69 Fibre 11.26 Protein 13.88 Calcium 30.91 Potassium 27.69 Phosphorus 27.61 Magnesium 27.11 Sodium 22.86	Reduce Blood pressure; stomach trouble, malarial and bronchitis treatment, cure intestinal-helminth parasitic infections, anthelmintic properties, treating cardiac (hypertension), hepatic, and inflammatory disorders, use against dizziness, greenish swelling (gland), sore tongue in children, skin disease, cough, and dysentery	Cooked as vegetables	Kutum et al., 2011 Yumge et al., 2017 GOSWAMI et al., 1996 Kalita et al., 2014 Ogunwa et al., 2015
70.	**English:** Tropical Chickweed, Chickweed, **Assamese:** Laijabori **Hindi:** Pithpapra **Manipuri:** Tandal Pambi **Nepali:** Abhiijaalo **Tangkhul:** Biviyena	*Drymaria cordata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Caryophyllaceae Genus Drymaria Species cordata	Africa, Asia America	Stigmasterol, cerebroside, acylated stigmasteryl glucoside, stigmasteryl glucoside, glucocerebroside, monogalactosyldiacylglycerol and digalactosyldiacylglycerol	Moisture(%) 87.85 Carbohydrates 23.21±0.01 Fibre 16.53±0.05 Protein 12.51±0.39 Fat 1.73±0.02 Sodium 20.10±0.32 (mg) Potassium 317.51±0.10 Calcium 67.53±0.05 Phosphorus 50.56±0.20	Anti-inflammatory, antitussive, antibacterial, cytotoxic, anxiolytic activity, analgesic, anti-nociceptive and antipyretic properties, used for snake bite, for burns and skin diseases, used as an antidote, appetizer, depurative, emollient, febrifuge, laxative and stimulant in both human and animals, pneumonia, jaundice, muscular sprain	Cooked as vegetables	Kutum et al., 2011 Raymond et al., 2014 Arya et al., 2016
71.	**English:** Cluster Fig **Hindi:** Goolar **Manipuri:** Heibong **Telugu:** Paidi **Sanskrit:** Udumbara **Marathi:** Umber **Malayalam:** Atti **Tamil:** Atti **Kannada:** Rumadi **Oriya:** Dimri **Nepali:** Gular	*Ficus glomerata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Rosales Family Moraceae Genus Ficus Species racemosa	Australia, Malesia, Indo-China and Indian subcontinent	Tetra triterpene, glauanol acetate, and racemosic acid, gallic acid, vanillic acid, caffeic acid, vanillin, trans-ferulic acid, arbutin, hydroquinone, (+)- catechin; 5, syringic acid, (−)-epicatechin, p-coumaric acid, trans-ferulic acid, rutin hydrate, ellagic acid, benzoic acid, rosmarinic acid, myricetin, quercetin trans-cinnamic acid, kaempferol, Stigmasterol, β-sitosterol, gluanol acetate, ceryl behenate, lupeol acetate	Moisture(%) 65±0.23 Protein 1.48±0.15 Fat 0.95±0.08 Total sugars 5.70±0.06 SDF 2.60±0.02 IDF 5.17±0.02 TDF 5.52±0.04 Calcium 1729.3 ± 13.02 (ppm) Magnesium 196.2 ± 4.63 Phosphorous 443 ± 8.98 Zinc 0.49 Manganese 1.9 ± 0.14 Sodium 255 ± 42.03 Potassium 11975 ± 537.74 Iron 159.2 ± 2.03	treatment of diabetes, liver disorders, respiratory, urinary diseases and inflammatory conditions, anti-microbial, anti-cancer and anti-oxidant activity, used in dysentery, diarrhoea, billious affection and in dysmenorrhoea, antidiarrhoeal activity, hypoglycaemic activity, anti-inflammatory activity, hepatoprotective activity and the treatment of bronchitis, antihyperglycemic, anti-inflammatory, antibacterial effects, ailments such as dysentery, hiccoughs, asthma, diabetes, epididymis, cancer, scabies, myalgia, haemoptysis, intrinsic haemorrhage	Leaves are boiled with pork and eaten as curry	Kutum et al., 2011 Sudhakar et al., 2012 Ahmed et al., 2010 Zulfiker et al., 2010 Sumi et al., 2016 Smita et al., 2015
72.	**English:** Mustard, Leaf Mustard, Indian Mustard **Hindi:** Sarson **Manipuri:** Hangam **Tamil:** Kadugu	*Brassica juncea*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Brassicales Family Brassicaceae Genus Brassica Species juncea	Asia	Castasterone, teasterone, 24-epibrassinolide and typhasterol, 24-epibrassinolide, Oleic acid, n-pentacosane, gamolenic acid and tetrapentacontane, 1, 54-dibromo and linolenic acid, n-eicosane, 5-eicosene, benzenepropanoic acid, 3,5-bis(1,1-dimethylethyl)-4-hydroxy, methyl ester, cis,cis,cis-7,10,13- hexadecatrienal and eicosanoic acid and 9-octadecene, n-tetratetracontane, cis,cis,cis7,10,13-hexadecatrienal and pentadecanoic acid, n-tetratetracontane, alpha-linolenic acid and 2L,4Ldihydroxyeicosane	Moisture(%) 87.9±0.03 Carbohydrate 46.1±0.01 Crude fibre 6.5±0.06 Protein 33.1±0.01 Fat 2.7±0.01	Act as anti-cancerous and anti-microbial, anti-depressant effects during diabetes, possess antihyperglycemic activity, reduce diabetes related mental health problem, act as stimulants, diuretics and expectorants, act as anti-cancerous and anti-microbial compounds, anti-depressant effects during diabetes	Cooked as vegetables	Sharma et al.,, 2017 Sharma et al., 2015 Malan et al., 2011 Walia et al., 2011 Bembem et al.,2014

73.	**English:** Java Pennywort **Hindi:** Mahagotukola **Manipuri:** Awa Peruk **Malayalam:** Cheruvallei **Tamil:** Malai Vallarai	*Hydrocotyle javanica*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Apiales Family Araliaceae Genus Hydrocotyle Species sibthorpioides	Asia	δ–Elemene, τ –Elemene, Caryophyllene, cis-b-farnesene, Humulene, g-Elemene, b - Nerolidiol, (+)-Spathulenol, (-)-Spathulenol, Isoaromadendrene. Squalene (triterpene), phytol (diterpene), β-Sitosterol, Linoleic acid, Oleic acid methyl ester, Palmitic acid methyl ester, p – Cresol (Phenol), Cinnamic acid cyclohexyl ester	Moisture(%) 91.1 Carbohydrates 4.51 Sugars 1.41 Dietary fiber 2 Protein 2.56 Fat 0.47 Calcium(mg) 118 Iron 0.87 Magnesium 13 Phosphorus 42 Potassium 162 Sodium 9 Zinc 0.22	Cure stomach ulcer, urinary troubles, digestive complaints, dysentery, skin diseases, treating mental problems and to increase memory power, cure asthma and fits, used as a blood purifier, used as an aperient, against fever, skin diseases, ingested orally to cure sores of throats and lungs, used as eye drops to cure eye, infection and used in dressing of wounds to reduce swelling and treat gastritis and constipation, active against cancer, tumours, inflammation, pyrexia, microbes, fungus	Cooked as vegetables	Kutum et al.,2011 VAYAM et al., 2017 Mandal et al., 2017
74.	**English:** Creeping Tick Trefoil **Hindi:** Kudaliya **Mizo:** Bawngekhlo **Marathi:** Chipti **Tamil:** Sirupullati **Malayalam:** Munta-Mandu **Telugu:** Moohoodoo **Kannada:** Kaadu Pullampurasi **Bengali:** Kudaliya **Oriya:** Bawngekhlo **Sanskrit:** Hamsapadi, **Nepali:** Bute Kanike	*Desmodium triflorum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Fabales Family Fabaceae Genus Desmodium Species triflorum	Africa, Asia, Australia	Ursolic acid, vitexin, genistin, fucosterol and rare diholosylflavane, 2-0 glucosylvitexin, β-phenethylamine (major alkaloid), indole-3-acetic acid, tyrumine, trigonelline, hypaphorine and choline, beta phenylethaylamine, tyramine, hypaphorine, ursolic acid, vitexin, genistin, fucosterol, 2-o-β-xylosylvitexin, diholosylflavone, 2-o-glucosylvitexin	NF	Applied to wounds and abscesses that are usually difficult to heal, applied to sores and itch, use in dysentery and as a laxative, useful in curing bonefracture, used to promote labour and treat Vertigo, antispasmodic, sympathomimetic, central nervous system stimulation, curare-mimetic activity and used as mouth wash and as an expectorant, an antipyretic and to quench thurst, wounds, ulcers and for skin problems in general, antiseptic properties	Cooked as vegetables	Kutum et al., 2011 Gavalapu et al., 2013 Thankachan et al., 2017 Vedpal et al., 2016
75.	**English:** Curry Leaf **Hindi:** Kari Patta **Marathi:** Kudianim **Tamil:** Karivepillai **Malayalam:** Kareapela **Telugu:** Karepaku **Kannada:** Gandhabevu **Bengali:** Barsunga **Oriya:** Lesunadando **Assamese:** Bishahari **Mizo:** Arpatil **Sanskrit:** Alakavhaya	*Murraya koenigii*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Sapindales Family Rutaceae Genus Murraya Species koenigii	Asia	Tricyclene, α-Thujene, α-Pinene, Camphene, Sabinene, β-Pinene, Myrcene, α-Terpinene, p-Cymene, Limonene, cis-β-Ocimene, trans-β-Ocimene, γ-Terpinene, cis-Sabinene hydrate, α-Terpinolene, trans-Sabinene hydrate, Linalool, cis-p-2-Menthen-1-ol, trans-p-2-Menthen-1-ol, Terpinen-4-ol, α-Terpineol, Bornyl acetate, β-Bourbonene, β-Elemene, cis-Jasmone, β-Caryophyllene, α-Humulene, Bicyclogermacrene, α-Farnesene, δ-Cadinene, E-Nerolidol, Spathulenol, Caryophyllene oxide, Caryophylla-4, 8-dien-5-β-ol	Moisture(%) 76.6 ± 0.10 Carbohydrate 39.44 ± 0.04 Crude fibre 6.30 ± 0.05 Protein 8.38 ± 0.02 Fats 6.48 ± 0.22 Calcium 19.73 ± 0.02 (mg) Iron 0.16 ± 0.01 Magnesium 49.06 ± 0.02 Sodium 16.50 ± 0.21 Zinc 0.04 ± 0.001 Potassium 0.04 ± 0.001	Antiemetics, antidiarrheal, febrifuge, blood purifier, antifungal, depressant, anti-inflammatory, body aches, for kidney pain and vomiting	Cooked as vegetables	Kutum et al.,2011 Rana et al., 2004, Jain et al.,2012 Gahlawat et al., 2014 Senthilkumar et al., 2014 Rajendran et al., 2013 Igara et al., 2016 Nouman et al., 2015

76.	**English:** Chaste Tree **Hindi:** Nirgundi **Manipuri:** Urik Shibi **Tamil:** Nocchi **Malayalam:** Vennocchi **Telugu:** Vavili **Kannada:** Nochi **Bengali:** Nishinda **Sanskrit:** Sinduvara, **Urdu:** Sambhalu	*Vitex negundo*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Lamiaceae Genus Vitex Species negundo	Afghanistan, Pakistan, India, Srilanka, Thailand, Malaysia, Eastern Africa and Madagascar, America, Europe, China and West Indies	Friedelin, carotene, casticin, artemetin, terpinen-4-ol, α-terpineol, sabenine, globulol, spathulenol, β- farnesene, farnesol, bis(1,1dimethyl) methylphenol, α-pinene, β-pinene, linalool, terpinyl acetate, caryophyllene epoxide, caryophyllenol, vitexicarpin, viridiflorol, 4,4′′- dimethoxy-trans-stilbene, 5,6,7,8,3′4′5- heptamethoxy, 5-hydroxy-6,7,8,3′4′-pentamethoxy (5-Odesmethylnobiletin), 5-hydroxy-6,7,8,3′,4′,5-hexamethoxy(gardeninA), 5-hydroxy-6,7,8,4′-tetramethoxy (gardeninB), 5- hydroxy-7,3′,4′,5′-tetramethoxyflavone (corymbosin), terpinen-4-ol, α-copaene, β-caryophyllene, β-elemene, camphene, α-thujene, α-pinene, sebinene, linalool, stearic acid and behenic acid, α-elemene, δ- elemene, β-elemene, β-eudesmol, camphor, camphene, careen, 1,8- cineol, 1-oceten-3-ol, γ-terpinine, α-phellendrene, β-phellendrene, α- guaiene, abieta-7,13-diene, neral, geranial, bornyl acetate, nerolidol, β-bisabolol, cedrol, 2′-p-hydroxybenzoyl mussaenosidic acid, agnuside, lagundinin, aucubin and nishindaside, viridiflorol, squalene, 5-hydroxy-3,6,7,3′,4′- pentamethoxy flavone, 5-hydroxy-3,7,3′,4′-tetramethoxy flavones, 5,3-dihydroxy- 7,8,4- trimethoxy flavanone, p-hydroxybenzoic acid, 3,4-dihydroxybenzoicacid, luteolin-7-glucoside, isoorientin, 3′-benzoyloxylhydroxy-3,6,7,4-tetramethoxyflavone, 5,3′-dibenzoyloxy-3,6,7,4-teramethoxyflavone, 5,3′-Dipropanyloxy-3,6,7,4′-tetramethoxyflavone,5,3Dibutanoyloxy3,6,7, 4-tetramethoxyflavone, 5,3′-Dipenty4enoyloxy 3,6,7,4′tetramethoxyflavone, 5,3-Dihexanoyl 3,6,7,4-tetramethoxyflavone, betulinic acid, ursolic acid, dimethoxyflavonone, 5,3′-dihydroxy-7,8,4′-trimethoxyflavonone, 7,8-Dimehylherbacetin-3-rhamnoside, vitegnoside , 1,4a,5,7a tetrahydro 1βDglucosyl(3′,4′dihydroxybenzoyloxymethyl)-5-ketocyclopenta[c] pyran-4-carboxylic acid, luteolin-7-O-β-D-glucosid, 6′-p-hydroxy benzoylmussaenosidic acid	Moisture(%) 83.15 Carbohydrates 26.43 Crude Fiber 28 Crude Protein 13.73 Crude Fat 7	Treatment of inflammation, eye-disease, toothache, leucoderma, enlargement of the spleen, ulcers, cancers, catarrhal fever, rheumatoid arthritis, gonorrhea, sinuses, scrofulous sores, bronchitis and as tonics, vermifuge, lactagogue, emmenagogue, antibacterial, antipyretic, antihistaminic, analgesic, insecticidal,ovicidal, feeding deterrence, growth inhibition and morphogenetic agents, rheumatic pains, sprains, and inflammations	Cooked as vegetables	Kutum et al., 2011 Suganthi et al., 2016 Keerti et al., 2012 Mani et al., 2013 ROSE et al.,2011 Kumar et al., 2010 Panti et al.,2014
77.	**English:** Cuban Oregano, Indian Borage **Hindi:** Patharchur **Marathi:** Pathurchur **Tamil:** Karpuravalli **Malayalam:** Panikkurkka **Telugu:** Sugandhavalkam **Kannada:** Karpurahalli **Sanskrit:** Karpuravalli	*Plectranthus amboinicus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Lamiaceae Genus Plectranthus Species amboinicus	Asian and African countries	Biogenic zinc oxide nanoparticles, Carvacrol, p-Cymene, α-Terpinolene & β-caryophyllene, Pam-ZnO NPs (zinc oxide nanoparticles), Flavone (Luteolin), flavonols, Thymol, 1,8-Cineole, β-Pinene, α-pinene, phenolic compounds, Carvacrol, thymol, β-caryophyllene, cholorogenic acid, rosmarinic acid, kaempferol, quercetin, rutin, caffeic acid, myricetin, luteolin, apigenin	Moisture(%) 98.3 Carbohydrate 48.12 Crude fiber 11.13±0.28 Protein 16.45	Possess antimicrobial, antiepileptic and antioxidant properties, treatment of chronic coughs, cold, bronchitis, asthma, nasal congestion as well as diarrhoea, remedy for infections, rheumatism and flatulence, treat chronic cough, urinary disease, used as an aromatic carminative and anthelmintic, reported to have antimicrobial, cytotoxic and antioxidant activities	Tender shoots are eaten as vegetables, suitable with pork and considered a good vegetable by Mishing.	Kutum et al.,2011 Nataraj et al., 2013 hawary et al., 2012 Arumugam et al., 2016 Santhiya et al., 2013 IWANSYAH et al., 2016

78.	**English:** Sponge Gourd **Hindi:** Ghia Torai **Marathi:** Palo **Telugu:** Neyangnattakolu **Assamese:** Bhatkakrel **Kannada:** Thuppada Heere	*Luffa aegyptiaca*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Cucurbitales Family Cucurbitaceae Genus Luffa Species aegyptiaca	Asian and African countries	Lucyin A, lucyosides G, N, O, P, Q, R, 21β-hydroxyoleanoic acid, 3-O-β-Dglucopyranosyl- maslinic acid, ginsenosides Re, Rg1; flavonoids: apigenin	Moisture(%) 95.99 Carbohydrate 2.54 Fibre 12.00 Protein 0.30 Fat 0.006	Antioxidant, antimicrobial, antifungal, anticancer, anti-inflammatory, antiangionic and anti-alergic, used in snake bite, treatment of spleenopathy, leprosy, haemorroids, tumours, bronchitis and syphilis	Eat tender leafy twigs as leafy vegetable	Jana et al.,2007 Mhya et al., 2014 Nair et al., 2010 Sangh et al., 2012 Osuagwu et al.,, 2014 Sharma, et al., 2014 Aladejimokun et al., 2014
79.	**English:** Common Cocklebur, Broad Bur **Hindi:** Chota Dhatura **Marathi:** Ghagara **Tamil:** Marul-Umattai **Telugu:** Marulutige **Kannada:** Maruluummatti **Gujarati:** Godrian **Sanskrit:** Arishta	*Xanthium strumarium*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Asterales Family Asteraceae Genus Xanthium Species strumarium	Africa and Asian countries	Limonene, β-caryophyllene, α-cadinol, spathulenol, limonene and 1,3,5-trimethyl-2[2-nitroallyl]benzene, Phytol, α-muurolene, copaene, E,E,Z-1,3,12-nonadecatriene-5,14-diol, stigmasterol (1), 11-hydroxy-11-carboxy-4-oxo-1(5),2(Z)-xanthadien-12,8-olide (2), daucosterol (3) and lasidiol-10-anisate, γ-Cadinene, α-Muurolene, Valencene, cis-β-Guaiene, β-Selinene, Germacrene D, α-Humulene, β-Gurjunene, α-Pinene, Camphene, Sabinene, Myrcene, p-Cymene, Linalool , trans-Verbenol, Borneol, trans-Carveol, Bornyl acetate, Tridecane, α-Cubebene, Eugenol, α-Ylangene, α-Copaene, β-Cubebene, β-Elemene caffeic acid, potassium3-O-caffeoylquinate, 1-O-caffeoylquinic acid, chlorogenic acid, 4-O-caffeoylquinicacid, 1,4-di-O-caffeoylquinic acid, 1,5-di-O-caffeoylquinic acid, 3,5-di- O-caffeoylquinicacid, 4,5-di-O-caffeoylquinic acid, 1, 3, 5-tri-O-caffeoylquinic acid, 3, 4, 5-tri- O-caffeoylquinic acid and cynarin,	Moisture(%) 91.55 ± 0.01 Carbohydrate 19.30 ± 0.09 Fibre 61.80± 0.04 Protein 0.64 ± 0.01 Fats 5.51 ± 0.01 Calcium(mg) 9.95+0.02 Boron 0.38+0.09 Iron 0.076+0.06 Potassium 19.49+0.03 Magnesium 2.18+0.1 Manganese 0.02+0.01 Phosphorus 0.88+0.022 Zinc 0.02+0.023	Antiviral, antitumor, antimicrobial, insecticide, cooling, laxative, fattening, anthelmintic, alexiteric, tonic, digestive, antipyretic, and improves appetite, voice, complexion, and memory, cures leucoderma, biliousness, and poisonous bites of insects, epilepsy, salivation and fever, urticaria, headache, sinusitis, arthritis and emphysema, sedative, diaphoretic and diuretic properties, antitussive, antiplasmodial activites, antinociceptive, antimitotic	Cooked as vegetables	Srinivas et al., 2011 Parveen et al, 2017 Islam et al., 2009 Sharifi-Rad et al., 2015 Kumar et al., 2016 Kamboj et al., 2014 Hussain et al., 2013
80.	**English:** Chickweed, Starweed, Star Chickweed **Hindi:** Buch-Bucha **Manipuri:** Yerum Keirum	*Stellaria media*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Caryophyllaceae Genus Stellaria Species media	Asia and African, Europe and American countries	Orientin, isoorrientin, vitexin, isovitexin; isovitexin 7,2''-di-O-beta-glucopyra-noside; isovitexin 7-O-beta-D-galactopyranoside-2''-O-beta-glucopyranoside; luteolin; apigenin; genistein,6,8-2-C-vicenin-2; vanillic acid; p-hydroxybenzoic acid; ferulic acid; caffeic acid; chlorogenic acid; saccharopine; aminoadipic acid; ascorbic acid; dehydroascorbic acid	Moisture(%) 86.65 Carbohydrate 7.20 Fibre 10.36 Protein 18.58 Fat 4.86	Treatment of mental tension and inflammations of the digestive, renal, respiratory and reproductive tracts, anticancer, antipyretic, anti-inflammatory, antibacterial, antifungal, anxiolytic activity; Fresh leaves paste is applied topically for Swelling joints, broken bones; Fresh leaves decoction is taken orally for Constipation	Cooked as vegetables	Kayang et al., 2007 https://www.mdidea.com/products/proper/proper08903.html, Arora et al., 2014 Dong et al., 2007 Chandra et al., 2016, Abbasi et al., 2013

81.	**English:** Shiny Bush, Slate Pencil Plant, Pepper Elder, Rat's Ear **Malayalam:**Mashitandu Chedi **Assamese:** Pononoa **Sanskrit:** Toyakandha **Nepali:** Latapate	*Peperomia pellucida*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Magnolianae Order Piperales Family Piperaceae Species pellucida	South America and Asia	Carotol, apiols, peperomins, acacetin, apigenin, isovitexin, and pellucidatin, campesterol and stigmasterol, secolignans, two tetrahydrofuran lignans, methoxylated dihydronaphthalenone, peperomins A, B, C, E, 7, 8 - trans 8, 8‘ – trans -7‘ ,8‘- cis- 7, 7‘ – bis (5-methoxy-3,4methylenedioxyphenyl) - 8 - acetoxymethyl-8‘hydroxymethyltetrahydrofuran, 7, 8 – trans - 8, 8‘ – trans - 7‘, 8‘ – cis -7- (5-methoxy-3,4 methylenedioxyphenyl) -7‘ -(4-hydroxy -3, 5-dimethoxyphenyl) -8, 8‘ diacetoxymethyltetrahydrofuran, sesamin, and isoswertisin, Patuloside A, apigenin 6-C-beta-D-galactopyranosyl-8-C-alpha-L-arabinopyranoside, apigenin 6-C-alpha-L-arabinopyranosyl-8-C-beta-D-galactopyranoside, apigenin 6-C-beta-D-galactopyranosyl-8-C-beta-L-arabinopyranoside, apigenin 6-C-beta-D-glucopyranosyl-8-C-beta-D-galactopyranoside, apigenin 6, 8-di-C-alpha-L-arabinopyranoside	Moisture(%) 90.09 Carbohydrate 38.97 Fibre 22.35 Protein 7.68 Calcium 1.82 Magnesium 0.62 Potassium 0.59	Treating abdominal pain, abscesses, acne, boils, colic, fatigue, gout, headache, renal disorder and rheumatic joint pain, as a hypocholesteremic agent, cough suppressant, emollient and diuretic, treatment of proteinuria, stop hemorrhages, treatment of excited mental disorder, used against eye inflammation, described to passify vitiated cough, pitta, constipation, kidney diseases, urinary retention, dysuria, urinary tract infections, emaciation, edema and general weakness	Cooked as vegetables	Kayang et al., 2007 Egwuche et al.,2011 Majumder et al., 2011 Verma et al., 2014 TEKNOLOGI et al., 2012 Wei et al., 2011
82.	**English:** Sweet Potato **Gujarati:** Ratalu **Hindi:** Shakrkand **Kannada:** Sihigensu **Malayalam:** Madhurakkilannu]**Manipuri:** Mangra **Marathi:** Kanamgi **Sanskrit:** Raktaluh **Tamil:** Sarkaraivallikizangu **Telugu:** Genusu **Tangkhul:** Meiteipai	*Ipomoea batatas*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Solanales Family Convolvulaceae Genus Ipomoea Species batatas	Asia	Tetracosane, myristic acid, beta-sitosterol, beta-carotene, daucosterol and quercetin, abietadiene, β-caryophyllene, abieta-8,11,13-triene, trans-(Z)-α-bergamotol, cissabinene and spathulenol, caffeic acid and chlorogenic acid, β- sitosterol, scopoletin, cis-methylcaffeate, transmethylcaffeate, cis-ethylcaffeate, trans-ethyl caffeate, scopolin and adenosine [25,26]. Quercetin-3-o-β-D-glucopyranosyl(6→1)-o-α-Lrhamnopyranoside, kaempferol-4,7-dimethylether, quercetin-3-o-β-D-glucoside and quercetin, 3,4-di-O-caffeoylquinic acid, 3,5-di-Ocaffeoylquinic acid, 4,5-di-O-caffeoylquinic acid and 3,4,5-tri-O-caffeoylquinic acid	Moisture(%) 88.92 Carbohydrate 20.1 Dietary fibre 3 Protein 1.6 Calcium(mg) 30 Magnesium 25 Phosphorus 47 Potassium 337 Sodium 55 Iron 0.6 Zinc 0.3	Used in the treatment of urinary infections, fever, skin diseases, diabetes, curing boils and acnes, improve insulin sensitivity, displayed antibacterial, antidiabetic and anti-neuroinflammatory activities, Hypoglycemic Activity, Antiulcer Activity, Wound healing Effect, Antimutagenicity, Cardiovascular Effect, Hepatoprotective Effect, Immunomodulatory Effect, Anti-proliferative Activity, Antifungal Activity	Cooked as vegetables	Kayang et al., 2007 Ogunmoye et al.,2015 Panda et al., 2012
83.	**English:** Tubeflower, Turk's-Turban **Hindi:** Bharangi **Manipuri:** Kuthap **Bengali:** Bamunhati **Tamil:** Kavalai **Telugu:** Bharangi **Sanskrit:** Bhargi	*Clerodendrum indicum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Lamiaceae Genus Clerodendrum Species indicum	Asia	Clerodendrone, hydroquinone diterpenoid, scutellarein, hispidulin and their 7-O-glucuronides and also sterol, β-sitosterol, 3, 4-dihydroxyphenyl ethanol, cupafolin, laricirecinol 9-0-β-D-glucoside	NF	Treats malaria and rheumatism, antinociceptic activity, as analgesic, uses in serofuloud infection, buboes, venereal infection and skin diseases, as a vermifuge, febrifuge, rheumatism, asthma and other inflammatory diseases, antiasthma, anti-inflammatory and antipyretic, antifungal, antioxidant and wound healing, anti-obesity, antinociception, antimicrobial, inhibition of angiotensin converting enzyme and a-glucosidase and antimutagenicity	Cooked as vegetables	Kayang et al., 2007 Raihan et al., 2012 Barua et al., 2014, Pal et al., 2012 http://www.mpbd.info/plants/clerodendrum-indicum.php, Pallab Kar et al., 2014

84.	**English:** Nongmangkha **Assamese:** Titaaphul **Bihar:** Chuhai **Manipur:** Nongmangkha **Khasi:** Dieng-Soh Kajut **Garo:** Ellot **Bengali:** Tamropuspi Basak **Tangkhul:** Sipchang **Nepali:** Chuwaa	*Phlogacanthus thyrsiflorus*		Kingdom Plantae Division Magnoliophyta Class Magnolipsida Order Lamiales Family Acanthaceae Subfamiliy Acanthoideae Genus Phlogacanthus Species thyrsiflorus	India, Burma, Malaya peninsula and Indonesia	Quericetin and Kaempferol, Phenol, 2,6-dimethoxy-, Dispiro [2.2.2.2] deca-4,9-diene, N, N-dimethyltrimethylsilamine, 1, 8-diamino-3,6-dioxaoctane, Benzoic acid, 4-hydroxy-3,5-dimethoxy-, hydrazide, Orcinol, 2,6,6-trimethyl-bicyclo[3.1.1]heptane, trans, Hexadecanoic acid, methyl ester, 9-Octadecenoic acid (Z)-, methyl ester, Phytol, Methyl stearate, Cyclopropane, isothiocyanate-, 7H-Purin-6-amine, 7-methyl, Squalene, Alloaromadendrene, Stigmasterol, 5-methyl-2-phenyl-1H-indole, 2-Ethylacridine, diterpene lactone, Phlogantholide.	NF	Opthalmia, acidity, indigestion, cough and cold, whooping cough, asthma, chronic bronchitis, worm, heart disease, rheumatism, diarrhea, dysentery, piles, pox, antiseptic, leukoderma, treat fever, Rheumatoid arthritis, cancer, whooping cough, Menorrhagia, uses are cold, cough, influenza, easy delivery of childbirth, abortion, irregular menstruation, diarrhea, dysentery, cholera, high blood pressure control, boils, smallpox, skin problems, sprains, body ache, constipation, and burns	Cooked as vegetables	Sharma et al., 2016 KITLANGKI et al., 2017 Chakravarty et al., 2012 Kumar et al., 2017 Ahmed et al.,2016 Phurailatpam et al., 2014 Gupta et al., 2018
85.	**English:** Prickly Sow-Thistle **Hindi:** Dudhi **Manipuri:** Khomthokpi **Marathi:** Mhatara	*Sonchus asper*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Asterales Family Asteraceae Genus Sonchus Species asper	Asia	Trans-anethole, Diethoxymethyl-3-methylbutanol, 2-Pentadecanone,6,10,14-trimethyl 38.21 2.54 1-Dodecanol,3,7,11-trimethyl, Heneicosane, 2-Hydroxy-1,1,10-tri methyl-6,9-epidioxyde, Phytol, Phytol isomer, Hexatriacontane, Heptacosane, 1,3-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester, Dotriacontane	Moisture(%) 89.87± 1.87 Carbohydrate 7.75 ± 0.50 Fibre 18.33 ± 0.72 Protein 13.25± 0.05 Sodium(mg) 0.288 Potassium 2.366 Calcium 3.397 Magnesium 0.689 Iron 883 Zinc 50 Phosphorus 0.297 Copper 16 Manganese 117	Used in various human disorder including wounds and burns, cough, bronchitis and asthma, gastrointestinal infection, inflammation, diabetis and cardiac dysfunction, kidney and liver disorders, reproductive disorder like impotence (erectile dysfunction) in humans, jaundice and cancer, bacteriocidal, fungicidal and phytotoxic activities, Leaves decoction is taken orally for Fever, constipation	Cooked as vegetables	Kayang et al., 2007 Jimoh et al., 2011 Ibrahim et al., 2015 Upadhyay et al., 2013; Abbasi et al., 2013
86.	**English:** Chinese Mallow, Cluster Mallow, Curled Mallow **Lahaul:** Mikanchi	*Malva verticillata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Malvales Family Malvaceae Genus Malva Species verticillata	E. Asia - China	L-arabinose, Dgalactose and D-glucose, myristoleic acid, verticilloside, tetracontanyl palmitate and a waxy ketone, Tetracontanyl palmitate, quinic acid, tryptophan, hyperin, kaempferol-3-O-rutinoside, quercetin-3-rhamnoside (quercitrin), and biochanin A	NF	Used to enhance kidney strength, remove renal stones, and phagocytic, anticomplementary and hypoglycemic, phagocytic and anticomplementary, antidaebetic, lubricates the intestines, cleansing the bowels, induces diuresis and promotes lactation and has further curative effects on diseases, such as edema, kidney heat, bladder heat, odynuria, urodialysis, diabetes and abscess	Cooked as vegetables	Kutum et al., 2011 https://www.pfaf.org/user/plant.aspx?LatinName=Malva+verticillata Azab et al., 2017 Bao et al., 2017 Shovan et al., 2017
87.	**English:** Winged Bean **Manipuri:** Tengnoumanbi **Bengali:** Charkoni-Sem **Tangkhul:** Tengnoumanbi	*Psopocarpus tetragonolobus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Fabales Family Fabaceae Genus Psophocarpus Species tetragonolobu	Malaysia, Indonesia, Thailand, the Philippines, India, Bangladesh, Myanmar, Sri Lanka, West Indies, and South Florida	Gallic, protocatechuic, chlorogenic, caffeic, ferulic acid, rutin, quercetin and kaempferol	Moisture(%) 75.29 Protein 26.29 Fiber 10.04 Calcium 0.30 Phosphorus 0.35 Magnesium 0.40 Potassium 0.84 Iron(mg) 18.16 Zinc 6.13	Used as a lotion to cure smallpox, used as a poultice to treat vertigo, leaf infusion is used as a wash for inflammation and suppurating sores, and the leaves are applied to cure boils	Cooked as vegetables	Kutum et al., 2011 Alalade et al., 2016 Latha et al., 2007 Mohanty et al., 2013

88.	**English:** Butterfly Tree, Pink Butterfly Tree, Purple Bauhinia **Hindi:** Kaniar **Tamil:** Nilattiruvatti **Bengali:** Koiral **Assamese:** Og-Yok **Marathi:** Rakta Kanchan **Kannada:** Devakanchan, **Tangkhul:** Haochokwon	*Bauhinia purpurea*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Fabales Family Fabaceae Genus Bauhinia Species purpurea	India, Pakistan, and Sri Lanka	5,6-Dihydroxy-7- methoxyflavone 6-O- β –D xylopyrano-Side, bis [3',4'-dihydroxy-6-methoxy-7,8-furano-5',6'- mono-methylalloxy]-5-C-5-biflavonyl and (4'-hydroxy-7-methyl 3-C-α-L-rhamnopyranosyl)-5-C5-(4'-hydroxy-7-methyl-3-C-α-D-glucopyranosyl) bioflavonoid, bibenzyls, dibenzooxepins, mixture of phytol fatty esters, lutein, β-sitosterol, isoquercitin and astragalin	Moisture(%) 88 Carbohydrate 5±0.346 Protein 0.52±0.023	Anti-diarrhoeal, anticancer, thyroid gland stimulating properties, anti-oxidant activity, hepatoprotective activity, hypoglycaemic activity, antiproliferative, anti-inflammatory activity, treat ulcer, wound, glandular swelling, stomach tumor, antidote to poison, anastringent to treat diarrhea, antihelminths, leprosy, menstrual disorders, disorders of the rectum	Cooked as vegetables	Kayang et al., 2007 Marimuthu et al., 2014 Prasanna et al., 2012
89.	**English**: Shampoo Ginger **Assamese:** Gathian **Bengali:** Kulanjan **Hindi:** Banadrak **Kannada:** Agale Shunti **Malayalam:** Kathu-Inshi-Kua **Manipuri:** Yaimu **Marathi:** Kaali Halad **Oriya:** Viranam **Sanskrit:** Ahava **Tamil:** Araniyacaranai **Telugu:** Kaarallamu **Urdu:** Kapur Kachri	*Zingiber zerumbet*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Lilianae Order Zingiberales Family Zingiberaceae Genus Zingiber Species zerumbet	E. Asia - southern China, Indian subcontinent, Myanmar, Thailand, Cambodia, Laos, Vietnam, Malaysia, Indonesia, Philippines. Habitat	(E)-nerolidol, beta-caryophyllene and linalool, quercetin, catechin, rutin, luteolin, myricetin, kaempferol, α- and β-pinene, zingiberene, zerumbone, camphene, 1,5,5,8-tetramethyl-12-oxabicyclo[9.1.0]dodeca-3,7-diene, trans-nerolidolcamphor, caryophyllene oxide, limonene, eucalyptol, camphene, 3-carene, linalool, borneol, 4-terpineol and cycloheptane, 4-methylene-1-methyl-2-(2-methyl-1-propen-1-1-yl)-1-vinyl	NF	Used in therapies for joint pain, plant used as antiinflammatory adjuvant for stomach pains, fever and sprains, anticancerous activity	Young leaves and shoots - cooked as a vegetable	Koga et al., 2016; FADZIL et al., 2010 Ghasemzadeh et al., 2016 ; N. J. Yob, 2011 Sivasothy et al., 2011 Bhuiyan et al., 2009 Ming et al., 2003
90.	**English:** Climbing Acacia **Hindi:** Agla Bel **Marathi:** Shembarati **Tamil:** Inthu **Malayalam:** Kaariinja, **Telugu:** Guba Korinda **Kannada:** Kaadu Seege **Oriya:** Gohira **Konkani:** Sambu **Sanskrit:** Ari **Nepali:** Arkhu	*Senegalia pennata*		Kingdom Plantae Division Tracheophyta Class Magnoliopsida Order Fabales Family Fabaceae Genus Senegalia Species pennata	Asia	3-picoline-2-nitro, 1-acetyl beta carboline, Hydroxy citronellal, Trans decalone, Propionic acid-2-chloro,ethyl ester, Lavandulyl acetate and D-Glucoronic acid	Moisture(%) 60.9 Carbohydrate 7.9 Dietary Fiber 12 Protein 33.1 Fat 2.0 Ash 7.9 Vitamin C 18 Sodium(mg) 21 Potassium 88 Calcium 10 Iron 20	Treat coughs, headaches, rheumatism and fever, antibacterial activity, antimalarial activity, antifungal activity, antibiotic activity, anti-diarrhea activity, molluscidal activity, anti hypertensive activity, anthelmentic activity, anti denaturation property, antioxidant and anticancer property	Cooked as vegetables	Hemamalini et al., 2013 https://www.myfitnesspal.com/food/calories/vegetable-acacia-pennata-304775375

91.	**English:** Water Cabbage, Nile Cabbage, Tropical Duckweed, Water Lettuce **Assamese:** Borpuni **Bengali:** Takapana **Hindi:** Jal Kumbhi **Kannada:** Anthara Gange **Malayalam:** Kodda-Pail **Manipuri:** Kabokang **Marathi:** Gondala **Sanskrit:** Akashamuli **Tamil:** Agasatamarai **Telugu:** Akasatamara **Urdu:** Jalakumbhi	*Pistia stratiotes*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Lilianae Order Alismatales Family Araceae Genus Pistia Species stratiotes	Asia, Africa and America	Vitamins A & C, stigma-sterol, stigma-steryl, stigma-sterate, palmitic acids, 2-di-cgl-cosy-flavones of vicenin and lucenin type, anthocyanin cyaniding-3-glucoside, luteolin-7-glucoside and mono-C-glcosyl flavones–vitexin and orientin, Stratioside II (a new C13 norterpene glucoside), rich in proteins, essential amino acids, stigmatane, sito-sterol acyl glycosides, Vicenin, sitosterol acylglycosides; phytosterols, di-c-glycosyl-flavones, anthocyanin; cyanidin-3- glucoside and a luteolin-7-glycoside, mono-cglycosylflavones, vitexin and orientin, Ergosta-7, 22-diene-3,5,6-triol, 7-hydroxyl-sitosterol, sitoindoside, soya-cerebroside, luteolin, chrysoeriol 4-O-Dglucopyranoside, sitosterol and daucoterol, Trideutero methyl ethyl ether (5.62%), Tetradecane (2.83%), Trans-2-fluoro-3-(trimethylsily) octanoli–de (3.66%), Phytol acetate (4.20%), 2-Hexadecan-1- 01, 3.7,11,15-tetramethyl (11.27%), Glycerol 1-Palmitate (5.64%) and 2,6,10,14,18,22-Tetra-Cosahexane	Moisture(%) 92.9 Carbohyrate 2.6 Crude fibre 0.9 Protein 1.4 Fat 0.3 Potassium 5.56 Calcium 3.24 Magnesium 1.00 Phosphorus 0.26 Sodium 0.61	Applied to boils, wounds, syphilitic lesions and skin infections, cure of dysentery, treatment of tuberculosis and asthma, worked well with skin and hair infections caused by various dermatophytes as well as fungi, used as antiseptic, antitubercular, used as an anodyne for eyewash and for relieving ear complaints, used in eczema, leprosy, ulcers, piles, and syphilis, leaf extract boiled in coconut oil is applied to the skin in chronic dermatitis, useful for relieving nervous disorders, fever and intestinal bacterial infections, useful in the treatment of stomach disorder, throat and mouth inflammation	The young leaves are served as cooked vegetable	http://manenvis.nic.in/Database/WildEdiblePlants_2940.aspx Adeyemi et al., 2016 KHAN et al., 2014 Nisha et al., 2018 Tyagi et al., 2016
92.	**English:** Sage Weed **Hindi:** Kamrkash **Kannada:** Kachora **Malayalam:** Pulam-Kizhanma **Sanskrit:** Samudraphala **Tamil:** Chimaikkarppuram Kasturimanjal **Telugu:** Kachoralu, Kichili-Baddalu	*Salvia officinalis*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Lamiaceae Genus Salvia Species officinalis	Asia and Europe	α- and β- thujone together with cineole, borneol, diterpenes, phenolic glycosides based on caffeic acid, p- hydroxybenzoic acid, α-humulene, 1,8-cineole, E-caryophyllene, camphor16, borneol, bornyl acetate, α-pinene, β-pinene, α-thujone, eucalyptol andmyrcene, carnosic acid and carnosol, rosmarenic acid, methyl rosmarenate, caffeic acid, cinnamic acid, chlorogenic acid, quinic acid and salvianolic acids, ferulic acid, apigenin, luteolin and quercetin, luteolin-7-glucoside and other phenolic glycosides, carnosic acid, rosemarinic acid and caffeic acid	Moisture(%) 6.77±0.51 Carbohydrate 67.89 Proteins 6.77±1.02 Lipids 8.96±0.65 Calcium (ppm) 18080±0.50 Potassium 18396±0.59 Magnesium 993±1.20 Iron 172.1±0.30 Zinc 3.33±1.34	Antidiarrhoeal; Antihydrotic; Antiseptic; Antispa smodic; Appetizer; Aromatherapy; Astringent; C arminative;Cholagogue; Galactofuge; Stimulant; Tonic; Vasodilator; treatment of excessive lactation, night sweats, excessive salivation (as in Parkinson's disease), profuse perspiration (as in TB), anxiety, depression, female sterility and menopausal problems; used to treat insect bites, aromatherapy, skin, throat, mouth and gum infections and vaginal discharge; used in small doses to remove heavy collections of mucous from the respiratory organs and mixed in embrocations for treating rheumatism; it can cause epileptic fits, giddiness; approve for loss of appetite, inflammation of the mouth, excessive perspiration	Cooked as vegetables	http://manenvis.nic.in/Database/WildEdiblePlants_2940.aspx Muttalib et al., 2012 Feky et al., 2016 Ghorbani et al., 2017 Khedher et al., 2017
93.	**English:** Ginkgo, Maidenhair Tree **Nepali:** Bal Kumari	*Ginkgo biloba*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Ginkgoopsida Subclass Ginkgooidae Order Ginkgoales Family Ginkgoaceae Genus Ginkgo Species biloba	East Asia	Quercetin-3-β-D-glucoside, Quercitrin, Rutin, Kaempferol, Isorhamnetin, Ginkgolide A-C, Bilobalide, 4-O-methylpyridoxine, catechin hydrate (15.1347%), eriodictyol (8.0492%), quercetin (5.5179%), ferulic acid(4.7164%), quercetrin (2.9307%), rutin (2.1532%), caffeine (2.0351%), narengin (1.5054%), apigenin (1.2922%), caffiec acid (0.9222%), hisperidin (0.8883%), luteolin (0.1544%), 7-hydroxy flavon(0.1186%) , kaempeferol (0.1135%), rosmarinic (0.1021%), narenginin (0.0892%), hispertin (0.0668%	Moisture(%) 78.18 Carbohydrate 0.21 Crude Protein 41.3 Ash 14.14 Sodium(mg) 28.1 Potassium 111.17 Cu 8.82 Mn 1.78 Zn 1.89	Treat patients with memory loss, dizziness, sleep disorders, dementia, tinnitus and peripheral circulatory disorders, used to treat heart and lung dysfunctions, skin infections, antiinflammatory, antitumor, anti-proliferation, cognitive, neuropsychiatric, hepatoprotective, cardiovascular, antidiabetic and other miscellaneous roles, treat diverse ailments such as cough, malaria, wounds, and rheumatism, antioxidant, antimicrobial, antivirus, anticancer	Cooked as vegetables	Ibrahim et al., 2016 Ding et al. 2006 Drewke et al., 2010 Mohanta et al., 2014 Salem et al., 2015 MOHEE et al., 2009; Sati et al., 2015

94.	**English:** Toothache Plant, Para Cress **Hindi:** Akarkar, Pipulka **Marathi:** Pipulka, Akarkara **Kannada:** Hemmugalu **Assamese:** Pirazha **Tangkhul:** Ansa Han	*Spilanthes oleracea*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Asterales Family Asteraceae Genus Spilanthes Species olercea	Southeast Asia	Quercetin-deoxyhexoside-di-hexoside, Cyanidin-3-O-glucoside, Quercetin-dihexoside, Quercetin-rhamnosyl-hexoside, Quercetin-rhamnosyl-rutinoside, Quercetin-3-O-rutinoside, Quercetin-3-O-glucoside, Delphinidina-3-O-glucuronide, Quercetin-3-O-glucuronide, Quercetin-acetylhexose-deoxyhexoside, Quercetin-acetyl dihexoside, dicaffeoylquinic acid, Quercetin-acetyl hexoside, Quercetin-diacetyl hexoside, Caffeoylquinic acid dihexose derivative	Moisture (%) 81.74 ± 0.13 Carbohydrates 13.56 ± 0.79 Dietary fibre 10.11 ± 0.41 Protein 2.84 ± 0.11 Fat 0.41 ± 0.03 Calcium 0.105 ± 0.035 (mg) Coper 0.165 ± 0.057 Iron 1.500 ± 0.540 Potassium 0.355 ± 0.007 Magnesium 0.06 ± 0.028 Manganese 0.555 ± 0.239 Sodium 0.010 ± 0.00 Potassium 0.080 ± 0.020 Sulfur 0.060 ± 0.014 Strontium 0.897 ± 0.328 Zinc 0.543 ± 0.144	Uses as anaesthetic, anticonvulsant, antiseptic, antifungal, antiprotozoal, antidiarrhoeal, analgesic, antiulcer, antipyretic, antidiuretic, antiinflammatory, diuretic, aphrodisiac and insecticidal agent, treatment of various mouth ailments such as gingivitis, oral ulcer, sore throat, and general toothache, used as the medicine for many infectious diseases and life-threatening conditions such as different blood diseases, anaemia, haemorhhage, cancer, dysentery, gastrointestinal ulcer, rheumatism, and snake bite, useful antimalarial medication, use in the treatment of blood related disorders has been attributed to its known cytotoxic, antioxidant, and vasorelaxant activities, aphrodisiacs (libido enhancers), and prescribed for cases of impotency, anaesthetic, antiinflammatory, analgesic, antipyretic, antiobesity and diuretic activities	Cooked as vegetables	Lalthanpuii et al., 2016; González et al.,, 2015
95.	**English:** Celery **Hindi:** Bari Ajmod **Marathi:** Bodiajamoda **Urdu:** Ajmod **Gujarati:** Bodiajamodia **Sanskrit:** Ugragandhika **Nepali:** Jangali Jwanu **Tangkhul:** Sirai Kahui	*Apium graveolens*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Apiales Family Apiaceae Genus Apium Species graveolens	Southeast Asia	z-3-Hexen1-ol, α–Pinene, Myrcene, Limonene, β-Caryophyllene, α-Humulene, β-selinene, α-Selinene, Kessane, 3-Butylphthalide, Sedanenolide, caffeic acid, p-coumaric acid, ferulic acid, apigenin, luteolin, tannin, saponin, and kaempferol	Moisture(%) 81.34 Crude Fibre 19.28 Crude Protein 7.53 Crude Fat 0.59 Crude Ash 0.35 Vitamin C 60.35 Calcium (mg) 0.82 ± 0.21 Magnesium 0.17 ± 0.08 Sodium 49.1 ± 16.3 Potassium 5.9 ± 0.1 Iron 3.93 ± 0.12 Copper 0.56 ± 0.09 Manganese 0.78 ± 0.16 Platinum 0.125 ± 0.08 Cadmium 0.165 ± 0.09 Selenium 0.177 ± 0.08 Chromium 0.138 ± 0.08	Antiapoptosis, anti-aging, anti-carcinogen, anti-inflammation, anti-atherosclerosis, cardiovascular protection and improvement of endothelial function, as well as inhibition of angiogenesis and cell proliferation activities, depict the analgesic, antispasmodic and antibacterial	Cooked as vegetables	Qureshi et al., 2014; Helaly et al., 2014 Ravichandran et al., 2015
96.	**English:** Yellow Rocket, Bittercress, Herb Barbara, Rocketcress	*Barbarea vulgaris*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Brassicales Family Brassicaceae Genus Barbarea Species vulgaris	Southeast Asia	Hederagenin cellobioside and oleanolic acid cellobioside	Moisture(%) 89 Carbohydrate 5.5 Fibre 1.1 Protein 2.6 Fat 0.7 Ash 1.8 Calcium (mg) 89 Iron 1.3 Magnesium 38 Phosphorus 76 Potassium 606 Sodium 14 Zinc 0.2 Copper 0.2 Manganese 0.6 Selenium (µg) 0.9	Pain, polyuria, wounds, achlorhydria, blood impurity, indigestion, scurvy	Cooked as vegetables	Benders' Dictionary of Nutrition and Food Technology Kuzina et al., 2009;

97.	**English:** Pea, Garden Pea **Hindi:** Matar **Manipuri:** Houwaitharak **Marathi:** Vatane **Tamil:** Pattani **Malayalam:** Pattani **Telugu:** Pantanlu **Kannada:** Batgadle **Bengali:** Matar **Urdu:** Matar **Gujarati:** Patana **Sanskrit:** Renuka	*Pisum sativum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Fabales Family Fabaceae Genus Pisum Species sativum	Asia	Apigenin, Hydroxybenzoic, Hydroxycinnamic, luteolin, and quercetin	NF	Antibacterial, antidiabetic, antifungal, anti-inflammatory, antihypercholesterolemia, and antioxidant activities and also shown anticancer property	Cooked as vegetables	Rungruang maitree et al., 2017 Christison et al., 1984
98.	**English:** Water Snowflake **Hindi:** Kumudini **Manipuri:** Tharo Macha **Tamil:** Chinnambal **Malayalam:** Nedel-Ambel **Telugu:** Anthara Thaamara **Kannada:** Neeru Thaavare **Bengali:** Chandmala	*Nymphoides indica*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Asterales Family Menyanthaceae Genus Nymphoides Species indica	Asia	Azelaic acid (nonanedioic acid), hexadecanoic acid, 4-methyl-heptanedioic acid, hexadecanol and stearic acid, 7-Epiexaltoside, 6″,7″-Dihydro-7-epiexaltoside, Menthiafolin, 3,7-Di-O-methylquercetin-4′-O-β-glucoside, 3-O-Methylquercetin-7-O-β-glucoside, 3,7-Di-O-methylquercetin, Scopoletin, Ferulic acid, 8-Hydroxy-2,6-dimethyl-(2E,6E)-octadienoic acid; foliamenthoic acid, 6,7-Dihydrofoliamenthoic acid methyl ester	Moisture(%) 89.5 Ash 6.3 Phosphorus 0.26 Calcium 0.87 Magnesium 0.44 Potassium 2.65 Sodium 0.33	Treats jaundice, dysentery and fever, to cure a bilious headache, scabies, rheumatism, s an antidote for scorpion sting and snake bite, as an anthelmintic drug	Cooked as vegetables	Amin et al., 2016; Khan et al., 2018 Esteves et al., 1990
99.	**English:** Basil **Bengali:** Khubkalam **Hindi:** Babui Tulsi **Kannada:** Kaama Gaggare **Malayalam:** Pach-Cha-Pushpam **Manipuri:** Tulsi **Marathi:** Bhoo Tulasi **Tamil:** Tirunittru **Telugu:** Bhoo Tulasi **Urdu:** Burg Faranjmushk	*Ocimum basilicum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Lamiaceae Genus Ocimum Species basilicum	Asia	Eucalyptol (1.79%), linalool (12.63%), α-terpineol (0.95%), eugenol (19.22%), β-elemene (2.68%), α-bergamotene (3.96%), α-guaiene (2.33%), germacrene D (8.55%), cubenol (1.78%), tau-cadinol (15.13%), camphor (0.70%), bornil acetate (1.97%), β-cariophylene (0.61%), α- cariophylene (1.67%), elixen (2.59%), β-cadinene (0.80%), α-copaene (0.33%), metil eugenol (0.76%), β-farnesene (0.58%), epibiciclosesquiphelandrene (0.76%), tau muralol (0.96%), α-bisabolol (0.35%), δ-gurjunene (5.49%) and δ-cadinene (5.04%)	Moisture (%) 90.81 Carbohydrate 50.9 Fibre 7.11 Crude Protein 17.32 Crude Fat 9.68 Ash 5.80	Treats of diarrhea, dysentery and wound healing, immunomodulatory activity, antioxidant activity, antihyperglycemic and hypolipidemic activity, anti-herpes simplex virus activity, anti-inflammatory activity, hepatoprotective and lipid peroxidation activity, central nervous system activity, antimicrobial activity, antifungal activity, antimutagenic activity, antierythmic and depigmenting activity, antitoxic activity	Cooked as vegetables	Bariyah et al, 2012 Warsi et al, 2017 Fathiazad et al., 2012 Nazni et al., 2020
100.	**English:** Hooker's Evening Primrose, Western Evening Primrose	*Oenothera hookeri*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Myrtales Family Onagraceae Genus Oenothera Species hookeri	Asia	Quercetin-3-O-glucoside, Quercetin-3-O-galactoside, Quercetin-7-O-rhamnoside, Quercetin-3-O-rhammnoglucoside, Quercetin-3-O-arabinoside, kaempferol galactoside, 2-Hydroxy-4-methoxybenzoic acid, salicyclic acid, ferulic acid, syringic acid, vanillic acid, p-coumaric acid, p-hydroxybenzoic acid, p-hydroxyphenylacetic acid, gemtisic acid, protocatechuic acid, caeffic acid, gallic acid	NF	Antioxidant activity, anti-diabetic activity, anti-inflammatory activity, anti-cancer and anti-tumor activity, treatment against kidney disorders, nematicidal activity, immune response activity, anti-bacterial activity, anti-neuropathic activity, hypocholesterolemic activity, thrombolytic activity, cariostatic activity, anti-ulcerogenic effects, anthelmintic activity, curing hepatic disorders, vasorelaxation activity, treatment of cardiac disorders, antiviral activity, anti-diarrheic activity	Cooked as vegetables	Panda et al., 2015 Fecker et al., 2020

101.	**English:** Radish **Hindi:** Mauli **Manipuri:** Mula **Marathi:** Mula **Malayalam:** Molabham **Telugu:** Mullangi **Kannada:** Molamgi **Bengali:** Mulo **Kashmiri:** Muju **Konkani:** Mulo **Urdu:** Fujul **Gujarati:** Mulo **Sanskrit:** Mulaka	*Raphanus sativus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Brassicales Family Brassicaceae Genus Raphanus Species sativus	Asia	2- hexen -1- al (leaf aldehyde) 3 – hexane -1-ol (leaf alcohol) and small quantities of n – and isobutyraldehyde and isovaleraldehyde	Moisture(%) 90.3 Carbohydrates 3.4 Fibre 0.9 Protein 2.7 Fat 0.6 Vitamin A(I.U.) 18,660 Thiamine(mg) 0.03 Riboflavin 0.16 Nicotinic acid 0.3 Vitamin C 103 Minerals 2.1 Calcium 310 Phosphorus 60 Iron 16.1	Treats whooping cough, cancer, gastric discomfort, liver problems, constipation, dyspepsia, gallbladder problems, arthritis, gallstones, kidney stones, anticancer, antimicrobial, antidiabetic, diuretic, antifertility, hypertensive, antimicrobial, nephroprotective, gastroprotective and hepatoprotective, gynecological disorders	Raw or cooked as vegetables	Panda et al., 2015
102.	**English:** Parsley	*Petroselinum crispum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Apiales Family Apiaceae Genus Petroselinum Species crispum	India and Asia	Flavonoids (apiin), glucosides, phthalide, furanocoumarins, carotenoids, apiol (phenylpropanoid), myristicin, apiolin, pinene, ascorbic acid, carotenoids, flavonoids, coumarins, apiole, various terpenoic compounds, phenyl propanoids, phathalides, furanocoumarins (bergapten, imperatori) and tocopherol, α-Pinene, β-Myrcene, α-Phellandrene, β -Phellandrene, cis-Ocimene, Isopropenyl-4-methylbenzene, α-Terpinolene, p-Mentha-1,3,8-triene, α-Copaene, Caryophylene, β −Farnesen, β-Selinene, γ-Cadinene, Myristici, β -Bisabolene, β -Sesquiphellandrene. The volatile oil of parsley seeds contain glycoside called apiin (apigenin-7-Oapiosyl-(1->2)-O-glucoside)	Moisture(%) 82.2 Carbohydrates 58.4 Fibre 14 Ash 17.5 Protein 4.1 Fat 1.7 Calcium 42.9 potassium 73.0 Sodium 66.1 Iron 1.3 Copper 0.2 Magnesium 46.1 Manganese 0.8 Phosphorus 70.7 Zinc 0.8	Diuretic, treats jaundice, dropsy, cystitis, good detoxifier, helping the body to get rid of toxins via the urine, rheumatism. antidandruff, antispasmodic, aperient, carminative, digestive, emmenagogue, expectorant, galactofuge, kidney, stomachic and tonic, treating anaemia and convalescents	Raw or cooked as vegetables	Panda et al., 2015 http://www.naturalmedicinalherbs.net/herbs/p/petroselinum-crispum=parsley.php Mahmood et al., 2014 Khalil et al., 2012
103.	**English:** Water Pepper, Marsh-Pepper Smartweed, Smartweed **Assamese:** Patharua Bihalagani **Bengali:** Packur Mul **Kannada:** Kari Agrada Gida, Kari Sanni **Manipuri:** Chakhong **Nepali:** Pire	*Persicaria hydropiper*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Polygonaceae Genus Persicaria Species hydropiper	Great Britain and Ireland, rarer in Scotland; is a native of most parts of Europe, in Russian Asia to the Arctic regions	Catechin, (−)-epicatechin, hyperin, isoquercitrin, isorhamnetin, kaempferol, quercetin, quercitrin, rhamnazin and rutin; drimane-typed sesquiterpenes, such as 3-β-angeloyloxy-7-epifutronolide, 7-ketoisodrimenin, changweikangic acid A, dendocarbin L, (+)-fuegin, futronolide, polygonumate, and (+)-winterin; phenylpropanoid esters, including hydropiperosides A and B, and vanicosides A, B and E; as well as phenolic acids, such as caffeic acid, chlorogenic acid and ρ-coumaric acid	Moisture(%) 85 Carbohydrate 8 Protein 7.5 Fat 1.9 Ash 2	Treats bleeding, skin problems, diarrhoea, stimulant, diuretic, diaphoretic, emmenagogue, efficacious in amenorrhoea, antiinflammatory; astringent; carminative; contra ceptive; diaphoretic; diuretic; emmenagogue; ho meopathy; stimulant; stomachic; styptic, treats diarrhoea, dyspepsia, itching skin, excessive menstrual bleeding and haemorrhoids	Raw or cooked as vegetables	Panda et al., 2015 Sauris Panda, 2015 https://pfaf.org/user/Plant.aspx?LatinName=Polygonum+hydropiper Moyeenul Huq et al., 2014, Oany et al., 2016
104.	**English:** Lettuce Tree **Tamil:** Leechai Kottai Keerai **Telugu:** Lanchamundaku **Gujarat:** Velati Salet	*Pisonia grandis*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Nyctaginaceae Genus Pisonia Species grandis	Africa, E. Asia - China, India, Sri Lanka, Malaysia, Indonesia to Australia and the Pacific	Pinnatol, Allantoin, βSitosterol, α-Spinasterol, β-Sitosterol glucoside, Octocosanal, Dulcitol, Flavonoids and Quercetin, Oflaxacin and Erythromycin, octocosanol, betositosterol, alphaspinosterol, dulcitol,	Moisture(%) 90 Ash 14 Crude Fibre 11.67 Volatile matter 74.2	Anti diabetic, anti inflammatory, wound healing, diuretic, analgesic, filariasis, dysentery and rheumatic disorders, treats of dysentery	Cooked as vegetables	Panda et al., 2015 ELUMALAI et al., 2014; http://tropical.theferns.info/viewtropical.php?id=Pisonia+grandis Poongothai and Sripathi et al., 2015

105.	**English:** Chicory, Blue Sailors, Succory, Coffeeweed **Hindi:** Kasni **Marathi:** Kachani **Malayalam:** Chikkari **Telugu:** Kasini **Kannada:** Chikory **Urdu:** Kasni, Tukme-E-Kasni **Sanskrit:** Kasni	*Cichorium intybus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Asterales Family Asteraceae Genus Cichorium Species intybus	South Africa Europe, Central Russia, Western Asia, Egypt and North America	cichoric acid, Lactucin, Lactucopicrin, 8-Deoxylactucin, Jacquilenin,11β,13-Dihydrolactucin, 11,13-Dihydrolactucopicrin, Crepidiaside B, Cyanidin 3-O-p-(6-O-malonyl)-Dglucopyranoside, 3,4β-Dihydro-15-dehydrolactucopicrin, Magnolialide, Ixerisoside D, Loliolide, Cichorioside B, Sonchuside A, Artesin, Cichoriolide, Cichorioside, Sonchuside C, Cichopumilide, Putrescine, Spermidine, β-Sitosterol, Campesterol, Stigmasterol, Crepidiaside A, Cichoralexin, Malic acid, Caffeic acid, 3-Caffeoylquinic acid, 5-Caffeoylquinic acid, 4-Caffeoylquinic acid, cis-5-Caffeoylquinic acid, cis-Caftaric acid, trans-Caftaric acid, 5-Caffeoylshikimic acid, 5-p-Coumaroylquinic acid, Kaempferol-3-O-sophoroside, Quercetin-7-O-glucoside	Moisture (%) 93.28 ± 0.04 Carbohydrate 18.40 ± 0.62 Crude Fibre 23.70 ± 1.12 Protein 18.61 ± 0.13 Fat 21.18 ± 0.48 Ash 11.39 ± 0.06	Anti-bacterial, anti-inflammatory, hyperglycaemic and anti-ulcerogenic activities, fever, diarrhoea, jaundice and gallstones, diabetes, atherosclerosis, hepatotoxicity, anti-inflammatory, anticarcinogenic, antiviral, antibacterial, antimutagenic, antifungal, anthelmintic, immune-stimulating, and antihepatotoxic and its antioxidative qualities	Cooked as vegetables	Panda et al., 2015 Saeed et al., 2017 Madan et al., 2018
106.	**Bengali:** Dheki Shak **Hindi:** Dheki Shak	*Ampelopteris prolifera*		Kingdom Plantae Phylum Tracheophyta Class Polypodiopsida Order Polypodiales Family Thelypteridaceae Genus Ampelopteris Species prolifera	Africa and Asia	Phenol 114.27±10.37 mg (GAE/g), Flavonoid 151.47±3.57 mg CE/g extract, Hydrolyzable tannins 337.50±5.00 mg CE/g extract, Peganine, 1-methyl tryptophan, rutin	NF	Treats meningitis and encephalitis, diabetes; Relieves constipation i.e. used as aperients	Cooked as vegetables	Panda et al., 2015; http://tropical.thefens.info/viewtropical.php?id=Ampelopteris+prolifera Rajbhandari et al., 2020 Poude and Rajbhandari, 2020
107.	**Bengali:** Baro Dheki Shak **Hindi:** Haththazori	*Blechnum orientale*		Kingdom Plantae Subkingdom Tracheobionta Division Pteridophyta Order Polypodiales Family Blechnaceae Genus Blechnum Species orientale	E. Asia - China, New Guinea, Australia and the western Pacific	22-dehydrocampesterol, 24-alpha-ethyl-cholest-5-en-3-beta-ol, 24-alphaethyl-methyl-cholest-5- en-3-beta-ol, 24-beta-methyl-cholest-5-en-3-beta-ol, 24- alpha-cholest-5, 22-dien-3-beta-ol and cholesterol	NF	Anthelmintic, antiviral, contraceptive and tonic, treats of urinary complaints, impotence; boils in infants and older children and diarrhoea, to treat abscesses and fungal skin infections, esp ringworm, and also to stop bleeding, o treat blisters, boils, carbuncles and sores, treating stomach pain and urinary bladder complaints, treatment of typhoid	Cooked as vegetables	Panda et al., 2015; http://tropical.theferns.info/viewtropical.php?id=Blechnum+orientale Lai et al., 2010
108.	**Bengali:** Pani Shak **Hindi:** Pani Shak	*Ceratopteris pteridoides*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Polypodiophytina Class Polypodiopsida Subclass Polypodiidae Order Polypodiales Family Pteridaceae Genus Ceratopteris Species pteridoides	Southeastern North America Central and South America, East and Southeast Asia	Alkaloids, arbutin and tannin have been found in the green parts of the plant	Moisture(%) 87-91.00 Carbohydrate 3.12-7.40 Crude Protein 4.22-5.28 Magnesium (mg) 23.55-194.65 Calcium 0.03	Used as medicine for foetal toxins and accumulation of phlegm	Raw or cooked as vegetable	Panda et al., 2015; http://www.stuartxchange.org/Pakong-roman.html https://www.flowgrow.de/db/aquaticplants/ceratopteris-pteridoides Oloyeda et al., 2010

109.	**English:** Asthmaweed **Hindi:** Bara Dudhi **Manipuri:** Pakhamba Maton **Marathi:** Dudhi **Tamil:** Ammam Paccharisi **Malayalam:** Nelapalai **Telugu:** Nanabalu **Kannada:** Achchedida **Bengali:** Barokarni **Konkani:** Dudurli **Tangkhul:** Pakhang Leiton **Nepali:** Ankhle Jhaar	*Euphorbia hirta*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Malpighiales Family Euphorbiaceae Genus Euphorbia Species hirta	Asia	Afzelin (I), quercitrin (II), and myricitrin (III), rutin (IV), quercitin (V), euphorbin-A (VI), euphorbin-B (VII), euphorbin-C (VIII), euphorbin-D (IX), 2,4,6-tri-O-galloyl-β-d-glucose, 1,3,4,6-tetra-O-galloyl-β-d-glucose, kaempferol, gallic acid, and protocatechuic acid, β-amyrin, 24-methylenecycloartenol, β-sitosterol, heptacosane, nnonacosane,[1] shikmic acid, tinyatoxin, choline, camphol, and quercitol derivatives containing rhamnose and chtolphenolic acid	Moisture (%) 75.18 Total Carbohydrate 13.92 Fibre 36.59 Protein 12.57 Calcium 116.94 Sodium (mg) 175.83 Potassium 5536.27 Lithium 39.44 Nitrogen 1981.32 Phosphorus 241.89 Sulphur 1746.11 Iron 82.82 Copper 2.60 Manganese 8.71 Zinc 5.44	Ttreats respiratory ailments (cough, coryza, bronchitis, and asthma), worm infestations in children, dysentery, jaundice, pimples, gonorrhea, digestive problems, and tumors, bronchitis, and asthma), worm infestations in children, dysentery, jaundice, pimples, gonorrhea, digestive problems, and tumors	Cooked as vegetables	Narzary et al., 2013 kumar et al., 2010 Prasad et al., 2014
110.	**English:** Purple Amaranth **Bengali:** Sada-Notey, Sada-Notia, Notiya Shak. **Hindi:** Chaulai, Marsa, Natiya Sag	*Amaranthus cruentus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Amaranthaceae Genus Amaranthus Species cruentus	tropical and subtropical regions, including tropical Africa, China, India, Japan, Indonesia, New Guinea, and West Indies	Betacyanin, cardenolids, palmitic acid, stearic acid, oleic acid and linoleic acid, docosaenoic acid	Moisture (%) 87.78 Carbohydrate 9.4 Protein 3.9 Fat 1.1 Ash 3.2 Calcium(mg) 323 Iron 8.3	Used as an astringent internally in the treatment of ulcerated mouths and throats, externally as a wash for ulcers and sores. The juice of the roots is used externally to relieve headaches. The plant has a folk reputation for being effective in the treatment of tumours and warts. good food with medicinal properties for young children, lactating mothers and for patients with fever, haemorrhage, anaemia or kidney complaints. The leaves are used as a febrifuge and poultice to treat inflammations, boils and abscesses, used as a medicine against lung disorders	Raw and cooked as vegetables	Panda et al., 2015 https://www.prota4u.org/database/protav8.asp?g=pe&p=Amaranthus+blitum+L. Martirosyan et al, 2007
111.	**English:** Chamber Bitter **Hindi:** Bhui Aonla **Manipuri:** Chakpa Heikru **Marathi:** Bhuiavali **Tamil:** Kizkaynelli **Malayalam:** Kilanelli **Telugu:** Nela Usiri **Bengali:** Bhui Amla **Sanskrit:** Bahupatra **Kannada:** Kiru Nelli	*Phylanthus nirruri*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Malpighiales Family Phyllanthaceae Genus Phyllanthus Species niruri	Asia, America, and China	Phyllanthin, hypophyllanthin, niranthin, phyltetralin, nirtetralin, isonirtetralin, hinokinin, lintetralin, isolintetralin, demethylenedioxy-niranthin, 5-demethoxyniranthin etc., flavonoïds such as gallocatechin, rutin, quercetin- 3-Oglucopyranoside, phyllanthusiin, quercetin, kaempferol 3-_-dglucopyranoside, kaempferol etc., ellagitannins include geraniin, amariin, furosin, geraniinic acid B, amariinic acid, amarulone, repandusinic acid A, corilagin, isocorilagin, elaeocarpusin, phyllanthusiin A, B, C, D and melatonin; securinega-type alkaloids such as isobubbialine and epibubbialine and sterol such as amarosterol A, amarosterol B, Ellagitannins (geraniin and corilagin), Phyllanthin and hypophyllanthin,	Moisture(%) 90.5±0.06 Carbohydrate 64.31±0.18 Crude fiber 17.10±0.14 Crude protein 9.52±0.02 Crude lipid 3.15±0.01 Calcium (mg) 25.58±1.03 Magnesium 25.85±4.03 Potassium 12.10±0.10 Phosphorus 15.42 ± 3.05 Sodium 0.44 ± 0.35 Iron 3.10 ± 0.03 Manganese 1.27 ± 0.02 Zinc 0.45 ± 0.05	Jaundice, ulcers, skin diseases, diabetes, chest pain and urinary complications, antimicrobial, antiviral, hepatoprotective, antioxidant, anticancer, anti-inflammatory, antiplasmodial and diuretic	Cooked as vegetables	Narzary et al, 2013 Kamruzzaman et al., 2016 Itodo et al., 2012

112.	**English:** Green Amaranth **Hindi:** Jungali Chaulayi **Konkani:** Ranbhaji **Malayalam:** Kuppacheera **Marathi:** Math **Sanskrit:** Tanduliya **Tamil:** Kuppai-K-Kirai **Telugu:** Chilaka-Thotakoora **Nepali:** Lunde Saag	*Amaranthus viridis*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Amaranthaceae Genus Amaranthus Species viridis	Tropical and subtropical regions, including tropical Africa, China, India, Japan, Indonesia, New Guinea, and West Indies	Linoleic acid, α- Linoleic acid, β-Carotene	Moisture(%) 87.90 Carbohydrate 44.1 Fibre 6.6 Protein 34.2 Fat 5.3 Ash 16.4 Vitamin A 50 Thiamine 0.07 Riboflavin 2.43 Niacin 11.8 Ascorbic acid 790 Calcium(mg) 2243 Phosphorus 500 Iron 27 Sodium 336 Potassium 2910	Used to stop dysentery and inflammations, and also to purify the blood, to treat inflammation during urination, to treat constipation, dysentery, are diuretic, febrifuge and purgative, to act as a vermifuge, being effective against filaria, as an emmenagogue and to relieve heart troubles, used in poultices (fresh or as dried powder) to treat inflammations, boils and abscesses, gonorrhoea, orchitis and haemorrhoids, used as an eye wash to treat eye infections	Cooked as vegetables	Panda, 2015; http://tropical.theferns.info/viewtropical.php?id=Amaranthus+viridis Ferdous et al., 2015
113.	**English:** Cat-Tail **Bengali:** Ramdana-Maris **Hindi:** Ramadana.	*Amaranthus caudatus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Amaranthaceae Genus Amaranthus Species caudatus	India , Africa , south Africa , Bangladesh , Pakistan	1,2,4-Butanetriol, trinitrate, N-Ethyl-N'-nitroguanidine, Phenol, 2,6-bis(1,1-dimethylethyl)-4-methyl-, methylcarbamate, 2,5-Pyrrolidinedione, 3-ethyl-1,3-dimethyl-, 2-Piperidinone, N-[4-bromo-n-butyl]-, 3-Hexadecyloxycarbonyl-5-(2-hydroxyethyl)-4-methylimidazolium ion, 2-(3-Oxo-3-phenylpropyl)-3,5,6-trimethylpyrazine, Pyridine-3-carboxamide, 4-dimethylamino-N-(2,4-difluorophenyl)-, Phytol, Pseudoephedrine	Moisture (%) 82.2 Total carbohydrate (mg) 57.68 Protein 19 Ascorbic acid 29	Anti-diarrheal, anti-hemorrhagic, nutritive, tonic, astringent, diuretic, cooling effect, laxative	tender leaves are occasionally cooked and eaten	Panda et al., 2015 https://keys2liberty.wordpress.com/tag/medicinal-uses-of-amaranthus/ Viswa et al., 2014 Paranthaman et al., 2012
114.	**English:** White Gourd **Hindi:** Petha **Manipuri:** Torobot **Marathi:** Kohla **Tamil:** Neer Poosanikai **Malayalam:** Kumbalanga **Telugu:** Boodida Gummadikaaya **Kannada:** Budekumbalakayi **Bengali:** Kumra **Assamese:** Komora **Sanskrit:** Brihatphala **Nepali:** Kubindo **Tangkhul:** Katsenghei	*Benincasa hispida*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Cucurbitales Family Cucurbitaceae Genus Benincasa Species hispida	Asia	ß-sitosterin and uronic acid, Benzoic acid, Benzyl-di-carboxylic acid and tricosane,	Moisture (%) 89 Crude Fibre Content 20 Total Ash 47 Acid-insoluble ash 38.29 Water soluble ash 23.40	Central nervous effects (anxiolytic , muscle relaxant , antidepressant , in the treatment of Alzheimer's disease and to minimize opiates withdrawal signs), antioxidant, anti-inflammatory, analgesic, antiasthmatic, diuretic , nephroprotective, antidiabetic, hypolipidemic and antimicrobial effects	Cooked as vegetables	Panda et al, 2015 Al-Snafi et al, 2013 Neha N et al., 2019
115.	**English:** Watermelon **Hindi:** Tarbooz **Manipuri:** Tarbuj **Marathi:** Kadu Vrindavana **Telugu:** Eriputccha **Kannada:** Kallangadi Balli **Bengali:** Tormuj **Urdu:** Tarbooz **Gujarati:** Indrak	*Citrullus lanatus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Cucurbitales Family Cucurbitaceae Genus Citrullus Species lanatus	South Africa and Asia	n-butanol, anthraquinones, Ethylacetate, (2E)-hexenal, Cucurbitacin E and Cucurbitacin L 2-O-β-glucoside	Moisture (%) 94.94 Carbohydrate 59.03 Crude Protein 7.87 Dry matter 98.9	Antibacterial, antifungal, antimicrobial, antiulcer, antioxidant, anti-inflammatory, gastroprotective, analgesic, laxative, antigiardial, hepatoprotective, against prostetic hyperplasia and atherosclerosis, gonorrhoea, mosquitocidal and Larvicidal effect	Cooked as vegetables	Panda et al., 2015; http://tropical.theferns.info/viewtropical.php?id=Citrullus+lanatus; Aruna et al, 2014, Alebiosu et al., 2015 Zubairu et al., 2018

116.	**English:** Wild Melon **Hindi:** Kachari **Marathi:** Shinde **Konkani:** Chibdin **Assamese:** Gurmi **Gujarati:** Kachari	*Cucumis melo*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Cucurbitales Family Cucurbitaceae Genus Cucumis Species melo	Asia	Meloside A, meloside L and their caffeoyl ester, A-carotene, β-carotene, C-carotene	Moisture (%) 96.15±0.02 Carbohydrate 22.35±0.05 Crude fiber 10.55±0.01 Crude Protein 24.50±0.05 Crude Lipid 35.45±0.05 Ash 3.30±0.01	Ophthalmia, liver disorders, kidney disorders, chronic and bilious fevers, cough due to heat, painful and burning, Micturition, burning sensation of the oesophagus, kidney and bladder	Cooked as vegetables	Panda et al., 2015; Preeti et al., 2017 M.E et al., 2019
117.	**English:** Cucumber **Hindi:** Khira **Manipuri:** Thabi **Marathi:** Kankri **Tamil:** Vellarikkay **Malayalam:** Vellari **Telugu:** Dosakaya **Kannada:** Soutekayi **Oriya:** Kaknai **Sanskrit:** Trapushpa	*Cucumis sativus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Cucurbitales Family Cucurbitaceae Genus Cucumis Species sativus	Asia	Flavone glycosides such as isovitexin, saponarin and various acylated flavone C-glycosides, (2S,3S,4R,10E)-2-[(2'R)-2-hydroxytetra-cosanoylamino]-1,3,4-octadecanetriol10-ene,1-O-β-D-glucopyranosyl (2S,3S,4R,10E)-2-[(2'R)-2-hydroxy- tetracosanoylamino]-1,3,4-octadecanetriol-10-ene and soyacerebroside I, linoleic acid, oleic acid, palmitic acid and stearic acid.	Moisturre (%) 94.2 ± 0.08 Carbohydrate 0.28 ± 0.09 Fibre 1.02 ± 0.01 Protein 3.01 ± 0.07 Lipid 0.55 ± 0.13 Ash 0.94 ± 0.24	Anti-bacterial activity, antifungal activity, cytotoxic activity, antacid & carminative activity, Activity against ulcerative colitis, hepetoprotective activity, Hypoglycemic and Hypolipidemic activity, Wound healing activity	Cooked as vegetables	Panda et al., 2015; Sahu et al, 2015 Agatemor et al., 2018
118.	**English:** Butternut Pumpkin **Assamese:** Kumra **Bengali:** Kumara **Hindi:** Halwa Kaddu **Kannada:** Sihi Kumbala Kaayi **Malayalam:** Kumpalam **Marathi:** Kala Bhopala **Punjabi:** Halwa Kaddu **Tamil:** Pucani **Telugu:** Gummadi **Urdu:** Kaddu	*Cucurbita moschata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Cucurbitales Family Cucurbitaceae Genus Cucurbita Species moschata	Asi and Africa	leutin, xanthin and carotenes, antioxidant	Moisture(%) 79 Carbohydrate 42 Protein 40 Fat 18 Vitamin A(IU) 1136	Treat haemorrhages, antidiabetic, antihypertension, antitumor, immunomodulation, antibacterial, anti-hypercholesterolemia, intestinal antiparasitia and anti-inflammation	Cooked as vegetables, used as a potherb or added to soups, stews	Panda et al, 2015; http://tropical.theferns.info/viewtropical.php?id=Cucurbita+moschata; Maitra et al., 2014
119.	**Common Name:** Onion **Hindi:** Pyaz **Manipuri:** Tilhou **Tamil:** Vengayam	*Allium cepa*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Lilianae Order Asparagales Family Amaryllidaceae Genus Allium Species cepa	Asia and Africa	Kaempferol, Myricetin, Quercetin, Quercitrin, Allyl sulphide, Isoamyl alcohol, Methyl palmitate, Ethyl palmitate, Methyl linoleate, 2-Methyl-3,4-dithiaheptane, Dipropyl tetrasulfide, 2-Tridecanone, 2-Hexyl-5-methyl 3(2H)-furanone, Di-1-propenyl trisulfide, 3-Methoxyoctane, Dimethyl tetrasulfide, Allyl methyl trisulfide, Ethyl-3-(methylthio)propionate, Diallyl disulfide, 2-Ethylpyridine, Allyl propyl sulfide	Moisture(%) 86.6 Carbohydrates 11.1 Fibre 0.4 Protein 1.2 Fat 0.1 Vitamin C 11 Minerals(mg) 6 Calcium 47 Phosphorus 50 Iron 0.7	Swelling of the osteo- and rheumatoid arthritis, the allergic inflammatory response of asthma, and the respiratory congestion associated with common colds, lowers homocysteine levels, an important risk factor for heart attacks and strokes, tooth disorders, anemia, sexual debility, skin disorders, scar removal, burns and wounds, hair loss, diabetes, atherosclerosis, high cholesterol, high blood pressure, asthma, upset stomach, loss of appetite, common clod, whooping cough, sore throat, bronchitis	Cooked as vegetables	Kumar et al., 2010; https://www.ayurtimes.com/onion-allium-cepa/ Mnayer et al, 2014

120.	**English:** Lotus Sweetjuice, Damascisa **Bengali:** Duserasag **Hindi:** Gandhi-Buti **Kannada:** Chandrakaasi Soppu **Marathi:** Kotak, Kadi-Bhaji **Sanskrit:** Ushandi **Tamil:** Cheruppadai, Ceruppati **Telugu:** Chadrasi Koora	*Glinus lotoides*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Molluginaceae Genus Glinus Species lotoides	Africa, Asia, Australia and South Europe	Vicenin-2 and mollugogenol B, sapogenins-Mollugogenols C& E-along with Mollugogenols A, beta and gamma sitosterol glucosides, Oleanolic acid, molligocin A-isolated & characterized as Mollugogenol a3;Mollugogenol7, Stidmollugogenol-F, new triterpenoid sapogenin – 3β,16β,22-trihydroxyisohopane, stereostructures of Mollugogenols A & E	Moisture(%) 78.77 Carbohydrate 47.0 Crude Fibre 22.4 Protein 12.5 Fat 2.3 Total Ash 11.30 Acid-insouble ash 1.02 Vitamin C (mg/100gm) 112	Purgation in abdominal diseases, diarrhoea, skin ailments and pruritus, used as an antiseptic, an anthelmintic, as a treatment for diarrhea and bilious attacks, and as a purgative for curing boils, wounds and pain in general, Cures vata diseases, gunmam, soolai, mandham, mega noigal (syphilis), leucorrhoea, kapha diseases	Cooked as vegetables	Barnali Gogoi, 2013; S. Bhavani, 2015 Ramaseshan et al., 2016
121.	**English:** Jima **Hindi:** Jima, Grishma-Sundaraka, Ghima **Tamil:** Pampantra, Thura Poondu **Telugu:** Chayuntarashi **Kannada:** Chadarasi Gida, Chandarasisoppu **Sanskrit:** Phanija, Ushnasundara, Lonika	*Glinus oppositifolius*		Kingdom Plantae Division Magnoliophyta Class Magnoliopsida Order Caryophyllales Family Molluginaceae Genus Glinus Species oppositifolius	Africa, Asia, Australia and South Europe	spergulagenic acid and a tri-hydroxy ketone, kaempferol 3-O-galactopyranoside, isorhamnetin 3-Oβ-D-xylopyranosyl-(1→2)-β-D-galactopyranoside, vitexin, vicenin-2, adenosine and L-phenylalanine, pectic polysaccharide, α-glucosidase inhibitory activity, glinoside C, 3-O-(βD-xylopyranosyl)-spergulagenin A, spergulacin, spergulin A, spergulacin A and spergulin B, benzoic acid, 4-hydroxybenzoic acid, 4-hydroxybenzaldehyde,hydroxy-acetophenone, methyl 4-hydroxybenzoate, anisic acid, vanillin, 4-hydroxy-3-methoxyacetophenone, acetosyringone, 4-hydroxy-3,5-dimethoxy benzaldehyde, 4-hydroxybenzyl alcohol, 2-(4-hydroxyphenyl ethanol, cinnamic acid, trans-ferulic acid, Kaempferol 3-O-galacto pyranoside, isorhamnetin 3-O-β-D-xylopyranosyl-β-D-galactopyranoside, vitexin, and vicenin-2	Moisture(%) 76.53 Carbohydrate 47.0 Crude Fibre 22.4 Protein 12.5 Fat 2.3 Calcium (mg) 1693 Iron 22.1 Zinc 43.2	Hepatoprotective activity, Anti-diarrhoeic activity, Anti-depressant and anxiolysis activity, Anti-inflammation and analgesic activity, Anti-diabetogenic activity, Anti-hyperlipidemic activity, Antiplasmodial activity, Immunomodulation activity	Cooked as vegetables	Barnali Gogoi, 2013 http://www.mpbd.info/plants/glinus-oppositifolius.php; Chhanda et al, 2014; Chakraborty et al., 2017 Ramaseshan et al., 2016
122.	**English:** Stemless Premna **Assamese:** Matiphesua, Matiya-Jam, Matia-Jam **Bengali:** Bamanhali **Kannada:** Nayit-Yaga **Marathi:** Gantubarangi Others Knappa **Sanskrit:** Boomi-Jambuka **Tamil:** Sirudekku **Telugu:** Nelaneredu	*Premna herbacea*		Kingdom Plantae Phylum Tracheophyta Class Magnoliopsida Order Lamiales Family Lamiaceae Genus Premna Species *herbacea*	E. Asia and Australia	Scutellarein, Sirutekkone, pygmacoherin, bharangin, pygmaeocine B, C and E	Moisture(%) 81 Protein 15.38 Fat 2.37 Ash 43 Total solids 19 Carbohydrate 41.75	Treat dropsy, cough, asthma, fever, rheumatism and cholera, used as laxative, stomachic, antidiabetic, antiasthmatic, antianemic, fever, sleeping sickness, and jaundice, cough, rheumatism; poultices applied to boils, bronchitis, asthma, hypertension, tumors, inflammation, hiccups, epilepsy and helminthiasis	Cooked as vegetables	Narzary et al., 2013; http://tropical.theferns.info/viewtropical.php?id=Premna+herbacea K. et al.,, 2015; Herbal resources of india and nepal, Brahma et al., 2014
123.	**English:** Lettuce, Garden Lettuce **Hindi:** Salad **Manipuri:** Salad **Tamil:** Shallattu Virai **Bengali:** Salad **Urdu:** Tukhm Kahu	*Lactuca sativa*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Asterales Family Asteraceae Genus Lactuca Species sativa	E. Asia	α-pinene (5.11% and 4.05%), γ-cymene (2.07% and 1.92%), thymol (11.55% and 10.73%), durenol (52.00% and 49.79%), α-terpinene (1.66% and 1.34%), thymol acetate (0.99% and 0.67%), caryophyllene (2.11% and 1.98%), spathulenol (3.09% and 2.98%), camphene (4.11% and 3.65%), limonene (1.28% and 1.11%), β-pinene, α-terpinolene, linalool, 4-terpineol, α-terpineol, o-methylthymol, L-alloaromadendrene and viridiflorene	Moisture (%) 92.96±0.43 Carbohydrate 1.17±0.13 Crude Fibre 3.34±0.00 Protein 1.24±0.22 Lipid 0.34±0.02 Ash 0.95±1.17	Anodyne, antispasmodic, digestive, diuretic, hypnotic, narcotic and sedative properties, reatment of insomnia, anxiety, neuroses, hyperactivity in children, dry coughs, whooping cough, rheumatic pain	Cooked as vegetables, eaten raw in salad and dried leaves in winter	Barnali Gogoi, 2013; AlNomaani et al., 2013; http://www.naturalmedicinalherbs.net/herbs/l/lactuca-sativa=lettuce.php;Ballabh et al., 2007,Obinn

										a-Echem et al., 2021
124.	**English:** White Sweet Clover, White Melilot **Hindi:** Khandai **Marathi:** Ran Methi	*Melilotus albus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Fabales Family Fabaceae Genus Melilotus Species albus	Europe to W. Asia	Coumarin, kaempferol 3-0-galactosyl-(l-*6)-glucoside 7-O-rhamnorhamnoside (melitin) and quercetin 3-rhamnosyl-(l->6)-galactoside 7-O-rhamnoside (clovin)	NF	used as an anticlotting agent for the blood, Anticoagulant; Aromatic; Carminative; Emollient; Poultice, used in ointments for external ulcers, as an insect repellent, Fresh leaves paste is applied topically for Inflammation, joint pain	Cooked as vegetables	Barnali Gogoi, 2013; https://pfaf.org/USER/Plant.aspx?LatinName=Melilotus+albus; Nicollier et al, 1982, Abbasi et al, 2013 Rigal et al., 2016
125.	**English:** Chinese Cucumber **Hindi:** Kakur **Manipuri:** Karot **Marathi:** Gulkakra **Malayalam:** Kshudramalakasanda **Telugu:** Varivalli **Bengali:** Golkakra **Assamese:** Bhat Kerala **Sanskrit:** Katamala	*Momordica cochinchinensis*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Cucurbitales Family Cucurbitaceae Genus Momordica Species cochinchinensis	E. Asia	Momordine, A-spinaterol, sesquibenihol	Moisture (%) 83.12 ± 0.16 Carbohydrate 14.13 ± 0.14 Protein 3.61 ± 0.04 Lipid 1.72 ± 0.02	used as a remedy for intestinal disturbances, pain after childbirth, stomach cramps and various swellings, to aid in the relief of dry eyes, as well as to promote healthy vision	Cooked as vegetables	Barnali Gogoi, 2013; http://tropical.theferns.info/viewtropical.php?id=Momordica+cochinchinensis; Mukherjee et al.,2017
126.	**Bengali** – Ghima **Hindi** – Sureta	*Polycarpon prostratum*		Kingdom Plantae Phylum Tracheophyta Class Magnoliopsida Order Caryophyllales Family Caryophyllaceae Genus Polycarpon Species prostratum	E. Asia	Betaamyrin, betasitosterol, betasigmasterol, hentriacontanol, hentriacontane	NF	Used for diabetes, sore throat, gastric and stomach problems, or coughs following fever, particularly in measles; malarial fever	Cooked as vegetables	Barnali Gogoi, 2013; Debbarma et al, 2017; Chandra et al., 2015; Indian Medicinal Plants: An Illustrated Dictionary By C.P. Khare
127.	**Common Name:** Dwarf Morning Glory Kalowa	*Evolvulus adscendens*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Solanales Family Convolvulaceae Genus Evolvulus Species Evolvulus adscendens	Asia	Alkaloid evolvine; β-sitosterol, stearic, oleic and linoleic acid, betaine, pentatriacontane and triacotane	NF	Cure indigestion and constipation, used as brain tonic, to cure fever, cough and cold	Cooked in water as vegetables	Wild Edible Vegetables of Lesser Himalayas: Ethnobotanical and ..., Volume 1 Jayasuriya et al., 2021

128.	**English:** Bladder Dock **Hindi:** Chooka **Manipuri:** Torong Khongchak **Marathi:** Amlavetasa **Tamil:** Cukkan-Kirai **Tangkhul:** Hangam Ashinba **Telugu:** Chukka Kura **Kannada:** Chukki Soppu **Bengali:** Bun Palung **Nepali:** Amilo Bethe **Urdu:** Tukhm Hummaz **Assamese:** Chuka Sak **Sanskrit:** Amlavetasa	*Rumex vesicarius*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Polygonaceae Genus Rumex Species vesicarius	S. Europe, N. Africa, through Asia	emodin, aloe-emodin, chrysophanol, chrysophanic acid, physcion; isovitexin, iso-orientin, quercetin, kaempferol and luteolin glucosides, Delphinidin-3-sambubioside and cyaniding-3-Sambubioside	Moisture(%) 87.8–93.5 Protein 17.1–20.1 Lipids 3.1–3.8 Calcium 1790-3680 Copper 2.1–3.9 Iron 24.1–42.5 Magnesium 1320–2270 Potassium 2710–3230 Sodium 846–1100 Zinc 3.7–8.8	Aperient, astringent, diuretic and cooling, useful in treating heat of the stomach, to allay the pain of toothache and, by its astringent properties, to check nausea, constipation, asthma, bronchitis, hiccough, dyspepsia, vomiting and piles, disease of spleen	Leaves and tender stems, which is sour in taste, is prepared chutneys, also a sour curry with other vegetables, used like sorrel as a flavouring in salads	Barnali Gogoi, 2013; http://tropical.theferns.info/viewtropical.php?id=Rumex+vesicarius https://pfaf.org/user/Plant.aspx?LatinName=Rumex+vesicarius; Mohammed et al., 2006; Mukherjee et al., 2017
129.	**English:** Annual Sea-Blite, Herbaceous Seepweed **Hindi:** Alur **Tamil:** Nila Vumarai **Telugu:** Alagu, Kodee Kasseery Kura, Vellakora, Yella Kura	*Suaeda maritima*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Amaranthaceae Genus Suaeda Species maritima	Asia, E. Indies, N. America	Cirtonellyl propionate, Cirtonellyl acetate, Tetradecanoic acid(myristic acid), Scytalone, Hexadecanoic acid methyl ester, Tritetracontane, 9,12-Octadecadienoic acid, 2-hexyl-1-octanol, Diisobutylene, n-Hexatriacontane, Citronellal, Palmitic acid, Hexacontanoic acid, n-Octadecane, 9-Eicosyne, Campesterol, Aciphyllene, Ethanone	Moisture (%) 91.22 Carbohydrate 4.85 Dietary fiber 4.10 Crude protein 1.71 Crude fat 0.63	Treats hepatitis and reported to have antiviral, hepatoprotective, anti-inflammatory and antioxidant activities, curing liver, heart, and lipid disorders, treatment of poisonous snakebites and scorpion stings	Cooked as vegetables	Barnali Gogoi, 2013; Dinesh et al., 2016; Pornpitakdamrong et al., 2014
130.	**English:** Tamarind **Hindi:** Imli **Bengali:** Amli **Manipuri:** Mange **Tamil:** Puli **Telugu:** Chinta **Marathi:** Chinch	*Tamarindus indica*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Fabales Family Fabaceae Genus Tamarindus Species indica	Asia and Africa	pipecolic acid nicotinic acid, 1-malic acid, volatile oils (geraniol, limonene), pipecolic acid, lupanone , lupeol , orientin , isoorientin, vitamin B3, vitamin C , vitexin, isovitexin, benzyl benzoate (40.6%), cinnamates, serine, pectin, beta alanine, proline, phenylalanine, leucine, potassium, 1-malic acid, tannin, glycosides, vitexin, phenylalanine, leucine, potassium, Campesterol, β-amyrin, β-sitosterol	Moisture (%) 93.7 Carbohydrates 62.50 Dietary fiber 5.10 Protein 2.80 Total fat 0.60 Sodium(mg) 28 Potassium 628 Calcium 74 Copper 0.86 Iron 2.80 Magnesium 92 Phosphorus 113 Zinc 0.10 Selenium(μg) 1.30	Used as decoction variegated with potash for the treatment of stomach disorder, general body pain, jaundice, yellow fever and a blood tonic and skin cleanser, otent antibacterial, antifungal, hypoglycaemic, cholesterolemic, hypolipidemic, antioxidant, antihepatotoxic, anti-inflammatory, and antidiabetic properties	Cooked as vegetables and chutney	Barnali Gogoi, 2013; http://tropical.theferns.info/viewtropical.php?id=Tamarindus+indica
131.	**English:** Snake Gourd **Hindi:** Chachinda **Kannada:** Adla Balli **Malayalam:** Padavalanga **Marathi:** Jangli Padavala **Sanskrit:** Amritaphala, Bijagarbha **Tamil:** Pudalankaai **Telugu:** Potlakaaya, Adavi Potla	*Trichosanthes cucumerina*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Cucurbitales Family Cucurbitaceae Genus Trichosanthes Species cucumerina	E. Asia	cucurbitacin B, cucurbitacin E, isocucurbitacin B, 23,24-dihydroisocucurbitacin B, 23,24-dihydrocucurbitacin E, sterols 2 β-sitosterol stigmasterol, 23, 24-dihydrocucurbitacin D, 23,24-dihydrocucurbitacin B, cucurbitacin B, 3β-hydroxyolean-13(18)-en-28-oic acid, 3-oxo-olean-13(18)-en-30- oic acid and the sterol 3-O-β-D-glucopyranosyl-24ξ-ethylcholest-7,22-dien-3β-ol	Moisture(%) 78.40 ± 0.15 Carbohydrate 16.50 ± 0.15 Crude Fibre 1.03 ± 0.09 Crude Protein 1.97 ± 0.09 Crude Lipid 0.47 ± 0.03 Ash 1.63 ± 0.15	Bilious disorders and skin diseases and as an emmenagogue. Leaf is alexiteric, astringent, diuretic and emetic, remittent fevers, has anti-spasmodic property, used as appetizer, laxative, aphrodisiac and blood purifier and also in cardiac failure, used as appetizer, laxative, aphrodisiac and blood purifier and also in cardiac failure	Tender-most leaves, sour in taste, are made chutneys / sour-curries	Barnali Gogoi, 2013; PinarKuru et al., 2014; Sandhya et al.,2010; Singh et al, 2017 Ugbaja et al., 2017

132.	**English:** Cultivated Fenugreek, Wild Trefoil **Hindi:** Kasuri Methi	*Trigonella corniculata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Fabales Family Fabaceae Genus Trigonella Species corniculata	Europe - Mediterranean to W. Asia.	Lupeol, Octadecane, Stigmasterol, Campesterol, Nonadecane, Hexadecanoic acid, butyl ester, Phytol, 10,13-Octadecadienoic acid, methyl Ester, Eicosane, Hexadecanoic acid, ethyl ester, n-Hexadecanoic acid, Hexadecanoic acid, methyl ester, 2-Pentadecanone, 6,10,14-trimethyl, Octadecane, Hexadecane, 3-Buten-2-one, 4-(2,6,6-trimethyl-1-cyclohexen-1-yl)-, 1-Heneicosyl formate,	Moisture(%) 86.1 Carbohydrates 6 Fiber 1.1 Protein 4.4 Fat 0.9	Antileukaemic activity, swellings and bruises, anti-inflammatory, anti-carcinogenic activities	Cooked as vegetables	Barnali Gogoi, 2013; Anupama et al., 2017; Pasricha et al., 2014
133.	**English:** Velvet Leaf, False Pareira Brava, Abuta, Pereira Root, Barbasco **Nepali:** Baatulpaate Paathaa	*Cissampelos Pareira*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Ranunculanae Order Ranunculales Family Menispermaceae Genus Cissampelos Species pareira	Asia	cycleanine, hayatidin, hayatinin and hayatin, Bulbocapnine, Corytuberine, Curine, Cycleanine, Hayatine, Laudanosine, Magnoflorine, Nuciferine, Quercitol	NF	Antileukaemic activity, used in the treatment of chronic non-healing ulcers and sinuses. It is also used in the treatment of chronic skin diseases and in the treatment of poisonous bites. Its anti-inflammatory activity	Cooked as vegetables	Barnali Gogoi, 2013; ; https://www.dabur.com/in/en-us/about/science-of-ayurveda/herbal-medicinal-plants/patha-plant;, Samanta et al., 2011 Patel et al., 2013
134.	**English:** Malabar Nut, White Vasa, Yellow Vasa **Assamese:** Boga Bahok **Bengali:** Basak **Gujarati:** Aradusi **Hindi:** Arus **Kannada:** Adusoge **Konkani:** Adulasha **Malayalam:** Aatalootakam **Manipuri:** Nongmangkha Angouba **Marathi:** Adulasa **Mizo:** Kâwl-Dai **Nepali:** Asuro **Oriya:** Basango **Sanskrit:** Atarusa **Tamil:** Acalai **Telugu:** Addasaramu	*Justicia adhatoda*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Acanthaceae Genus Justicia Species adhatoda	Eastern Asia	vasicine, adhatodic acid, teolin, Tritriacontane, B- Sitosterol, Kaempferol, 3-Sophoroside, Adhatodic acid, q-Hydroxyvasicinine, Vit –C, vasicol. Vasicinol, Vaicinolone, Adhatodine, Adhavasinone, Anisotine, Carotene, Vasakin, Vasicinone, Vascicolone, Vasicolinone	Moisture (%) 81.8 Total Ash content 21.40 Acid insoluble ash 0.92 Water soluble ash 4.85	Treatment of cough and other respiratory ailments, used in many pharmaceutical formulations as an expectorant, act as an antihistamine agent, antiinflammatory, antispasmodic, febrifuge, pectoral, for treating bronchitis, asthma, fever and jaundice, A medicine for setting broken bones, relieving pain, resolving phlegm, leaves are antiseptic	Cooked as vegetables	Barnali Gogoi, 2013; http://www.gyanunlimited.com/health/vasaka-malabar-nut-medicinal-uses-benefits-and-side-effects/11317/, Gangwar et al., 2014 Shoba et al, 2015
135.	**English:** Black Galangal, Wild Ginger **Bengali:** Jangli Ada, Tara **Kannada:** Betta Shunthi **Malayalam:** Malainschikua **Manipuri:** Pullei **Marathi:** Giri-Kulimjan	*Alpinia nigra*		Kingdom Plantae Order Zingiberales Family Zingiberaceae Subfamily Alpinioideae Genus Alpinia Species nigra	E.Asia	Astragalin and kaempferol-3-O-glucuronide, caryophyllene oxide 23%, geraniol19.9%, eudesmool19.4% and citronellyl OAc 16.5% caryophyllene (47.7–49.0%), pinene (13.7–14.4%), humulene(7.5–7.8%), (E)-nerolidol (3.6–3.7%)	NF	Treats dyspepsia, gastric disease, and insect bites, antibacterial, antioxidant, antiprotozoal, hepatoprotective and glycation inhibitory effects, rheumatism, bronchial catarrh, bad breath, and ulcers whooping colds in children, throat infections, to control incontinence, fever and dyspepsia antibacterial, antifungal, anti-protozoal, antiinflammatory and analgesic, diuretic, antihypertensive, anticancer, and antiulcer effective against HIV-1 integrase and neuraminidase enzymes	Cooked as vegetables	Barnali Gogoi, 2013; Saboo et al., 2014; Roy et al., 2012 Firdusi et al., 2013

136.	**English:** Sophera Senna **Hindi:** Kasaunda **Manipuri:** Thounam **Marathi:** Kashawada **Tamil:** Poonaverie **Telugu:** Pydee Tanghadu	*Senna sophera*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Fabales Family Fabaceae Genus Senna Species sophera	Asia and America	anthraquinones, including chrysophanol and emodin, flavanol-C-glycoside and sennosides, Butanedioic Acid, Hydroxy-Diethyl ether, 1,2,4-Butanetriol, Triacetate, 7-Hexadecene (z)-, E-15-Heptadecenal, 1,2-Benzenedicarboxylic acid, Butyl octyl ester, 3-Eicosene (E)-, 10-Heneicosene (C, T)	NF	Anthelmintic, expectorant and febrifuge, as a remedy for rheumatic and inflammatory fevers, fever and malaria, used as an eye-bath to cure conjunctivitis, used for wound healing and is applied against ringworm, used to treat epilepsy	Cooked as vegetables	Barnali Gogoi, 2013; http://tropical.theferns.info/viewtropical.php?id=Senna+sophera, http://www.ebbd.info/senna-sophera.html, Amol R.Kharat Aziza et al., 2019
137.	**English:** Siam Weed **Hindi:** Tivra Gandha, Bagh Dhoka **Malayalam:** Communist Pacha, Venapacha **Nepali:** Aule Banamaaraa	*Chromolaena odorata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Asterales Family Asteraceae Genus Chromolaena Species odorata	Asia and Africa	β-caryophyllene (21%) and germacrene-D (15.3%), Bicyclogermacrene (12.55%), geigerene (11.85%), (Z)-β-farnesene (9.98%) and α-pinene (9.36%), Pregeijerene(19.9%), α–pinene (17.9%); β-caryophyllene (21.0%), germacrene-D, kaempferol and quercetin, apigenin and luteolin, quercetagetin, scutellarein, artemitin, jaceidin, centaureidinm, eupatorine, Eupafolin, eupatilin and tetramethoxyflavone, chalcone glycosides, Aromadendrin and its 7-methylether and flavonolignans	Moisture (%) 59.50 Total carbohydrate 20.58 Crude fiber 10.76 Crude protein 6.56 Crude lipid 0.10 Calcium(mg) 487.40±1.06 Magnesium 116.70±1.01 Potassium 96.91±1.05 Sodium 44.22±1.02 Phosphate 143.15±1.04 Iron 67.71±1.01 Zinc 3.77±0.19 Copper 1.41±0.98 Manganese 0.81±0.10 Chromium 0.97±0.08	Used as a cough remedy, used as a haemostatic on wounds and anti-inflammatory, used for the treatment of leech bite, soft tissue wounds, burnt wounds, skin infection and dento-alveolitis, reduce the desire of smoking, cures fever, coughing, jaundice and stomach ache, antidiarrhoeal, astringent, antispasmodic, antihypertensive, antiinflammatory and diuretic	Cooked as vegetables	Barnali Gogoi, 2013; Ngozi et al., 2009;Chakraborty et al., 2011; Félicien et al., 2012;
138.	**English:** Air Plant, Donkey Ears, Life Plant, Leaf Of Life **Hindi:** Amar Poi **Malayalam:** Elamarunna **Tamil:** Runakkalli **Bengali:** Kop Pata **Urdu:** Zakhmhaiyat **Manipuri:** Manahidak	*Kalanchoe pinnata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Saxifraganae Order Saxifragales Family Crassulaceae Genus Kalanchoe Species pinnata	Asia	Taraxerone, B-amyrene 3-acetate, B-Sitosterol, astragalin, 3,8-dimethoxy 4,5,7-trihydroxyflavone, friedelin, epigallocatechin-3-o-syrigate, luteolin, rutin, kaempferol, quercitin, quercitin-3L-rhamonsido-L-arabino furanoside, quercitin-3-O-di arbinoside and kaempferol-3-glucoside, β- sitosterol, bryophyllol, bryophynol, bryotoxin A, bryotoxin B, campesterol, 24-ethyl-25-hydroxycholesterol, isofucosterol, clionasterol, codisterol, peposterol, 22-dihydrobrassicasterol, clerosterol, 24-epiclerosterol, 24-ethyl- desmosterol, stigmasterol, 1-octane3-O-α-L-arabinopyranosyl-(1→6)-glucopyranoside	Moisture(%) 91.03± 0.55 Carbohydrate 4.46 ± 0.52 Fibre 6.02 ± 1. 06 Protein 5. 38 ± 0.10 Fat 1.38 ± 0.06 Potassium 3.74 ±0.04 Calcium 6.82 ± 0.04	Heamatemesis, haemorrhoids, menorrhagia, cuts and wounds, discoloration of the skin, boils, sloughing ulcers, ophthalmia, burns, scalds, corn, diarrhea, dysentery, vomiting and acute inflammation, astringent, sour, and sweet, refrigent, emollient, mucilaginous, haemostatic, vulnerary, depurative, constipating, anodyne, carminative, antiinflammatory, disinfectant and tonic	Cooked as vegetables	Barnali Gogoi, 2013; Chaturvedi et al, 2012; Ramesh et al., 2014
139.	**English:** Blue Fountain Bush **Hindi:** Bharangi **Manipuri:** Moirang Khanam **Marathi:** Bharangi **Tamil:** Sirutekku **Malayalam:** Cherutekku **Telugu:** Gantubarangi **Kannada:** Gantabarangi **Gujarati:** Bharangi **Nepali:** Andekhi	*Rotheca serrata*		Kingdom Plantae Division Tracheophyta Class Magnoliopsida Order Lamiales Family Lamiaceae Genus Rotheca Species serrata	Asia	Stigmasterol, α- spinasterol, luteolin, luteolin 7 - O glucuronide, apigenin, baicalin and scutellarin 7 - O glucuronide, β- sitosterol, 24 (s) - ethyl cholesta - 5, 22, 25 trien - 3β ol, 5 hydroxy - 7, 4 -dimethoxy flavones, luteolin, apigenin, scutellarien and ursolic acid, γ-sitosterol, β-sitosterol,cholesterol, clerosterol, campesterol; Phenolic content 34.3 ± 0.05 mg GAE/g FW, Flavanoid Content 13.8 ± 0.01 mg RE/g FW	NF	Antihistaminic, antiallergic agent, antinociceptive and anti-inflammatory properties, hepatoprotective activity, anticancer activity, used for stiffness in the joints, used to cure many life threatening diseases, asthma, cholera, eye diseases, fever, bronchitis, tuberculosis wounds, malaria, ulcers, snakebite, rheumatism, leucoderma, liver disorders	Cooked as vegetables	Barnali Gogoi, 2013; Jayashree et al., 2018 Patil et al., 2019

140.	**English:** Hill Glory Bower **Hindi:** Titabhamt **Manipuri:** Kuthap Manbi **Marathi:** Bhandira **Tamil:** Perukilai **Malayalam:** Peruku **Telugu:** Gurrapu Katilyaku **Kannada:** Ibbane **Bengali:** Bhant **Sanskrit:** Bhandirah **Nepali:** Rajbeli	*Clerodendrum infortunatum*		Kingdom Plantae Division Spermatophyta Subdivision Angiospermae Class Dicotyledonae Order Lamiales Family Lamiaceae Genus Clerodendrum Species infortunatum	Asia	saponin, alkyl sterols, some enzymes, and 2,-(3, 4-dehydroxyphenyl) ethanol1-O-α-2 rhamnopyranosyl (1→3)-β-D-(4-O-caffeoyl) glycolpyranoside(acetoside), Lenoleic, oleic, stearic and lignoceric acid, caffeic acid, acetoside, fumaric acid, apegerin, acacetin, cabrubin, quercitin, scutellarein, hispidulin, clerodolone, clerodin	NF	Used as anthelmintic, analgesic, anticonvulsant, antidiabetic agent and also to increase haemoglobin level in the blood, used as an antitumor agent, use as traditional medicine to cure common ailments such as in the treatment of bronchitis, asthma, fever, diseases of the blood, inflammation, burning sensation, tuberculosis, hepatoprotective, given orally in fever and bowel troubles	Cooked as vegetables	Barnali Gogoi, 2013; Bhattacharjee et al., 2011; Dey et al., 2015; DAS et al., 2014; Singhmura et al., 2016 Gera et al., 2020
141.	**English:** Garlic Pear Tree, Caper Tree **Hindi:** Barna **Manipuri:** Loiyumba Lei **Tamil:** Marvilinga **Bengali:** Barun **Sanskrit:** Varuna **Malayalam:** Nir Mathalam **Kannada:** Nirvala **Telugu:** Voolemara	*Crateva magna*		Kingdom Plantae Division Tracheophyta Class Magnoliopsida Order Brassicales Family Capparaceae Genus Crateva Species magna	East Africa, Asia	l-stachydrine. Root bark contains rutin, quercetin, lupeol, varunol and ß-sitosterol, lauric, stearic, undecylic, oleic and linolenic acids and a new triterpene alcohol – lupa-21, 20(29)dien-3ß-ol, friedelin, diosgenin, sitosterol, butulic acid, dodecanoic anhydride, methyl pentacosanoate, kaemferol-3-O-α-D-glucoside and quercitin-3-O-α-D-glucoside	NF	Stomachic, tonic, rubefacient and febrifuge; used in rheumatism, promote the appetite, used to treat various ailment to urolithiasis, hepatoprotective, cardioprotective, anti-arthritic and rubefacient, oxytosic, laxative, anti-periodic and bitter tonic, diuretic	Cooked as vegetables	Barnali Gogoi, 2013; http://www.mpbd.info/plants/crataeva-magna.php, Sovan Pattanaik et al., 2013, R et al., 2017 Venkataraman et al., 2017
142.	**English:** Bermuda Grass **Assamese:** Dubari **Bengali:** Durba **Hindi:** Doob, Dobri **Kannada:** Garikehullu **Manipuri:** Tingthou **Marathi:** Haryali, Dhurva **Mizo:** Phaitualhnim **Oriya:** Dubbo Ghas **Sanskrit:** Niladurv **Tamil:** Arugampillu **Telugu:** Ghericha **Urdu:** Doob	*Cynodon dactylon*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Lilianae Order Poales Family Poaceae Genus Cynodon Species dactylon	East Africa, Asia, Australia and southern Europe	apigenin, luteolin, orientin and vitexin, beta-carotene, neoxanthin, violaxanthin, phytol, tricosane, glycerine(38.49%), 9, 12-octadecadienoyl chloride, (Z, Z)-(15.61%), hexadecanoic acid, ethyl ester (9.50%), ethyl α-D-glucopyranoside (8.42%), linoleic acid ethyl ester(5.32%), tricosane (22.05%), 1, 2-propanediol (20.30%), 3- benzyloxy-1, 2 diacetyl (12.62%), hexadecenoic acid, ethyl ester (17.49%), D-mannose (11.48%) and linolenic acid, ethy ester (11.28%), hydroquinone (69.49%), furfural (6.0%) and levoglucosenone(2.72%)	Moisture (%) 98 Carbohydrate 75.9 Fiber 25.9 Protein 11.6 Fat 2.1 Calcium (mg) 530 Phosphorus 220 Iron 112 Potassium 1630	Improves digestion and cures stomach ailments, treat varied ailments such as cough, headache, diarrhea, cramps, epilepsy, dropsy, dysentery, hemorrhage, hypertension, hysteria, measles, snakebite, sores, stones urogenital disorders, tumors, and warts, used for diuretic, anti-emetic, purifying agent	Cooked as vegetables	Barnali Gogoi, 2013; Ashokkumar et al., 2013; Snafi et al., 2016
143.	**English:** Telegraph Plant **Bengali:** Nageswar **Hindi:** Dudli **Kannada:** Aelemudure **Tamil:** Thozhuganni **Telugu:** Thozhuganni	*Codariocalyx motorius*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Fabales Family Fabaceae Genus Codariocalyx Species motorius	South East Asia	chlorogenic acid (465.87 µg/g) followed by myricetin (155.12 µg/g). Other phenolic compounds include naringenin (125.49 µg/g), O-coumaric acid (100.45 µg/g), gallic acid (98.88 µg/g), rutin (83.98 µg/g), ferulic acid (37.12 µg/g), quercetin (24.59 µg/g), caffeic acid (16.68 µg/g) and protocatechuic acid (2.02 µg/g), Gallic acid, protocatechuic acid, chlorogenic acid, caffeic acid, rutin, naringenin, ferulic acid, ortho-coumaric acid, quercetin and myricetin	Moisture(%) 45.6±1.2 Crude fiber 3.5±0.02 Total Sugars 15.6±0.04 Soluble Sugars 8.5±0.21	Treat snake poison, heart diseases, wound healer, rheumatic problems, Diabetes, skin disorders	Cooked as vegetables	Barnali Gogoi, 2013; http://www.medicinalplantsindia.com/telegraph-plant.html, Uma et al., 2014 Li et al., 2020
144.	**English:** Elephant Foot Yam **Hindi:** Oal, Gandira **Kannada**: Gandira **Malayalam**: Cinapavu, **Marathi**: Suran **Sanskrit**: Arsaghna **Tamil**: Anaittantu, Boomi **Telugu**: Daradakandagadda, **Urdu**: Zamin-Kand	*Amorphophallus campanulatus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytin Class Magnoliopsida Superorder Lilianae Order Alismatales Family Araceae	Asia	Amblyone (Triterpenoid), Betulinic acid (Organic Acid), Stigmasterol, β-sitosterol (Phytosterols)	Moisture (%) 92.7 Carbohydrate 70.75 Crude fibre 14.32 Protein 11.53 Fat 3.52 Ash 6.9	Piles, rheumatism, cough, body pain, insect sting	Cooked as vegetables	Soumen Maitra, 2014 Srivastava et al., 2014

				Genus Amorphophallus Species campanulatus						
145.	**English:** Hemp-Agrimony Or Holy Rope	*Eupatorium cannabinum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Asterales Family Asteraceae Genus Eupatorium Species cannabinum	E.Asia	9-O-angeloyl-8,10-dehydrothymol; 9-(3-methylbutanoyl)-8,10-dehydrothymol; Eupatobenzofuran; 2-hydroxy-2,6-dimethylbenzofuran-3(2H)-one; 1-(2-hydroxy-4-methylphenyl)propan-1,2-dione; 9-acetoxy-8,10-epoxythymol 3-O-tiglate; 9-acetoxy-8,10-dehydrothymol 3-O-tiglate; 9-acetoxythymol 3-Otiglate; 9-hydroxy-8,10-dehydrothymol; 9-isobutyryloxy-8,10-dehydrothymol; 8-methoxy-9-Oisobutyrylthymol; 8-methoxy-9-O-angeloylthymol;10-acetoxy-8-hydroxy-9-O-angeloylthmol; 30,40,4a0,9a0-tetrahydro -6,70-dimethylspiro[benzofuran-3(2H),20-pyrano[2,3-b]benzofuran]-2,4a0-diol; 1-[2-hydroxy-4(hydroxymethyl) phenyl]ethan-1-one; hofmeisterin II;euparin; 2H-chromen-2-one; taraxasterol acetate;mixture of β-sitosterol and stigmasterol, Caffeic Acid (%mg) 56.86, Eupatorine (%mg) 1.26, Eupatilin (%mg) 18.06, Quercetin (%mg) 97.03, Rutin (%mg) 762.63	NF	Alterative, Antitumor, Cholagogue, Depurative Diaphoretic, Diuretic, Emetic, Expectorant, Febrifuge, Homeopathy, Laxative, Purgative, Tonic, used a cholagogue, laxative, diuretic and hypocholesterolemic and for wound healing, diarrhea and livers diseases	Cooked as vegetables	Barnali Gogoi, 2013; IONITA et al., 2013; Snafi et al., 2017 Ionita et al., 2013
146.	**English:** Wild Hops, Luck Plant **Assamese:** Makhiyati **Gujarati:** Poptyo **Hindi:** Kanphuta **Kannada:** Kumalu **Malayalam:** Kanalam Kumalu **Marathi:** Bundar **Nepali:** Bhatmase **Telugu:** Nalla Baddu	*Flemingia strobilifera*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Fabales Family Fabaceae Genus Flemingia Species strobilifera	E. Asia	Quercitin, rutin, quercimeritin, leptosidin, leptosin, phloridzin and naringin, chalcones, n-triacontane, sitosterol, 3,6,dihydroxy2,4,5,4tetramethoxychalcone	Moisture(%) 94.15 Total Ash content 3.07 Acid insoluble ash 0.72 Water soluble ash 0.52	Used in the treatment of epilepsy, insomnia, ulcer, pain ,swelling, used in the treatment of tuberculosis, rheumatish, vermifuge, tuberculosis, indigestion, fevers epilepsy and hysteria, swellings, hepatic injury	Cooked as vegetables	Barnali Gogoi, 2013; Ghalot et al., 2011; Ghalot et al., 2012
147.	**English:** Roselle, Hibiscus **Hindi:** Lal Ambari **Manipuri:** Silo-Sougree **Marathi:** Laal-Ambaari **Tamil:** Simaikkasuru **Malayalam:** Polechi **Telugu:** Erragomgura **Kannada:** Kempupundrike **Bengali:** Chukar **Mizo:** Lekhar-Anthur **Assamese:** Chukiar, Tengamora **Sanskrit:** Ambasthaki	*Hibiscus subdarifa*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Malvales Family Malvaceae Genus Hibiscus Species sabdariffa	E.Asia	Succinic acid; glucose, ascorbic acid, β-carotene and lycopene, anthocyanin pigments (Delphinidin-3-sambubioside and cyaniding-3-Sambubioside), lemingiaflavanone (8, 3' -diprenyl-5, 7, 4' -trihydroxy flavanone), Genistin (5, 4' - dihydroxy isoflavone 7-O-glucoside) and β - sitosterol-D glucoside	Moisture(%) 88.26 Carbohydrate 9.2 Protein 3.3 Fat 0.3 Phosphorus(mg) 214 Iron 4.8	Treatment of abscesses, bilious conditions, cancer, cough, debility, dyspepsia, fever, hangover, heart ailments, hypertension, and neurosis, antiscorbutic, emollient; diuretic, refrigerant, and sedative, cardioprotective, hypocholesterolemic; antioxidative and heaptoprotective	Cooked as vegetables	Barnali Gogoi, 2013; Mungole et al., 2011

148.	**Bengali:** Kantakachu; **Tribal Name**: Gandagi (Chakma); Taratu (Marma), Kattolii (Tanchangya)	*Lasia spinosa*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Lilianae Order Alismatales Family Araceae Genus Lasia Species spinosa	E. Asia	α-carotene, ß-carotene, ß-carotene-5, 6, 5' , 6'diepoxide, 5, 6, 5' , 6' - diepoxy-5, 8, 5' ,8' -tetrahydro-ß, ßarotene-3,3' -diol, or cis-neoxanthin	Moisture (%) 83 Carbohydrate 35.7 Protein 17.6 Fat 1.16 Ash 34 Total solids 17 Zinc(ppm) 7.44 Magnesium 6.22 Molybdnum 1.18 Copper 0.31 Iron 17.06 Manganese 1.33	Used for treating lymphotuberculosis, lymphonoditis, stomach aches, snake and insect bites, injuries, and rheumatism, treatment of throat ailments, remedy for piles, anti-helminthic, anti-bacterial, anti-inflammatory, antioxidant, anti-diabetic, anti-hyperlipidemic, anti-tumor	Cooked as vegetables	Barnali Gogoi, 2013; Kankanamge et al., 2017; Brahma et al., 2014
149.	**English:** Malabar Melastome, Indian-Rhododendron **Hindi:** Shapti **Rongmei:** Bobuchunmei **Marathi:** Rindha, Palore **Malayalam:** Palore **Telugu:** Nekkarike **Kannada:** Ankerki **Oriya:** Gongoi, Koroti **Konkani:** Myetpyai **Assamese:** Phutuki **Nepali:** Angeree, Chulese	*Melastoma malabathricum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Myrtales Family Melastomataceae Genus Melastoma Species malabathricum	Asia	anthocyanins (e.g., cyanidin- (Cy-) 3-glucoside and Cy-3,5-diglucoside), *β*-sitosterol, melastomic acid (5-hydroxylup-20(29)-en-28-oic acid), 1-octyl docosanoate and 11-methyl-1-tricontanol, 32-methyl-1-tritriacontanol, ursolic acid, p-hydroxybenzoic acid and gallic acid, and kaempferol, kaempferol-3-*O*-*β*-D-xyloside, quercetin-3-*O*-*α*-L-rhamnosyl-(1→2)-*β*-D-galactoside, flavan-3-ol, 4′-methylpeonidin-7-*O*-*β*-D-glucoside	NF	Treat various types of ailments and diseases, for example, diarrhoea, dysentery, leucorrhoea, hemorrhoids, cuts and wounds, infection during confinement, toothache, stomachache, flatulence, sore legs, and thrush, diarrhea, alleviate rheumatism, arthritis, and tenderness in the legs, used to relieve the discomfort of hemorrhoids, useful for the treatment of cholera, diarrhoea, prolonged fever, dysentery, leucorrhoea, wounds, and skin diseases and for the preparation of gargles	Fresh and cooked as vegetables	Barnali Gogoi, 2013; Joffry et al., 2012; http://tropical.theferns.info/viewtropical.php?id=Melastoma+malabathricum
150.	**English:** Nilofar, Romanian White Waterlily **Bengali:** Swetshaluk **Manipuri:** Tharo-Angouba **Sanskrit:** Kumuda **Tamil:** Neytarkilanku **Urdu:** Nilofar **Kashmiri:** Brimposh	*Nymphaea alba*		Kingdom Plantae Division Tracheophyta Class Magnoliopsida Order Nymphaeales Family Nymphaeaceae Genus Nymphaea Species alba	Asia	Galacturonic acid and raffinose	Moisture(%) 93.6±0.03 Carbohydrate 14.48±0.34 Crude Fat 4.48±0.21 Fibre 15.53±0.45 Protein 19.54±0.78	Hemorrhage from the stomach, dysentery, Loss of appetite	Cooked as vegetables	Maitra et al., 2014 Abarike et al., 2015 Mohammed et al., 2013
151.	**English:** Spearmint, Garden Mint, Lamb Mint **Hindi:** Pahari Pudina	*Mentha spicata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Lamiaceae Genus Mentha Species spicata	East Asia	β – myrcene, Trans-carveol, Limonene, Carvone, Γ-terpinene, Dihydrocarvyl acetate, Menthone, L-carveol, Menthol, β – bourbonene, Terpinen-4-ol, Trans-caryophyllene, Ɑ-terpinol, γ – amorphene, Dihydrocarveol, α-amorphene, Cis-dihydrocarveol, Dihydrocarvone	Moisture(%) 83 Carbohydrate 8 Fibre 2 Protein 4.8 Fat 0.6 Calcium(mg) 200 Phosphorus 80 Iron 15.6	Treats colds and flu, respiratory tract problems, gastralgia, hemorrhoids, and stomachache, used as antimicrobial and antioxidant agents, insecticides; useful to treat ulcers, gastric ulcers, scar, pimple, and black spot at skin	Cooked as vegetables and chutney	Barnali Gogoi, 2013; https://pfaf.org/user/Plant.aspx?LatinName=Mentha+spicata; Kee et al., 2017; Sevindik et al., 2018

152.	**English:** Arrow Leaf Pondweed, Arrow-Leaf Monochoria, Hastate-Leaf Pondweed, Monochoria **Hindi:** Launkia **Bengali:** Nukha	*Monochoria vaginalis*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Lilianae Order Commelinales Family Pontederiaceae Genus Monochoria Species vaginalis	E.Asia	Alnustone {(4E,6E)-1,7-diphenylhepta-4,6-dien-3-one} (1), 4- hydroxyanigorufone {2,4-dihydroxy-9-phenylphenalen-1-one}, anigorufone {2- hydroxy-9-phenylphenalen-1-one} and anigorootin {rel-(7aR,7bR,14aR,14bR)-7b,14bdihydro-7a,14a-dihydroxy-6,13-diphenyl-(7H,14H)-diphenalen[2,3,3a,4-b,c,d:2,3,3a,4-g,h,i]pyrano[4,3-c]pyran-7,14-dione}, n-hexadecanoic acid, 3-methyl- acetate-1-butanol, 1,1,3-triethoxy-propane, Z,Z,Z- 1,4,6,9 - nonadecatetraene, undecanoic acid, 3-trifluoroacetoxy penta decane and 4-ethyl-5-octyl-2,2-bis (trifluoromethyl) - cis-1,3-dioxalone	Moisture(%) 97.5 ± 0.1 Carbohydrate 38.5 ± 1.1 Fiber 11.3 ± 0.4 Protein 19.6 Fat 0.9 ± 0.1 Calcium 4.4 Sodium(mg) 18.8 ± 2.1 Potassium 20.2 ± 5.0 Magnesium 1.64 ±0.1 Iron 33.1 ± 0.5 Zinc 3.78 ± 0.12 Copper 6.71 ± 0.1	Used to treat stomach and liver problems, used as a treatment for asthma and to relieve toothache, used to treat fevers, used for curing coughs pounded, then mixed with turmeric (Curcuma longa) and Portulaca pilosa, and applied to boils after they have burst	Cooked as vegetables	Barnali Gogoi, 2013; http://tropical.theferns.info/viewtropical.php?id=Monochoria+vaginalis https://herbpathy.com/Uses-and-Benefits-of-Monochoria-Vaginalis-Cid4481 Rahul Chandran et al., 2012, Qader et al., 2017;
154.	**English:** Gulf Leaf-Flower **Bengali:** Bhui-Amla, Hazarmani **Hindi:** Bhuinanvalah, Hajarmani, Kanocha **Kannada:** Kirunelli, Nelanelli **Malayalam:** Kiizhaarnelli **Manipuri:** Chakpa-Heikru **Marathi:** Bhuiavali **Mizo:** Mithi-Sunhlu **Sanskrit:** Bhumyamalaki, Tamalaki **Tamil:** Kila-Nelli **Telugu:** Nela Usiri	*Phyllanthus fraternus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Malpighiales Family Phyllanthaceae Genus Phyllanthus Species fraternus	E. Asia	Phyllanthin, hypophyllanthin, Niranthin, nirtetralin, phyltetralin, E,E-2,4-Octadienamide, E,Z2,4-decadienamide	Moisture (%) 88.2 Carbohydrate 1.5 Crude Fibre 36.7 Crude Protein 0.88 Fat 10 Ash 40	Diuretic, facilitate childbirth, and against oedema, costal pain and fever, dysentery, treatment for coughs and hiccups, used as a laxative and to treat gonorrhoea, dropsy, diarrhoea and malaria, treat skin infections, treat bruises, sores and ulcers, and mixed with oil against ophthalmia and conjunctivitis, used in the treatment of ulcers, wounds, sores, scabies, ringworm and other skin problems, used to treat malaria, used as a galactagogue, seful in the treatment of thirst, bronchitis, asthma, leprosy, anaemia, venereal diseases, problems of the genito-urinary tract, anuria, biliousness and hiccups	Cooked as vegetables	Barnali Gogoi, 2013; http://tropical.theferns.info/viewtropical.php?id=Phyllanthus+fraternus https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3932249/ Ananias et al., 2021
155.	**English:** Long Pepper, Indian Long Pepper **Hindi:** Pipli **Marathi:** Pimpli **Tamil:** Tippili **Malayalam:** Tippali **Telugu:** Pippallu **Kannada:** Kandan Lippili **Konkani:** Pipli **Urdu:** Pipul **Gujarati:** Pipari **Sanskrit:** Pippali, Magadhi	*Piper longum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Magnolianae Order Piperales Family Piperaceae Genus Piper Species longum	Asia	Resin, piperin, piperlongumine, piperlatin, barchyamide A, barchyamide B, barchystine, sterols, glycosides	NF	Treat Sinus congestion, coughs, and hiccups, Cough, Fever, Headache, Insomnia or trouble sleeping, Asthma, Enlarged spleen and liver, Rapid heartbeat, Chronic malaria patients with splenomegaly	Cooked as vegetables	Gogoi et al., 2013;
156.	**English:** Broad Leaf Plantain, Greater Plantain, Common Plantain **Hindi:** Lahuriya, Luhuriya **Mizo:** Kelbean **Tamil:** Ishappukol Vitai **Urdu:** Bartang **Assamese:** Singa Gach **Sanskrit:** Asvagola **Nepali:** Isabagol	*Plantago major*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Plantaginaceae Genus Plantago Species major	Africa, Asia, Australia	baicalein, hispidulin, plantaginin, luteolin 7-glucoside, hispidulin 7-glucuronide, luteolin 7-diglucoside, apigenin 7-glucoside, nepetin 7-glucoside and luteolin 6-hydroxy 4′-methoxy 7-galactoside, loliolid, ursolic acid, oleanolic acid, sitosterol acid, asperuloside, majoroside, 10-hydroxymajoroside, 10-acetoxymajoroside, catapol, gardoside, geniposidic acid, melittoside, palmitic acid, stearic acid, oleic acid, linoleic acid and linolenic acid	Moisture (%) 91.78±0.03 Ash Content 9.51 ±0.59 Crude Fibre 6.24 ±0.02	Antidote; Astringent; Demulcent; Deobstruent; Depurative; Diuretic; Expectorant; Haemostatic; Laxative; Ophthalmic; Poultice; Refrigerant; Vermifuge	Raw and Cooked as vegetables	Gogoi et al., 2013; https://pfaf.org/user/plant.aspx?LatinName=Plantago+major; Adom 2017 Samuelsen, 2000 Adeyi et al., 2010

157.	**English:** Bengal Pogostemon **Manipuri:** Lamgi Thoiding **Marathi:** Pangli **Bengali:** Jui-Lata **Oriya:** Pokasunga **Nepali:** Rudhilo	*Pogostemon benghalensis*		Kingdom Plantea Division Eudicota Class Angiospermae Order Lamiales Family Lamiaceae Genus Pogostemon Species Benghalensis	Asia	α-pinene, camphene, methyl heptanone, linalool, linalyl acetate, citronella, geranyl acetate, δ-3- carene, geraniol, limonene and p-cymene, α-phellandrene, β-caryophyllene, χ-cadinene, β-bisabalol, αelemene, β-elemene, α-murolene, α-copane, α-patchulene, χ-patchulene and δ-guaiene, azulene-2-ol (32%), octatriene (6.5%), beta patchoulene(6.4%), germacrene D (5.1%), germacrene B(5.0%), Beta caryophyllene (3.9%), delta-cadinene (3.3%)and T-cadinol(3.1%)	Moisture(%) 85.28 Iron 4.76 Calcium 73.79 Phosphorus 61.67 Potassium 376.32	Used as poultices to clean wounds and promote their healing, antifungal, used as styptic, fever, treat piles, treatment as stomach disorders like diarrhea, dysentery, indigestion, etc, remedy for the snake bite, treatment of food poisoning, vomiting and stomach troubles	Cooked as vegetables	Gogoi et al., 2013, V et al., 2013; Khatoniar et al., 2018
158.	**English:** Chinese Knotweed **Manipuri:** Angom Yensil **Marathi:** Paral **Assamese:** Kelnap	*Persicaria chinensis*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Polygonaceae Genus Persicaria Species chinensis	Asia	α-amyrin, betulinic acid, oleanolic acid, and ursolic acid, dotriaeontanol, β-sitosterol, methyl 3,4,5-trihydroxybenzoate, daucosterol, 3,4,5-trihydroxybenzoic acid, quercetin, quercitrin, hyperoside and 3-O-Methy-lellagic acid 4'-O-rhamnopyranoside, hecogenin, aurantiamide , stigmastane-3,6-ione, and 25-r-spirost-4-ene-3,12-dione	Moisture(%) 92.35 ± 0.61 Fat 0.333 ± 0.02 Fibre 2.57 ± 0.52 Protein 3.66 ± 0.22 Carbohydrate 2.07 ± 0.61 Na(mg) 53.35 ± 0.06 K 1155.28 ± 0.21 Ca 5.11 ± 0.02 Mg 4.20 ± 0.06 Fe 1.60 ± 0.16 Cu 2.60 ± 0.41 Zn 0.30 ± 0.05 Mn 0.60 ± 0.02 Ni 4.70 ± 0.08 Cr 2.38 ± 0.19 Co 0.36 ± 0.07 Se 0.84 ± 0.24 Pb 2.39 ± 0.31	Used for dysentery, gastroenteritis, bloody stool, indigestion, hepatitis, tonsillitis, laryngopharyngitis, used for sprains, bruises, poisonous snake bites, used to treat ulcers, eczema, stomach aches and various inflammatory diseases, used to treat worms and scorpion bites	Cooked as vegetables	Gogoi et al., 2013; Lai et al., 2012, Basumatary et al., 2017, http://www.stuartxchange.org/Daynon.html,
159.	**English:** Eagle Fern And Eastern Brakenfern	*Pteridium aquilinum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Polypodiophytina Class Polypodiopsida Subclass Polypodiidae Order Polypodiales Family Dennstaedtiaceae Genus Pteridium Species aquilinum	Asia and S. America	Benzaldehyde, 2-n-Pentylfuran, Benzeneacetaldehyde, Limonene, Linalool oxide B, Linalool oxide C, Linalool, 2-noneal, alpha-terpineol, beta-cyclocytral, 2-methoxy-4-vinylphenol, Naphthalene-1,2-dihydro-1,1,6-trimethyl, Dehydroionoe, 2-phenylethylisothiocyanate, monoterpenes (3.20%) and sesquiterpenes (2.40%), tetratriacontane (12.40%), hexatriacontane (8.10%) and heptacosane (8.10%), γ-terpinene (0.44%) and 1, 8-cineole (0.40%), and sesquisabinene (0.39%) and β-panasinsene	Moisture(%) 90.74 Ash 7.12 Crude Fat 2.66 Crude Fibre 4.10 Crude Protein 21.90	Diuretic, refrigerant and vermifuge, treatment for cancer, treatment for arthritis, used in the treatment of tuberculosis, used to treat sores of any type and also to bind broken bones in place, antiemetic, antiseptic, appetizer and tonic, used in the treatment of rheumatism, used in the treatment of stomach cramps, chest pains, internal bleeding, diarrhoea, colds and also to expel worms, poulticed root is applied to sores, burns and caked breasts	Raw and Cooked as vegetables	Gogoi et al., 2013; http://www.ejpau.media.pl/volume13/issue4/art-20.html http://www.naturalmedicinalherbs.net/herbs/p/pteridium-aquilinum-esculentum=bracken.php S and O.O et al., 2015

160.	**English:** Agati **Hindi:** Gaach-Munga, Hathya, Agasti **Manipuri:** Houwaimal **Marathi:** Shevari, Hatga **Tamil:** Sevvagatti, Muni **Malayalam:** Akatti **Telugu:** Ettagise, Sukanasamu **Kannada:** Agasi **Bengali:** Buko, Bak **Urdu:** Agst **Gujarati:** Agathio **Sanskrit:** Varnari	*Sesbania grandiflora*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Fabales Family Fabaceae Genus Sesbania Species grandiflora	E. Asia	3,4,5-Trimethoxyphenol, Erucic acid, Phytofluene, 2-Furancarboxaldehyde, Nonanoic acid, methyl ester, Acrylonitrile, 4-methyloxazole, 1-Propanol, 2-methyl-,3-Hexen-2-one, 3,4-dimethyl- , Benzoic acid, 4-ethoxy-,ethyl ester, 6-Octadecenoic acid, methyl ester, 3,5-di-t-butyl phenol, Palmtic acid, 9-hexadecenol, Dioctyl ester, Malonic acid, ethyl 3-hexyl ester	Moisture(%) 73.1 Protein 36.3 Fat 7.5 Carbohydrate 47.1 Fiber 9.2 Ca(mg) 1684 P 258 Na 21 K 2,005	Used as an ailment for migraine, sinusitis, rheumatism, arthiris, gout and wound healing. Leaves are used as tonic or paste to treat oral and throat infections, used in colic disorder, jaundice, poisoning condition, small-pox, eruptive fever, epilepsy	Cooked as vegetables	Gogoi et al., 2013; Hussain et al. 2014, Kumar et al., 2015, https://hort.purdue.edu/newcrop/duke_energy/Sesbania_grandiflora.html, https://pfaf.org/user/Plant.aspx?LatinName=Sesbania+grandiflora
161.	**English:** Kumarika **Hindi:** Kumarika **Mizo:** Kaitha **Marathi:** Ghotvel **Tamil:** Ayadi, Malaittamarai **Malayalam:** Kaltamara, Karivilanti **Telugu:** Kondadantena **Kannada:** Kaadu Hambu **Bengali:** Kumarika **Oriya:** Mootrilata **Sanskrit:**Vanamadhusnahi	*Smilax ovalifolia*		Kingdom Plantae Division Tracheophyta Class Liliopsida Order Liliales Family Smilacaceae Genus Smilax Species ovalifolia	Asia	NF	Moisture(%) 89.4 Carbohydrate 3.14 ± 0.009 Protein 4.82 ± 0.166 Lipid 2.01 ± 0.100 Crude fiber 25.65 ± 0.338	Treats jaundice, skin problems, toothache, urinary complain, muscular sprain, stomach pain, rheumatic arthritis, venereal diseases, infertility, as sexual stimulant, in abnormal semen discharge, uterine diseases sores, dysentery, malaria, tuberculosis, leucorrhoea, wound healing, to increase appetite, different types of gastric disorders and also used as antibiotic, antifungal, antiseptic and blood purifier	Cooked as vegetables	Gogoi et al., 2013; Shah et al., 2015; Shah et al, 2016
162.	**English:** Holy Basil **Hindi, Tamil, Telugu:** Tulsi **Malayalam:** Trittavu **Marathi:** Tulshi	*Ocimum tenuiflorum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Lamiaceae Genus Ocimum Species tenuiflorum	Southeast Asia	dl-Glyceraldehyde dimer, L-Proline, 1-acetyl, 1,2,3-Propanetriol, 1-acetate, Phenol, 2-methoxy-3-(2-propenyl), 2-Allyl-1,4-dimethoxybenzene, Caryophyllene, Caryophyllene oxide, Pentadecanoic acid, 9,12,15-Octadecatrienoic acid, methyl ester, 9,12,15-Octadecatrienoic acid, Behenic acid, Arachidic acid, Linolenic acid, Oleic acid, Stearic acid, Palmitoleic acid, Palmitic acid, Myristic acid, Lauric acid, Eugenol	Moisture(%) 77.43 ± 0.61 Fats 3.66 ± 0.28 Carbohydrates 33.67 ± 0.93 Protein 8.17 ± 0.15 Dietary fibber 4.90 ± 0.40 Fe 4.53 ± 0.20 P 8.94 ± 0.31 Zn 1.68 ± 0.08 Mn 5.40 ± 0.56 Na 5.47 ± 0.48 K 58.37 ± 1.34 Mg 2.69 ± 0.11 Ca 13.73 ± 0.91	Antimycotic, Antiviral, Desinsection, Antiparasitic, Antioxidant, Anticancer, and Antiinsect activities, hypolipidemic, digestive stimulant action, anti-inflammatory, antimicrobial, antimutagenic, hepatoprotective and antihypercholesterolemic, antidiabetic, hypolipidemicand anti-dysenteric activities	Cooked as vegetables	Vidhani et al., 2016, Jayant et al., 2017
163.	**English:** Bushy Lippia, Bushy Mat Grass	*Lippia alba*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Verbenaceae Genus Lippia Species alba	Asia and Australia	Borneol, camphor, 1,8-cineole, citronellol, geranial, linalool, myrcene, neral, piperitone, sabinene, 2-undecanone, α-muurolene, β-caryophyllene, β-cubebene, β-elemene, γ-cadinene, allo-aromadendrene, caryophyllene oxide, 1-Oct-en-3-ol, 2-methyl-1-Hepten-6-one, Myrcene, Linalol	NF	Intestinal and respiratory disturbances, including influenza, A well-sugared infusion is drunk to bring relief of heart problems and to soothe tachycardia, used externally, the aromatic leaves are used in herbal baths, to cure fevers and severe stomach pain, and to cleanse the bladder, stomachic, antispasmotic, digestive, anti-hemorrhoidal and anti-asthmatic, such as cytotoxic, antifungal, antibacterial, antiviral and anti-inflammatory	Cooked as vegetables	Narzary et al., 2013; Rashid et al.,2013; http://tropical.theferns.info/viewtropical.php?id=Lippia+alba Glamočlija et al., 2011

164.	**English:** Leathery Premna **Kannada:** Chaankhaari, Javangi Balli **Marathi:** Chambarvel, Chambarti, Rawan	*Premna coriacea*		Kingdom Plantae Division Tracheophyta Class Magnoliopsida Order Lamiales Family Lamiaceae Genus Premna Species coriacea	Africa, southern Asia	aromadendrene, caryophyllene, tetracontane, 17-pentatriacontene, 3',8,8'-trimethoxy-3-piperidyl-2,2'- binaphthalene1,1',4,4'-tetrone, cis-α-bisabolene, octadecane, 3-ethyl-5-(2-ethylbutyl)-, αcaryophyllene, 2-mercaptobenzothiazole and tetratetracontane, hept-2-ene, 2,6,6-trimethyl-, 2-octadecodyethanol, phytol, caryophyllene oxide, Hepatodecane9-hexyl, ledene oxide-(II), α-farnesene, 2,5-octadecadiynoic acid, methyl ester, τ-elemene, β-cubebene, copaene, 1,6- cyclodecadiene, 1-methyl-5-methylene-, 1,9-nheptadecane, 1-octen-3-ol, cyclopentadecanol, 1,6-octadien-3-ol, 3,7-dimethyl-, 2-aminobenzoate and Z,Z,Z-4,6,9-nonadecatriene, Octadecanoic acid, ethyl ester possess antiinflammatory. 15 2(4H)Benzofuranone,5,6,7,7atetrahydro4,4,7 atrimethyl, 1-octen-3-ol, Copaene Caryophyllene, Aromadendrene, α-caryophyllene	NF	Antiinflammatory, hypocholesterolemic, cancer preventive, hepatoprotective, nematicide, insectifuge, anti- histaminic, anti-eczemic, anti-acne, alpha reductase inhibitor, anti-androgenic, antiarthritic, anticoronary, Cosmetics /antipsychotic, medication/Antioxidant, hypocholesterolemicnematicide, pesticide, antiandrogenic flavour, haemolytic, 5-Alpha reductase inhibitor. 7-9 Propanoic acid, 2-oxo-, methyl ester has been used as flavor, fungicide, irritant, perfumery, pesticide	Cooked as vegetables	Narzary et al, 2013; Sadashiva et al., 2013; Adjalian et al., 2015; Karthikeyan et al., 2017 Sadashiva et al., 2013
165.	**English:** Perennial Buckwheat **Hindi:** Ban Ogal, Kanjolya **Khasi:** Jarain **Nepali:** Ban Phappar	*Fagopyrum esculentum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Polygonaceae Genus Fagopyrum Species esculentum	Africa and Asia	Quercitrin, Hyperoside, Rutin, Chlorogenic, Neochlorogenic, P-Coumaric, Ferulic, Gallic, P-Hydroxybenzoic, Fagopyrin, Tannic, Salicylaldehyde (2-hydroxybenzaldehyde) is a characteristic component of buckwheat aroma. 2, 5-dimethyl-4-hydroxy-3(2H)-furanone, (E,E)-2,4-decadienal, phenylacetaldehyde, 2-methoxy-4-vinylphenol, hexanal and (E)-2-nonenal, decanal	Moisture(%) 92 Protein 12.25 Ash 2.34 Fat 2.79 Soluble carbohydrates 48.74 Crude fiber 17.79	Useful in the treatment of a wide range of circulatory problems, it dilates the blood vessels, reduces capillary permeability and lowers blood pressure, used internally in the treatment of high blood pressure, gout, varicose veins, chilblains, radiation damage etc., used in conjunction with vitamin C since this aids absorption, used in the treatment of erysipelas, used in the treatment of eczema and liver disorders, antioxidant, diuretic, anti-inflammatory and antispasmodic	Raw or Cooked as vegetables	Narzary et al., 2013; http://www.naturalmedicinalherbs.net/herbs/f/fagopyrum-esculentum=buckwheat.php; Ratan et al., 2011, Sadauskiene et al., 2018,
166.	**English:** Slender Brake, Silver Lace Fern, Sword Brake Fern, Or Slender Brake Fern	*Pteris ensiformis*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Polypodiophytina Class Polypodiopsida Subclass Polypodiidae Order Polypodiales Family Pteridaceae Genus Pteris Species ensiformis	E. Asia	kaempferol 3-O-α-l-rhamnopyranoside-7-O-[α-d-apiofuranosyl-(1-2)-β-d-glucopyranoside], 7-O-caffeoylhydroxymaltol 3-O-β-d-glucopyranoside, hispidin 4-O-β-d-glucopyranoside, kaempferol 3-O-α-l-rhamnopyranoside-7-O-β-d-glucopyranoside, caffeic acid, 5-O-caffeoylquinic acid, 3,5-di-O-caffeoylquinic acid and 4,5-di-O-caffeoylquinic acid, 2R,3R-pterosin L 3-O-β-D-glucopyranoside, β-D-xylopyranosyl(1→2)-7-O-benzoyl-β-D-glucopyranoside and 4-O-benzoyl-β-D-xylo-pyranosyl(1→2)-7-O-benzoyl-β-D-glucopyranoside, together with nine known compounds: 5-[2-hydroxyethylidene]-2(5H)-furanone, pterosin B, β-D-glucopyranosyl benzoic acid ester, benzoic acid, 5-O-coumaroylquinic acid, coumaric acid, cyclolaudenol, β-sitosterol-3-O-β-D-glucoside, and β-D-sitosterol, (2S)-13-hydroxypterosin A and (2S,3S)-12-hydroxypterosin Q,	NF	Astringent properties, given in dysentery, glandular swelling of the neck, Antipyretic, antirheumatic, antidysenteric, immunomodulatory, anti-inflammatory, antioxidant, antiatherogenesis, cytotoxic, antitubercular	Cooked as vegetables	Narzary et al., 2013 http://tropical.theferns.info/viewtropical.php?id=Pteris+ensiformis http://wiki.medicinalplants-uses.com/index.php?title=Pteris_ensiformis, http://www.stuartxchange.org/PakongParang.html,

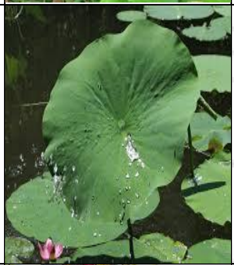
167.	**English**: Prickly Chaff Flower, Rough Chaff Tree **Gujarati**: Safad Aghedo **Tamil**: Shiru – Kadaladi **Telgu**: Uttaraene **Punjabi**: Kurti **Malyalam**: Kadaladi **Unani**: Chirchitaa **Bengali**: Apang, Uputhlengra **Assamese**: Apang	*Achyranthes aspera*		Kingdom Plantae Division Magnoliophyta Class Magnoliopsida Subclass Caryophyllidae Order Caryophyllales Family Amaranthaceae Genus Achyranthes Species aspera	Asia, Africa, Australia and America	pbenzoquinone, hydroquinone, spathulenol, nerol, α-ionone, asarone and eugenol, 3-Acetoxy-6-benzoyloxyapangamide, β-D-glucopyranosyl3β-[O-α-Lrhamnopyranosyl-(1→3)-O-β-D-glucopyranuronosyloxy]machaerinate, β-Dglucopyranosyl3β-[O-β-Dgalactopyranosyl-(1→2)-O-α-Dglucopyranuronosyloxy]machaerinate, 27-cyclohexylheptacosan-7-ol and 16-hydroxy-26-methylheptacosan-2-one, 17-pentatriacontanol, tetracontanol-2, 4-methoxyheptatriacont-1-en-10-ol and β-sitosterol, 20-hydroxyecdysone, and quercetin-3-O-β-D-galactoside	Moisture(%) 98.85 ± 0.03 Fibre 40.10 ± 0.20 Proteins 0.88 ± 0.03 Fats 1.08 ± 0.12 Carbohydrate 45.50 ± 0.20 Ca(mg) 84.9+0.2 B 4.3+0.1 Fe 0.80+0.6 K 172.3+10.0 Mg 25.0+0.1 Mn 2.20+0.3	Treat cough, renal dropsy, fistula, scrofula, skin rash, nasal, infection, chronic malaria, impotence, fever, asthma, piles and snake bites. This plant is astringent, digestive, diuretic, laxative, purgative and stomachic. The juice of the plant is used in the treatment of boils, diarrhea, dysentery, hemorrhoids, rheumatic pains, itches and skin eruption	Cooked as vegetables	Singh et al., 2018 Ghimire et al., 2015, Hussain et al., 2013
169.	**English:** Pani Bel, Wavy-Leaved Cissus **Hindi:** Pani Bel, Dekarbela **Manipuri:** Khongngouyen **Marathi:** Gendal **Telugu:** Gummadithige, Nelaboddu, **Assamese:** Medmedia-Lop	*Cissus repanda*		Kingdom Plantae Phylum Tracheophyta Class Magnoliopsida Order Vitales Family Vitaceae Genus Cissus Species repanda	Asia	prenylated benzo-lactone (4, 6-dihydroxy-5-methoxy-3-(1, 2, 3, 4, 5-pentahydroxypentyl)-2-benzofuran-1(3H)-one)	Moisture(%) 89.25 Total Ash 12.5 Water soluble ash 0.7 Acid insoluble ash 1.3	Treats cuts, wounds, bone fractures, boils and piles, used for piles, asthma, digestive, troubles, cough and loss of appetite	Cooked as vegetables	Narzary et al., 2013; Deshmukh et al, 2017 Bhusari et al., 2019
170.	**English:** Bushkiller	*Cayratia japonica*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Vitales Family Vitaceae Genus Cayratia Species japonica	Southeast Asia and North America	Linalool (19.4%), trans-α-ionene (11.4%), α-terpineol (7.9%), dihydroactinolide (7.8%) and geranial (5.8%), sabinene, 4-terpineol, α-terpineol, piperitone, bornyl acetate and trans-α-ionene, ginesenoside, gypenosides, apigenin-7-O-13-D-glucuronopyranoside, apigenin, luteolin, luteolin-7-O-13-D-glucopyranoside, (+)-dihydroquercetin (taxifolin), (+)-dihydrokaempferol (aromadendrin) and quercetin, apigenin and luteolin, taxifolin, aromadendrin	NF	Used in the treatment of fever and malaria, used on swellings	Cooked as vegetables	Liu et al., 2012, Chromatographic Fingerprint Analysis of Herbal Medicines Volume ..., Volume 3, Han et al, 2007
171.	**English:** Bitter Groud **Hindi:** Ban Karela **Marathi:** Kartoli **Gujarati:** Katwal **Assamese:** Avandhya **Telugu:** Agakara	*Momordica dioica*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Cucurbitales Family Cucurbitaceae Genus Momordica Species dioica	E.Asia	oleanoic acid, stearic acid, gypsogenin, alpha-spiranosterol, hederagenin, momordicaursenol, β-sitosterol	Moisture(%) 84.1 Ash 6.7 Lipids 4.7 Fibre 21.3 Protein 19.38 Carbohydrate 47.92 Calcium(mg) 33 Sodium 1.51 Potassium 8.25 Iron 4.6 Phosphorus 42	Analgesic (Leaf juice is mixed with coconut, pepper, red sandalwood, and so forth in order to form an ointment to relieve pain), Skin disease reducer, antioxidant activity, fight cancer, diabetes, treatment of eye diseases, against fever, snake bite, inflammation caused by lizard; is also used as medicine for diabetes	Cooked as vegetables	Talukdar et al., 2014; Thongam et al., 2016; Singh et al., 2014; Kumar et al., 2010 Jha et al., 2017, Bawara et al., 2010

172.	**English**: Clustered Hiptage, Madhavi Latha, **Bengali:** Madhabilata **Hindi:** Madhavi Lata **Kannada:** Madhvi **Malayalam:** Pongapoo, Chittilakody, Seethambu, Sitampu, Njarambodal **Manipuri:** Madhabi **Tamil:** Karipakkukodi	*Hiptage benghalensis*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Malpighiales Family Malpighiaceae Genus Hiptage Species benghalensis	Asia	2(3,4dihydroxyphenyl)-3 (4,6 dihydroxy 3methoxytetrahydro-2H-pyran-2carbaldehyde)- 5hydroxy, 7methoxy-4H-chromen-4one; friedelin, epifriedelinol, octacosanol, α-amyrin, β-sitosterol and its glucoside and traces of alkaloids. Root bark contains mangiferin	Moisture(%) 84.8 Total Ash 6.3 Acid soluble Ash 1.3 Water soluble Ash 4.5	Used as an anti-allergic, anti-inflammatory, anti-microbial and anti-cancer activities, role in analgesic activity primarily by targeting prostaglandins, antidiarrheal, hemostatic, antihemorrhoidal, astringent, and anti-infective, used for immediate relief of sore throats, diarrhea, dysentery, hemorrhaging, fatigue, skin ulcers and as a cicatrizant on gangrenous wounds, used against poisons, anti-nociceptive activity,ability to inhibit pain perception	Cooked as vegetables	Panda et al., 2015; Kumudhavalli et al., 2010; Meena, 2014, http://www.mpbd.info/plants/hiptage-benghalensis.php Venkataramani et al., 2015
173.	**English:** Indian Field-Cress, Variableleaf Yellowcress, Yellow Cress **Hindi:** Chamsuru **Kannada:** Kaadu Saasive **Nepali:** Pahelo Jhar **Telugu:** Aaku Mullangi	*Rorippa indica*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Brassicales Family Brassicaceae Genus Rorippa Species indica	Asia	Roripamine (sylphonylalkyl amine), glucosinolate compound, salicin	NF	Used as diuretic, stimulant, and antiscorbutic, toothaches, abscesses, scald burns, bronchitis. Laxative, treat cough, diarrhea, and rheumatoid arthritis, diuretic, anti-inflammatory, febrifuge, and to improve blood circulation, treatment of asthma, chronic catarrh, and pyorrhea, used for kidney trouble, asthma, diarrhea and dysentery	Cooked as vegetables	Panda et al., 2015; http://www.stuartxchange.com/Sabi; Long-Ze Lin et al, 2014 Ashish Tewari, Supriya Tiwari
174.	**English:** Marsh Barbel **Bengali:** Shulamardan **Gujarati:** Ekharo **Hindi:** Bhankari **Kannada:** Gokantaka **Konkani:** Kolsundo **Malayalam:** Bahel-Schulli **Marathi:** Ekhara **Oriya:** Koilakha **Sanskrit:** Ati-Chattraka **Tamil:** Nir-Mulli **Telugu:** Enugu Palleru	*Hygrophilla auriculata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Acanthaceae Genus Hygrophila Species auriculata	Africa and Asia	apigenin (with derivatives apigenin-7-o-glucuronide and 7-o-glucoside), luteolin (and derivative luteolin-7-rutinoside), triterpene lupeol; the triterpenes betulin and hentriacontane, β-carotene, β-sitosterol and stigmasterol, vanillic acid, syringic acid, hygrosterol, myristic acid, palmitic acid, stearic acid, linoleic acid, oleic acid	Moisture(%) 87.2 Protein 3 Fat 0.4 Minerals 2.4 Fiber 1.4 Carbohydrate 5.2 Ca 330 P 21	As a diuretic, treatment of blennorrhoea, hydropsy and anuria, as well as catarrh, stomach ache, used as a cooling medicine and diuretic in cases of hepatic obstruction, dropsy, rheumatism, etc; possess bacteriostatic action against both gram positive and gram-negative organisms; nduce menstruation, particularly in young mothers on weaning a baby, used to fumigate the eyes in order to treat corneal ulcers	Cooked as vegetables	Sustainable future food security in changing environments http://tropical.theferns.info/viewtropical.php?id=Hygrophila+auriculata, Saha et al., 2017
175.	**English:** Small Knotweed **Hindi:** Machechi **Manipuri:** Tarakmana **Marathi:** Gulabi Godhadi **Nepali:** Bethe **Bengali:** Chemti Sag **Oriya:** Muthisag **Gujarati:** Zinako Okhrad **Sanskrit:** Sarpakshee	*Polygonum plabeium*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Polygonaceae Genus Polygonum Species plebeium	Africa and Asia	oleanolic acid, betulinic acid, epi-friedelinol, β-sitosterol, quercetin-3-arabinoside and quercetin-3-rutinoside	Moisture(%) 83.2 Protein 3.2 Fat 0.7 Minerals 3.9 Fiber 2.1 Carbohydrate 6.9 Ca 194 P 48	Given in bowel complaint, pneumonia	Cooked as vegetables	Sustainable future food security in changing environment, Divya Pandey; http://www.mpbd.info/plants/polygonum-plebejum.php

176.	**English:** Grape Leaved Mallow **Marathi:** Van Kapus. **Gujarati:** Dhakto Kalo Bhendo **Kanadam:** Mani Tutthi Balli **Telugu:** Adavi Benda **Malayalam:** Vellipparuthi **Tamil**: Manjal Tutthi	*Mollugo cerviana*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Molluginaceae Genus Mollugo Species cerviana	Asia and africa	leteolin-8-C-glucoside, vitexin (apigenin-8-C-glucoside) and their 2″-O-glucosides,	Moisture(%) 91.7 Protein 2.4 Fat 0.4 Minerals 1.0 Fiber 2.2 Carbohydrate 2.3 Ca 370 P 67 Fe 12.3	Stomachic, aperient, febrifuge, antiseptic, blood purifier (used for venereal diseases), cardiostimulant, antibacterial, reduce abdominal disorder, blood impurity, burns, gonorrhoea, hangover, jaundice, cooling, diuretic, febrifuge, relieves thrist, Reducing fever, as an antiseptic and stimulating the secretion of gastric juices (plant); gout and rheumatism (root); to relieve fevers (flowers and tender shoots). An infusion of the plant promotes lochial discharge and is considered a cure for gonorrhoea	Cooked as vegetables	Sustainable future food security in changing environment, Divya Pandey; Khare, 2014 http://tropical.theferns.info/viewtropical.php?id=Mollugo+cerviana;
177.	**English:** Water Clover	*Marsilea minuta*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Polypodiophytina Class Polypodiopsida Subclass Polypodiidae Order Salviniales Family Marsileaceae Genus Marsilea Species minuta	Asia and Africa	Metltylamine, beta-sitosterol, hydroxyketone, 3-hydroxytriacontan-11-one, marsiline (a ketonic compound)	Moisture(%) 86.9 Protein 3.7 Fat 1.4 Minerals 2.1 Fiber 1.3 Carbohydrate 4.6 Ca 46 P 53 Fe 91	Used as aphrodisiac and for increased fertility, to stop nose bleeding, applied to swollen gums in order to reduce the swelling, reduced cholesterol and triglyceride levels in blood and liver substantially	Cooked as vegetables	Sustainable future food security in changing environment, CHAKRAVARTI et al., 1974
178.	**English**: Pot Cassia **Hindi**: Chakunda **Assamese**: Soru-Medelua **Karbi**: Hadi Diga **Tamil**: Tagrai **Others**: Bagarai/Oosi Thagarai, Segutha	*Cassia tora*		Domain Eukaryota Kingdom Plantae Phylum Spermatophyta Subphylum Angiospermae Class Dicotyledonae Order Fabales Family Fabaceae Subfamily Caesalpinioideae Genus Cassia Species tora	Asia	Limonene, 1,8-Cineole, Salicylaldehyde, Linalool, 2-Ethylhexanoic acid, Camphor, δ-Terpineol, Terpinen-4-ol, α-Terpineol, Nerol, Geraniol, α-Copaene, Geranyl acetate, (E)-β-Caryophyllene, α-trans-Bergamotene, α-Humulene, (E)-β-Farnesene, n-Dodecanol, γ-Muurolene , β-Selinene, trans-Calamenene, δ-Cadinene, Elemol, Dodecanoic acid, 5-epi-7-epi-α-Eudesmol, β-Oplopenone, 1,10-di-epi-Cubenol, γ-Eudesmol epi-α-Cadinol, α-Eudesmol, β-Eudesmol, α-Cadinol, Tetradecanoic acid, Cryptomeridiol, Methyl palmitate, Palmitic acid, (E)-Phytol, Stearic acid	Moisture(%) 87.18 + 0.15 Lipids 2.02 + 0.82 Crude fibre 27.07 + 0.10 Crude protein 11.63 + 0.20 Carbohydrate 36.60 + 1.10 Ca 3.52 + 0.40 Fe 0.22 + 0.07 Na 0.10 + 0.00 Mg 0.86 + 0.12 Zn 0.04 + 0.01 Mn 0.10 + 0.02 Co 0.02 + 0.00 K 0.96 + 0.06	Laxative, skin diseases, ringworm, eye disease, liver complaint, dysentery, and anthelmintic, antioxidant, hypoglycemic, hypolipidemic, antinociceptive, antiplasmodial, antifungal antimicrobial, hyperlipemia and hypotensive.	Cooked as vegetables	Kubmarawa et al., 2011; Das et al., 2011; Satyal et al., 2013
179.	**English**: Potato **Hindi**: Alu **Tamil**: Urulai	*Solanum tuberosum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Solanales Family Solanaceae Genus Solanum Species tuberosum L	Asia and Africa	Potassium, sulfur, phosphorus, chloride, solanine and solasodine	Moisture(%) 85.12 P 4.1±0.7 K 39.7±5.4 S 5.1±0.3 Ca 18.6±2.1 Mg 7.9±1.3 B 42.9±5.3 Cu 24.1±4.3 Fe 58.6±17.3 Mn 39.7±18.8 Mo 6.6±2.5 Zn 47.3±6.2	Treats diarrhea, purgative	Cooked as vegetables	Maitra et al., 2014 Jaradat et al., 2016

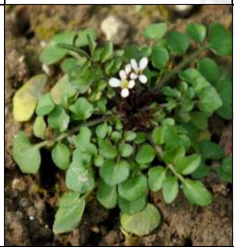
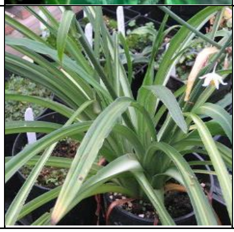
180.	**English** : Chowchow, Choko, Chayote, Vegetable Pear, Custard Marrow **Hindi**: Chow Chow **Nepali**: Iskus **Manipuri**: Daskush **Tamil**: Seema-Kattirikkai **Kannada**: Seemebadane **Bengali**: Quash **Tangkhul**: Squash	*Sechium edule*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Cucurbitales Family Cucurbitaceae Genus Sechium Species edule	Asia and Africa	Amino acids, Vitamin C	Moisture (%) 91.8 Carbohydrate 0.3-2.1 Fats 0.016-0.4 Proteins 3.0 Ash 1.1 Crude Fibre 1.1-0.9	Diuretic, cardiovascular and Anti-inflammatory	Cooked as vegetables	Maitra et al, 2014 Coronel et al., 2017
181.	**English** : Grass Pea, Chickling Pea, Indian Vetch	*Lathyrus sativus*		Kingdom Plantae Subkingdom Tracheobionta Superdivision Spermatophyta Division Magnoliophyta Class Magnoliopsida Subclass Rosidae Order Fabales Family Fabaceae Genus Lathyrus Species sativus	Asia and Africa	Vitamin A, B-complex, phenols	Moisture (%) 89.55 Protein 25.15 Ash 3.30 Fibre 15.22	Constipation, joint	Cooked as vegetables	Maitra et al, 2014 Shankar et al., 2014
182.	**English** : Giant Taro, Upright Elephant Ear **Hindi**: Mankanda **Kannada**: Baalaraaksha **Manipuri**: Hongoo **Marathi**: Kaasaalu **Sanskrit**: Alooka **Tamil**: Merukan **Tangkhul**: Paankhot	*Alocasia indica*		Kingdom Plantae Subkingdom Tracheobionta Superdivision Spermatophyta Division Magnoliophyta Class Liliopsida Subclass Arecidae Order Arales Family Araceae Genus Alocasia Species indica	Asia and Africa	Alocasin, flavonoids and glycosides	Moisture(%) 42.48±0.49 Carbohydrate 45.58±0.59 Fat 1.426±0.550 Fibre 2.95±0.69 Ash 2.62± 0.45	Laxative, digestive, piles	Cooked as vegetables	Maitra et al., 2014 Basu et al., 2014
	Common Name: Fishtail Fern	*Microsorum punctatum*		Kingdom Plantae Subkingdom Tracheobionta Division Pteridophyta Class Filicopsida Order Polypodiales Family Polypodiaceae Genus Microsorum Species punctatum	Asia and Africa	Flavanoids, hydroxycinnamic acids, proanthocyanidins	NF	Used as purgative, diuretic and healing wounds	Cooked as vegetables	Yumkham et al., 2016
183.	**Common Name:** Bracken	*Pteridium aquilinum*		Kingdom Plantae Class Polypodiopsida Order Polypodiales Family Dennstaedtiaceae Genus Pteridium Species aquilinum	East Asia and South Africa	Adenosine, quercetin, rutin, ponasterone, daucosterol	Moisture (%) 90.74 Ash 7.12 Crude Fat 2.66 Crude Fibre 4.10 Crude Protein 21.90	Anti-diabetic and anti-obesity activities, antioxidant, diuretic, astringent, antipyretic, antitussive, anthelmintic, healing, bacteriostatic, laxative, tonic, wound healing; in diseases of the respiratory, stomachalgia, myalgia, diarrhea,	boiled, fried, pickled state	Yumkham et al., 2016; Minarchenko et al, 2017 O et al., 2015
184.	**Common Name:** Polypody, Adders Fern, Golden Maidenhair Fern, Wall Fern, Common Polypod Fern	*Polypodium vulgare*		Kingdom Plantae Phylum Pteridophyta Class Polypodiopsida Order Polypodiales Family Polypodiaceae Genus Polypodium Species vulgare	Asia	Essential oils, (sesquiterpenes (39.6%) and their oxidized forms (21.9%), fatty oils, catechins, Shikimic acid, Gallic acid, (-)-Epicatechin, Rutin, Hyperoside	NF	Used in traditional medicine as an expectorant in cough and cold, and constipation. It stimulates bile secretion and is a gentle laxative, traditionally used as a treatment for hepatitis and jaundice and as a remedy for indigestion and loss of appetite, used as a remedy against respiratory complaints and rheumatism, expectorant and laxative effect.	Cooked as vegetables	Minarchenko et al., 2017 Farras et al., 2021

185.	**Common Name:** Smooth Rock Spleenwort	*Asplenium fontanum*		Kingdom Plantae Phylum Tracheophyta Class Polypodiopsida Order Polypodiales Family Aspleniaceae Genus Asplenium L. Species fontanum	Asia and Africa	Kaempferol 3-gentiobioside, kaempferol 3-polygly- coside, kaempferol 3,7-glycoside, Kaempferol 3-(6-sulphate-gentiobioside)	NF	Used to treat respiratory diseases	Cooked as vegetables	Minarchenko et al, 2017; Iwashina et al, , 2011 Khoja et al., 2022
186.	**Common Name:** Royal Fern, Flowering Fern, Regal Fern	*Osmunda regalis*		Kingdom Plantae Subkingdom Tracheobionta Division Pteridophyta Class Filicopsida Order Polypodiales Family Osmundaceae Genus Osmunda Species regalis L.	Asia and Africa	Flavonoids, phenols, steroids, primary and secondary alcohols, fatty acids. b-sitosterol, alkanediols, ketoalcohols, ketoaldehydes Hexahydrofarnesyl acetone (11.82%), 2,4-di-t-butylphenol (6.80%), Phytol (6.46%)	NF	Used in treatment of bone fractures, rheumatic and arthritic pain, treatment of rheumatism and intestinal gripping, cures toothache, antispasmodic, astringent	Used for preparing *Pakori*	Yumkham et al., 2016; Thomas et al., 2011 Bouazzi et al., 2018
187.	**English**: Bengal Arum, Lobed Leaf Typhonium **Tamil**: Karunai-K-Kilanku, Pitikarunai, Karunai, Karu Karunai Kilanku **Bengali**: Ghatkanchu, Kharkon, Ghet Kachu **Assamese**: Chema Kachu	*Typhonium trilobatum*		Kingdom Plantae Subkingdom Tracheobionta Superdivision Spermatophyta Division Magnoliophyta Class Liliopsida Subclass Arecidae Order Arales Family Araceae Genus Typhonium Species trilobatum	Asia and Africa	Beta-sitosterol, Virstatin (isoquinoline alkaloid), 2-aminoimidazole, berberine and pyrrole–imidazole alkaloids, Squalamine	NF	Constipation, colic, digestive, cancer, rheumatoid, arthritis and arteriosclerosis as well degenerative processes associated with aging	Taken leaves curry, also taken tuber curry and paste	Shafa et al., 2016; Manna et al., 2016 Saha et al., 2022
188.	**English** : Indian Wormwood **Hindi**: Nagdona **Manipuri**: Leibakngou **Marathi**: Dhordavana **Tamil**: Makkippu **Malayalam**: Makkippuvu **Telugu**: Masipatri **Kannada**: Manjepatre **Bengali**: Nagadana **Oriya**: Dayona **Konkani**: Surpin **Assamese**: Nilum **Sanskrit**: Nagadaman **Tangkhul**: Harana	*Artemisia annua*		Kingdom Plantae Subkingdom Tracheobionta Superdivision Spermatophyta Division Magnoliophyta Class Magnoliopsida Subclass Asteridae Order Asterales Family Asteraceae Genus Artemisia L. Species annua	Asia and Africa	Artemisinin, 3',5-Dihydroxy-3,4',6,7-tetramethoxyflavone, 4,11(13)-Cadinadien-12,6-olide, 4,11(13)-cadinadien-12-ol, 2',4',5,5',6,7-Hexahydroxyflavone, Deoxyartemisinin, 2',4',6'-Trihydroxyacetophenone	Moisture (%) 11.4 Carbohydrate 8.3 Ash 7.5 Fat 6.07 Fibre 14.2 Protein 24.37	Phytotoxic agent, antimalarial agent, inhibits apoptosis. active against fungi and bacteria, potent inhibition against lymphocyte proliferation, and cytotoxic activity, Cytostatic agent	Cooked as vegetables	Minarchenko et al., 2017 Iqbal et al., 2012
189.	**English**: Dandelion **Bengali**: Pitachumki **Hindi**: Dudhi, Baran, **Kannada**: Kaadu Shaavanthi **Ladakhi**: Han **Malayalam**:Dugddhapheni **Sanskrit**: Dugdhapheni **Telugu**: Patri **Urdu**: Bathur	*Taraxacum campylodes*		Kingdom Plantae Phylum Tracheophyta Class Magnoliopsida Order Asterales Family Asteraceae Genus Taraxacum Species campylodes	Asia and Africa	1-Tridecanol, 20(30)-Taraxasten-3-ol, 14-Taraxeren-3-ol	Moisture(%) 91.53 ± 0.83 Protein 15.48 ± 0.47 Ash 14.55 ± 0.64 Carbohydrates 58.35 ± 0.32 TDF 47.80 ± 0.63	Antibacterial activity, fungicidal activity, Possesses antiulcer properties, chemopreventive agent	Cooked as vegetables	Minarchenko et al., 2017 Escudero et al., 2001

190.	**English**: Bracted Bugleweed Nepali: Nil Phal	*Ajuga integrifolia*		Kingdom Plantae Phylum Tracheophyta Class Magnoliopsida Order Lamiales Family Lamiaceae Genus Ajuga L. Species integrifolia	Europe, Asia and Africa	Moracin C, Moracin D, Moracin P, Moracin E, Moracin G, Moracin L , Moracin K and Moracin G, Moracin X and Moracin Y, Moracin I, Rosmarinic acid, Chlorogenic acid, Apigenin,Quercetin	NF	Antifungal activity, inhibits lipid peroxidation, shows antiinflammatory activity, antimicrobial activity, antihyperglycaemic activity, anticancer activity, cytotoxic activity, hepatoprotective activity	Cooked as vegetables	Minarchenko et al., 2017 Ullah et al., 2021
191.	**English**: White Mulberry, Russian Mulberry, Silkworm Mulberry **Hindi**: Shahtoot **Tamil**: Kambli Chedi **Manipuri**: Kabrangchak Angouba	*Morus alba*		Kingdom Plantae Subkingdom Tracheobionta Superdivision Spermatophyta Division Magnoliophyta Class Magnoliopsida Subclass Hamamelididae Order Urticales Family Moraceae Genus Morus Species alba L.	Asia	Isorhamnetin 3-glycosides, 4-Hydroxybenzoic acid, Roemerine, Pronuciferine, Neferine, Higenamine, 1,2-Dihydroxyaporphine	Moisture (%) 94.7 ± 0.2 Ash 8.91 ± 0.51 Lipid 6.57 ± 0.23 Fibre 10.11 ± 0.37 Protein 18.41 ± 1.36	Antioxiant activity, pharmaceutical aid, anti fungal agent, antimicrobial agent, antifungal agent, used in vaccines and ointments, serotonin receptor antagonist, cytotoxic and insecticidal activity, strong local anaesthetic activity	Cooked as vegetables	Minarchenko et al., 2017 Iqbal et al., 2012
192.	**English**: Lotus **Hindi**: Kamal, Pundarika, **Manipuri**: Thambal **Marathi**: Pandkanda **Tamil**: Chenthaamarai **Malayalam**: Tamara **Telugu**: Tamara **Kannada**: Tavare-Gadde **Bengali**: Komol **Oriya**: Padam **Urdu**: Nilufer **Assamese**: Padam **Gujarati**: Motunkamal **Sanskrit**: Sarsija	*Nelumbo nucifera*		Kingdom Plantae Subkingdom Tracheobionta Superdivision Spermatophyta Division Magnoliophyta Class Magnoliopsida Subclass Magnoliidae Order Nymphaeales Family Nelumbonaceae Genus Nelumbo Species Nelumbo nucifera	Asia	Quercetin 3-O-*β*-D glucuronide, Quercetin 3-O-*β*-Dxylopyranosyl-*β*-D galactopyranoside, Rutin, Isoquercitrin, Hyperin	Moisture (%) 72.14 Carbohydrate 16.03 Protein 2.60 Fat 0.10 Fibre 4.20 Total ash 1.18 Vitamin C (mg) 38.00	Treatment of pharyngopathy, pectoralgia, spermatorrhoea, leucoderma, small pox, dysentery, cough, haematemesis, epistaxis, haemoptysis, haematuria, metrorrhagia, hyperlipidaemia, fever, cholera, hepatopathy and hyperdipsim	Cooked as vegetables	Minarchenko et al., 2017, Raj et al., 2015 Panjikkaran et al., 2019
193.	**English:** Toothache Plant, Para Cress **Hindi:** Akarkar, Pipulka **Marathi:** Pipulka, Akarkara **Kannada:** Hemmugalu **Assamese:** Pirazha **Tangkhul:** Ansa Han	*Acmella oleracea*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophyta Class Magnoliophyta Superorder Asteranae Order Asterales Family Asteraceae Genus Acmella Species oleracea	Brazil, South America, Asia, Africa	Lipophilic alkylamides or alkamides such as spilanthol, rhamnogalacturonan, three N-alkylamides, namely (2E,4Z)-N-isobutyl-2,4-undecadiene-8,10-diynamide, (2E,6Z,8E)-N-isobutyl-2,6,8-decatrienamide or spilanthol and (2E,6Z,8E)-N-(2-methylbutyl)-2,6,8-decatrienamide, amide mixture(nona-(2Z)-en-6,8-diynoic acid 2-phenylethylamide (4) and deca-(2Z)-en-6,8-diynoic acid 2-phenylethlylamide)	NF	Toothache, Blood disorder, constipation, gout, paralysis, scurvy, wounds, stomache ache, nausea, malaria, vomiting, wrinkles, rheumatism, inflammation, candidiasis, scabies, stammering, snake bite, stomatitis and cold	As steamed vegetable, raw leaves are used as a flavouring for salads, soups and meats	Jambey Tsering et.al, 2017; https://herbpathy.com/Uses-and-Benefits-of-Acmella-Oleracea-Cid930; Nomura et al., 2013; Nascimento et al., 2013; KatoSimao et al., 2013

194.	**English:** Hooker Chives **Manipuri:** Maroi Napakpi **Tangkhul:** Namrei	*Allium hookeri*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophyta Class Liliopsida Order Asparagales Family Amaryllidaceae Genus Allium Species Allium hookeri	E. Asia - Southern China, India, Sri Lanka, Bhutan, Myanmar	γ-L-glutamyl-S-allyl-l-cysteine (GSAC), γ-L-glutamyl-S-(trans-1-propenyl)-l-cysteine (GSPC), γ-L-glutamyl-S-methyl-l-cysteine (GSMC) and γ-glutamyl-phenylalanine (γGPA). S-alk(en)yl-l-cysteines as S-alk(en)yl-l-cysteine sulphoxides(ACSOs), γ-glutamyl peptides by γ-glutamyl peptidase and consist of (+)-S-allyl-lcysteine (SAC), (+)-S-(trans-1-propenyl)-l-cysteine (SPC) and (+)-S-methyl-l-cysteine (SMC), S-alk(en)yl-l-cysteines chemically change in ACSOs by oxidase and ACSOs are (+)-S-allyll-cysteine sulphoxide (alliin), (+)-S-(trans-1-propenyl)-l-cysteine sulphoxide (isoalliin), (+)-S-methyl-l-cysteine sulphoxide (methiin) and (1S,3R,5S)-3-carboxy-5-methyl-1,4-thiazane1-oxide (cycloalliin), ferulic acid-4-O-β-Dglucopyranoside	Moisture (%) 85 Ash 0.68 Fibre 1.05 Fat 0.08 Protein 1.57 Carbohydrate 81.62	Anti-cancer properties, lipid level, blood pressure, blood cholesterol-level lowering effects, anti-glycative effect and an antioxidant capacity, anxyolytic, cardioprotective, antiviral, analgesic, anti-inflammatory, anthelmentic and antidiabetic activities	Raw or as cooked vegetables	Tsering et.al, 2017; Kim et al., 2016; Jun et al., 2015 Mar et al., 2016
195.	**English:** Stinging Nettle **Assamese:** Chorat **Hindi:** Bichchhu, Kali, Kandadli, Bichchhu Buti **Sanskrit:** Vrscikali	*Urtica dioica*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Rosales Family Urticaceae Genus Urtica Species Urtica dioica	Europe, much of temperate Asia and Western North Africa	Myristic acid, Pentadecanoic acid, Palmitic acid, Stearic acid, Arachidic acid, Behenic acid, Palmitoleic acid, Oleic acid, linoleic acid, Linolenic acid, Lupeol, Neophytadiene, Phytol, Stigma-4-en-3-one, *β*-Sitosterol, rutin, kaempferol, quercetin,	Moisture (%) 89 Protein 33.8 Crude fiber 9.1 Crude fat 3.6 Carbohydrate 37.4	Used as a cleansing tonic and blood purifier, hay fever, arthritis, anaemia, antiasthmatic, antidandruff, astringent, depurative, diuretic, galactagogue, haemostatic, hypoglycaemic and a stimulating tonic, treat anaemia, excessive menstruation, haemorrhoids, arthritis, rheumatism and skin complaints, especially eczema, skin complaints, arthritic pain, gout, sciatica, neuralgia, haemorrhoids, hair problems	Cooked as vegetables	http://tropical.theferns.info/viewtropical.php?id=Urtica+dioica; http://biowe b.uwlax.edu /bio203/2011/homolka_kail/medicine2.htm; Karama Zouari Bouassida et al., 2017; Adhikari et al., 2015; TRAK et al, 2017
196.	**Common Name:** Suomi	*Asystasia neesiana*		Kingdom Plantae Phylum Tracheophyta Class Magnoliopsida Order Lamiales Family Acanthaceae Genus Asystasia Species Asystasia neesiana	East Asia	NF	Moisture (%) 86.44 ± 0.03 Ash 21.06 ± 0.01 Crude fat 2.42 ± 0.04 Crude Protein 25.29 ± 0.35 Carbohydrate 35.79 ± 0.35	Present in Ayurveda (science of life) as coded text needs translation	Cooked as vegetables	Leafy and Edible Plants of North-East India, Maina et al., 2019 https://www.wisdomlib.org/definition/obul-oying

197.	**English:** Kachnar, Orchid Tree, Varigated Bauhinia **Hindi:** Kachnar **Manipuri:** Chingthrao **Marathi:** Kanaraj **Malayalam:** Chovanna-Mandaru, **Telugu:** Bodanta **Kannada:** Arisinantige **Bengali:** Raktakanchan **Oriya:** Vau-Favang, Vaube, **Khasi:** Dieng Long, Dieng **Assamese:** Kotora, Kurol **Mizo:** Vau-Favang, Vaube **Sanskrit:** Ashmantaka **Nepali:** Koiraalo **Tangkhul:** Haochokwon	*Bauhinia variegata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Fabales Family Fabaceae Genus Bauhinia Species Bauhinia variegate	E. Asia - Southern China, India, Pakistan, Nepal, Bhutan, Myanmar, Thailand, Laos, Vietnam.	Kaempferol, Ombuin, Kaempferol 7, 4-dimethyl ether- 3-o- β-D-2 glycopyranoside, triterpene, Kaempferol-3-o-β-Dglycopyranoside, isorhamenetin-3-oβ-D-glycopyranoside and hesperidin, lupeol, β-sitisterol, kaempferol-3- glucoside, rutin, quercitin, apigenin, apigenin-7-o-glucoside amides, (2S)-5,7-dimethoxy-3′,4′-methylenedioxyflavanone and a new dihydrodibenzoxepin, 5,6-dihydro-1,7-dihydroxy-3,4-dimethoxy-2-methyldibenz [b,f]oxepin	Moisture (%) 73.95 Ash 6.53 Crude fat 2.42 Crude Protein 4.46 Carbohydrate 86.56 Total Ash 9.88 Acid insoluble ash 3.44	Anti-bacterial, anti-helmintic, anti-arthritic, anti-inflammatory, anti-diabetic, immunomodulatory, hepatoprotective, anti-oxidant, trypsin inhibitor and anti-carcinogenic activity, used as molluscicidal agent against harmful vectors/pests	Boiled and eaten as a vegetable, or pickled	Jambey Tsering et.al, 2017; Singh et al., 2016; Reddy et al., 2003 Yadav et al., 2015 Verma et al., 2012
198.	**English:** Large-Flowered Barberry **Nepali:** Chutre Kanda	*Berberis insignis*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Ranunculanae Order Ranunculales Family Berberidaceae Genus Berberis Species Berberis insignis	Asia	Umbellatine	NF	Used for the treatment of heart disease, colds, digestive ailments, and problems with the urinary tract	Cooked as vegetables	Jambey Tsering et.al, 2017; Chatterjee et al., 1941 Awan et al., 2014 Hassanabad et al. 2005;Bober et al. 2018
199.	**English:** Slender Rattan Cane **Kannada:** Ontibetta **Konkani:** Veta **Malayalam:** Cerucuural **Marathi:** Veta	*Calamus tenuis*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophyta Class Lilopsida Order Arecales Family Arecaceae Genus Calamus Species Calamus tenuis	Asia	resins, oleoresins, lactones, saponin, flavonoid, steroid, tannin and glycoside, phenol, flavonoid	NF	treating fever, piles, dyspepsia, biliousness, wounds, bacterial infections, anti-diabetic potential, have therapeutic potential against stomach disorder and intestinal worms	Cooked as vegetables	Jambey Tsering et.al, 2017; Khan et al, 2007 Khatun et al., 2018

200.	**English:** Shepherd's Purse, Cocowort, Blind Weed **Tangkhul:** Chamtruk **Nepali:** Chamure Jhaar, Chaalne, Toree Ghaans	*Capsella bursa-pastoris*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Brassicales Family Brassicaceae Genus Capsella Species Capsella bursa-pastoris	Europe and Asia	Three phytoalexins (camalexin , 6-methoxycamalexin and N-methylcamalexin), cholesterol, campesterol, , stigmasterol, βsitosterol, cholest-5-en-3-one, ergosta-4,6,8; 22-tetraen-3-one, lupeol, stigmasta-3,5-dien-7-one, stigmasta4-en-3-one in addition to unidentified phytosterols, tricin, kaempferol, quercetin, kaempferol-7-O-α-L-rhamnopyranoside, quercetin-3-O-β-D–glucopyranoside, quercetin-6-C-β-D-glucopyranoside, kaempferol-3-O-β-D-glucopyranosyl-7-O-α-Lrhamnopyranoside, quercetin-3-O-β-Dglucopyranosyl- 7-O-α-L-rhamnopyranoside and kaempferol-3-O-rutinoside	Moisture (%) 85.1 Protein 35.6 Fat 4.2 Carbohydrate 44.1 Fiber 10.2 Ash 16.1 Vitamin A(IU) 21949 thiamine (mg) 2.12 riboflavin 1.44 niacin 3.4 vitamin C 305 Calories(Kcal) 280 Pb(mg) 0.632±0.112 Zn 0.548±0.124 Mn 0.450±0.156 Co 0.015±0.002 K 22.44±1.866 Fe 4.436±0.447 Ca 0.2396±0.154 Na 0. 290±0.058	antiscorbutic, astringent, diuretic, emmenagogue, haemostatic, hypotensive, oxytocic, stimulant, vaso-constrictor; Fresh leaves decoction is taken orally for Menstrual disorder	Eaten raw or cooked	Jambey Tsering et.al, 2017; Jimenez et al., 1997;Snafi et al., 2015; Abbasi et al., 2013
201.	**English:** Hairy Bitter Cress, Lamb's Cress, Land Cress, Hoary Bitter Cress **Manipuri:** Uchi Hangam **Tangkhul:**Shiwokkayanghan	*Cardamine hirsuta*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Brassicales Family Brassicaceae Genus Cardamine Species Cardamine hirsute	Europe and Asia	Plants contain many phytochemicals such as alkaloids and phenolic compounds. It also contains, vitamin C, beta-carotine, and possibly lutein.	Moisture (%) 92.89±0.44 Ash 1.78±0.07 Fat 0.239±0.01 Fiber 1.64±0.01 Protein 3.99±0.21 Carbohydrate 1.70±0.51	Being in the brassica family bittercress has many health benefits. It contains glucosinolates which are known to help remove carcinogens from the body. It also contains, vitamin C, beta-carotine, and possibly lutein which is known to help reduce vision problems including cataracts.	Eaten raw or cooked, used as a garnish or flavouring in salads	Jambey Tsering et.al, 2017 Narzary et al., 2017
202.	**English:** Toothwort **Nepali:** Twelee	*Cardamine macrophylla*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Class Equisetopsida Order Brassicales Family Brassicaceae Genus Cardamine Species Cardamine macrophylla	E. Asia - China, Himalayas, Siberia	NF	NF	Asthma, diuretic, fever, tumour, wormicide	Cooked as vegetable	Jambey Tsering et.al, 2017 Gairola et al., 2014
203.	**English:** Nepal Chlorophytum **Nepali:** Danti Saag, Banpyajia	*Chlorophytum nepalense*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophyta Class Lilopsida Order Asparagales Family Asparagaceae Genus Chlorophytum Species Chlorophytum nepalense	Southeast Asia	Its tuberous roots which contains steroidal saponins, alkaloids, steroids.	NF	Aphrodisiac, Immuno-modulatory and Anticancer activities	Cooked as vegetables	Jambey Tsering et.al, 2017 \Kaushik et al, 2005 Verma et al., 2020

204.	**English:** East Indian Glory Bower **Assamese:** Nephaphu **Khasi:** Dieng Jakangum, Dieng Jalemkynthei **Mizo:** Phuihnam **Nepali:** Anpui **Tangkhul:** Nareihan	*Clerodendrum glandulosum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophyta Class Magnoliopsida Order Lamiales Family Lamiaceae Genus Clerodendrum Species Clerodendrum glandulosum	Southeast Asia	Strongyloster, lupeol, n-hentriacontane and Hexacosane, palmitic acid, vitamin E, 2-pentadecyn-1-ol, norolean-12-ene and octacosane	Moisture (%) 77.90 ± 0.08 Carbohydrate 4.28 ± 1.08 Total ash 11.15 ± 0.63 Crude protein 2.36 ± 0.04 Crude fibre 4.21.05 ± 1.03 Crude fat 0.35 ± 0.03	Lowers hypertension and cure skin diseases, treats diabetes, obesity and hypertension	Cooked as vegetables	Jambey Tsering et.al, 2017;Jadeja et al., 2012 Payum et al., 2020
205.	**Common Name:** Yam Jungli Kachaloo	*Dioscorea orbiculata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Lilianae Order Dioscoreales Family Dioscoreaceae Genus Dioscorea Species Dioscorea orbiculate	Asia	Diosgenin, dioscorin, dioscin and other alkaloids are also found. Root contains phytosterols, alkaloids, tannin and rich source of starch. Other substance found are aluminium, ascorbic acid, ash, beta-carotene, calcium, chromium, cobalt, iron, magnesium, manganese, niacin, potassium, phosphorus, protein, riboflavin, selenium, silicon, sodium, thiamine, tin, zinc.	Moisture (%) 73.00 Protein 1.80 Carbohydrate 21.00 Fat 1.10 Fiber 0.90	Cures constipation	Cooked as vegetables	Wild Edible Vegetables of Lesser Himalayas: Ethnobotanical and ..., Volume 1, Geervai et al., 1994 Dutta et al., 2014
206.	**English:** Lanceleaf Forget-Me-Not **Sanskrit:** Laksmana	*Cynoglossum lanceolatum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Boraginales Family Boraginaceae Genus Cynoglossum Species Cynoglossum lanceolatum	Ethiopia, south to South Africa, Madagascar, the Arabian Peninsula, Pakistan, Kashmir, India, Sri Lanka, Burma, Nepal, eastward to China and Malaysia	Hexadecanoic acid-methyl ester, β-sitosterol, daucosterol, 6-β-hydroxy-stigmast-4-en-3-one, 5-α-stigmastane-3,6-dione	NF	Treat acute nephritis, periodontitis, acute submandibular lymphadenitis, snake bite	Cooked as vegetables	Jambey Tsering et.al, 2017; Cheng-HaoYu et al., 2012
207.	**English:** Field Penny-Cress	*Thlaspi arvense*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Brassicales Family Brassicaceae Genus Thlaspi Species Thlaspi arvense	Europe, including Britain, from Norway south and east to N. Africa, W. Asia, Siberia and Japan	Two phytoalexins (wasalexin A and arvelexin), apigenin and luteolin Erucic acid, Oleic acid Linoleic acid, Linolenic acid	NF	Antirheumatic, diuretic, anti-inflammatory and febrifuge, being used in the treatment of pus in the lungs, renal inflammation, appendicitis, seminal and vaginal discharges. The entire plant is antidote, anti-inflammatory, blood tonic, depurative, diaphoretic, expectorant, febrifuge and hepatic. It is used in the treatment of carbuncles, acute appendicitis, intestinal abscess, post-partum pain, dysmenorrhoea and endometriosis. Use with caution since large doses can cause a decrease in white blood cells, nausea and dizziness	Raw or cooked or cooked in soups or used as a pother	Jambey Tsering et.al, 2017; http://www.naturalmedicinalherbs.net/herbs/t/thlaspi-arvense=pennycress.php JosephOnyilagha; 2003 Esfahanian et al., 2021

208.	**English:** Stalkless Elatostema **Chepang:** Ledem **Nepali:** Gagleto	*Elatostema sessile*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Rosales Family Urticaceae Genus Elatostema Species Elatostema sessile	Asia	NF	Moisture(%) 60.72 Crude Fiber 6.7±0.22 Crude Fat 9.99±0.15 Ash 11.70±0.54 Crude Protein 10.00±0.22	Plant paste of E. sessile was used to treat boils, pimples and blisters by Nyishis, Monpas and Adis of 12 Arunachal Pradesh, India.	Cooked as vegetables	Jambey Tsering et.al, 2017 Upadhyay et al., 2021
209.	**English:** Buckwheat, Common Buckwheat,Japanese Buckwheat **Assamese:** Doron, Phapar **Garo:** Phapar **Hindi:** Kotu, Kuktu, Phaphra **Malayalam:** Kaadu Godhi **Manipuri:** Wakha Yendem **Nepali:** Phapar **Tangkhul:** Harenhan	*Fagopyrum acutatum*		Kingdom Plantae Subkingdom Viridiplanta Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Polygonaceae Genus Fagopyrum Species Fagopyrum acutatum	Asia	D-chiro-inositol, fagopyritols, and rutin and quercetin	Moisture(%) 77.12±0.48 Crude Fat 0.75 - 2.33 Crude Protein 10.43 - 11.23 Total Ash 1.82 - 3.10 Crude Fibre 3.53 - 4.80 Carbohydrate 66.01 - 72.89	Hypocholesterolemic activity, suppression of body fat accumulation, anti-hypertension, anti-inflammation, reducing the occurrence of colon cancer, Arthritis; vermicidal; colic; choleric; diarrhea, abdominal obstructions	Cooked as vegetables	Jambey Tsering et.al, 2017; FanZhu et al., 2016 Raghuvanshi et al., 2017
210.	**English:** Hairy Quickweed, Shaggy Soldier, Peruvian Daisy, Hairy Galinsoga, Fringed Quickweed **Nepali:** Jhuse Chitlange	*Galinsoga quadriradiata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Asterales Family Asteraceae Genus Galinsoga Species Galinsoga quadriradiata	North and South America, Europe, Japan, Philippines, the northern India, Nepal	patulitrin (patuletin-7-O-β-d-glucoside), quercimeritrin (quercetin-7-O-β-d-glucoside), quercetagetrin (quercetagetin-7-O-β-d-glucoside), luteolin 7-β-d-glucopyranoside, apigenin 7-β-d-glucoside, galinsoside A (5′-hydroxy-7-methoxyflavanone 2′-O-β-d-glucopyranoside), galinsoside B (3′,4′-dihydroxy-7-methoxyflavanone 5-O-β-d-glucopyranoside), 7,3′,4′-trihydroxyflavanone and 3,5,7,3′,4′-pentahydroxyflavanone, and phenolic acids and depsides: vanilic, isovanilic, p-coumaric, p-hydroxybensoic, o-hydroxyphenyloacetic, caffeic, chlorogenic acid and caffeoylglucaric acids	Moisture(%) 77.12±0.48 Iron(mg) 7.51±0.48 Ascorbic acid 350.83±22.42 Ash 1.88±0.02 Protein 8.15±0.16 Crude fiber 2.15±0.08 Crude fat 2.46±0.04 Carbohydrates 8.24	Treat dermatological diseases, such as eczemas, lichens and hard-healing-wounds, and also to treat snakebites. Orally they are administered to treat flu and common cold	Salad and cooked as curries	Jambey Tsering et.al, 2017; Angélica Bautista-Cruz et al., 2011; Bazylko et al., 2015
211.	**English:** Bichchhoo, Indian Stinging Nettle **Hindi:** Bichchhoo **Ladakhi:** Zozot **Manipuri:** Santhak **Nepali:** Allo, Allo Sisnu, Bhyaangre Sisnu, Chaalne Sisnu, Kaali Sisnu, Lekh Sisnu, Thulo Sisnu	*Girardinia diversifolia*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Order Rosales Family Urticaceae Genus Girardinia Species Girardinia diversifolia	tropical Africa (from Ethiopia to Madagascar), Yemen, Nepal, India, Sri Lanka, southern China, Taiwan and Indonesia	β-Sitosterol, 3-Hydroxystigmast-5-en-7-one (II), 7-Hydroxysitosterol (III), Linoleic Acid (mg/g) 22.0; linolenic acid (mg/g) 9.7	Vitamin C (mg) 290 Vitamin B2 (mg) 12	Astringent and in treatment of scrofula, orally as a cure for malignant boils, gastric problems and constipation, treat fevers while its ashes are applied externally in the treatment of ringworms and eczema	Cooked as vegetables	Tsering et.al, 2017; NJOGU et al., 2011 Shrestha et al., 2020

212.	**English:**Hairy Pouzolz's Bush **Nepali:** Chiple Ghaans	*Gonostegia hirta*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Rosales Family Urticaceae Genus Gonostegia Species Gonostegia	Africa and Asia	NF	Moisture (%) 87.07 ± 0.021 Crude Protein 25.19 ± 0.77 Ash 35.047 ± 0.71 Crude fibre 18.43 ± 0.61 Carbohydrate 46.03 ± 0.47 Crude Lipid 31.37 ±0.39	Used to treat boils and abscesses, abdominal cramps in females and leucorrhoea	Cooked as vegetables	Tsering et.al, 2017 Jamoh et al., 2017 http://herbsfromdistantlands.blogspot.com/2017/10/gonostegia-hirta-pouzolzia-hirta-oik.html
213.	**English:**Least Mallow, Egyptian Mallow **Hindi:** Panirak, Soncheli, Golio, Guragped	*Malva microcarpa*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Malvales Family Malvaceae Genus Malva Species Malva macrocarpa	Europe, Africa, Asia	Cineole, Hexatriacontane, Tetratetracontane, α- selinene, coumarins	NF	Speed wound healing, protect against infection, reduce inflammation, reduce signs of aging, improve respiratory health, optimize digestive functions, improve sleep, and treat headaches.	Cooked as vegetables	Jambey Tsering et.al, 2017 Sharifi-Rad et al., 2019
214.	**English:**Chinese Mallow, Cluster Mallow, Curled Mallow **Lahaul:** Mikanchi	*Malva verticillata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Malvales Family Malvaceae Genus Malva Species Malva verticillata	Europe, Africa, Asia	benzyl-α-D-galactopyranoside, (-)-secoisolariciresinol-9'-O-β-D-glucopyranoside, transferulic acid and trans-ferulic acid methyl ester, (2S)-1-O-β-d-galactopyranosyl-3-O-linolenoyl glyceride, (2S)-1-O-β-d-galactopyranosyl-2,3-di-O-palmitoyl glyceride, (2S)-1-O-β-d-galactopyranosyl-2,3-di-O-linolenoyl glyceride, (2S)-1-O-6′-O-(α-d-galactopyranosyl)-β-d-galactopyranosyl-3-O-palmitoyl glyceride, (2S)-1-O-6′-O-(α-d-galactopyranosyl)-β-d-galactopyranosyl-3-O-linolenoyl glyceride, (2S)-1-O-6′-O-(α-d-galactopyranosyl)-β-d-galactopyranosyl-2,3-di-O-palmitoyl glyceride, (2S)-1-O-(6-O-α-d-galactopyranosyl)-β-d-galactopyranosyl-2-O-stearolyl-3-O-linolenoyl glyceride, (2S)-1-O-(6-O-α-d-galactopyranosyl)-β-d-galactopyranosyl-2,3-di-O-linolenoyl-glyceride	Moisture (%) 13.21±1.12 Total Ash 14.02±0.14 Total Protein 3.42±0.14 Fat 1.68±0.22 Sugars 67.7±1.31	Demulcent, diuretic, emollient, galactagogue and laxative, treatment of renal disorders, the retention of fluids, frequent thirst and diarrhoea, used to make a poultice for treating burns, stings, inflammations, skin irritations	Raw and cooked as vegetables	Tsering et.al, 2017; Shahabuddin et al., 2017; HwanKo et al., 2018 Salim et al., 2019
215.	**English:** Panicled Yellow Poppy **Nepali:** Gyashur	*Meconopsis paniculata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Ranunculanae Order Ranunculales Family Papaveraceae Genus Meconopsis Species Meconopsis paniculate	Asia	Kaempferol 3-O-glycosides, kaempferol 3,7-O-glycosides, quercetin 3-O-glycosides and isorhamnetin 3-O-glycoside.	NF	Clearing heat, reducing swelling, and easing pain, and is mainly prescribed for heat syndromes, hepatitis, pneumonia, and pain in joints	Cooked as vegetables	Jambey Tsering et.al, 2017

216.	**English:** East Himalayan Mussaend**a** **Assamese:** Soklati, Sokloti **Garo:** Gardek **Khasi:** Dieng Jalongtham, Jalai **Manipuri:** Hanu-Rei **Mizo:** Vakep, Vokep **Nepali:** Dhobini , Naolungkamchal **Tangkhul:** Kongrawon	*Mussaenda roxburghii*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Gentianales Family Rubiaceae Genus Mussaenda Species Mussaenda roxburghii	West Africa through the Indian sub-continent, South East Asia and Southern China	Shanzhiol, 2-propen, Ethyl dacylate, Hydrocoumarin, Chromen-2-one, Tetradecanoic acid, Heptadecanoic acid, ethy ester, Calendin, Neophytadiene, Perhydrofarnesyl acetone, 3,7,11,15-tetramethyl-2-hexadecen-1-ol, (E)-phytol, Hexadecanoic acid, methyl ester, Pentadecoinic acid, Methyl hexadec-9-enoate, Hexadeconoic acid, ethyl ester, Methyl linolenate, 2-hexadecen-1-ol,3,7,11,15 tetramethyl [R-[R-), 9,12,octadecadinoic acid(Z,Z-), Cis,cis,cis-7,3,13 hexadecatrienal, Ethyl linoleate, Ethyl (9Z,12Z)-9,12-octadecadenoate, Octadeconoic acid, ethyl ester, Phytol, acetate, Heptadeconoic acid, ethyl ester, Octanamide, N-(2-hydroxyethyl)-, Methyl 18-methylnonadecanoate, Linolenic acid, ethyl ester, tetramethylheptadecan-4-olide, Octadecanoicacid,ethyl ester, (Z,Z)-6,9-cis-3,4-epoxynonadecaciene, Squalene 38 28.295 485280 0.62 Heptadecafluorononanoic acid, udecyl ester, Triacontylpentafluoropropionate, Neryl linalool isomer, Geranyl linalool isomer, gamma-tocopherol, Vitamin E, Erost-5-EN-3-ol, (3,b, Hydrocoumarin, ethyl ester, Vitamin E, tetramethyl	NF	Possess antiinflammatory, antiviral, antioxidant and antibacterial properties, antitumor, immunostimulant, chemopreventive, lipoxygenaseinhibitor, diuretic, potential cytotoxic, antibacterial, antiviral, anti-RSV activity, antipyretic and effective in laryngopharyngitis, acute gastroenteritis and dysentery and also anti-fertility activity	Cooked as vegetables	Tsering et.al, 2017; De et al., 2011; Payum et al., 2016
217.	**English:**Watercress **Hindi:** Chhuch, Jal-Indushoor **Nepali:** Sim Rayo	*Nasturtium officinale*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Brassicales Family Brassicaceae Genus Nasturtium Species Nasturtium officinale	Asia	limonene (43.6%), -terpinolene (19.7%), p-cymene-8-ol (7.6%) and caryophyllene oxide (6.7%), myristicin (57.6%), -terpinolene (8.9%) and limonene (6.7%), caryophyllene oxide (37.2%), p-cymene-8-ol (17.6%), -terpinolene (15.2%) and limonene	Moisture (%) 87.50 ± 3.76 Ash 0.36 ± 0.05 Protein 2.85 ± 0.06 Fat 0.81 ± 0.07 Carbohydrate 7.40 ± 0.86 Fibre 1.06 ± 0.01	Depurative, diuretic, expectorant, hypoglycemic and odontalgic, Fresh leaves are cooked as vegetables and taken orally for Constipation	Cooked as vegetables	Tsering et.al, 2017;Yazdanparast et al., 2008, Abbasi et al., 2013 Sakil et al., 2019
218.	**English:** Climbing Senecio **Nepali:** Paheli Laharaa	*Senecio scandens*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Order Asterales Family Asteraceae Genus Senecio Species Senecio scandens	Asia	1-Hydroxy-4-oxo-2,5-cyclohexadiene-1-acetic acid, Protocatechuic acid, chlorogenic acid, p-Hydroxy benzeneacetic acid, Vanillic acid, Caffeic acid, Syringic acid, Coumaroylquinic acid, Jacaranone ethyl ester, p-Hydroxy benzeneacetic acid derivative, p-Hydroxycinnamic acid, Feruloylquinic acid, p-Hydroxycinnamic acid derivative, Quercetin-3-galactoside, Quercitin-3-glucoside, Dicaffeoylquinic acid, Kaempferol-3-O-hexoside, Quercetin-3-rhamnoside, Dicaffeoylquinic acid, Kaempferol-3-O-deoxyhexoside, Caffeoylferuloylquinic acid, p-Hydroxy benzeneacetic acid derivative, lupenone, oleanane, beta-sitosterol, daucosterol, adonifoline, phydroxy benzeneacetic acid, 2-(1,4-dihydroxy-cyclohexanyl) -acetic acid, hyperoside, linarin	NF	Treats bacterial diarrhea, enteritis, conjunctivitis, and respiratory tract infections	Cooked as vegetables	Tsering et.al, 2017; Yang et al., 2011; Wang et al., 2013; LX et al., 2006

219.	**English:** Drooping Prickly Pear, Cochineal Prickly Pear, Barbary Fig **Hindi:** Nag Phani **Tamil:** Sappattukkalli **Telugu:** Nagajemudu **Oriya:** Nagophenia **Nepali:** Naagaphani Paate Siundi, Haatteekaan	*Opuntia ficus indica*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Cactaceae Genus Opuntia Species Opuntia ficus-indica	Mexico, much of Latin America, South Africa and the Mediterranean Area	Flavonol 3-O-glycosides(quercetin, kaempferol, and isorhamnetin), dihydroflavonols, flavonones, and flavanonols, vitamins B1, B6 vitamin E and vitamin A	Moisture (%) 87.07 ± 0.86 Ash 4.03 ± 0.52 Protein 1.03 ± 0.0.06 Crude fat 0.40 ± 0 Crude Fibre 1.37 ± 0.06 Carbohydrate 92.57 ± 0.99 Vitamin C (mg) 5.17 ± 0.06	Treatment of burns, wounds, edema, and indigestion, possesses antiinflammatory, hypoglycemic, and anti-viral activities, used traditionally to treat diabetes, used in hyperlipidemy (excess of lipids in the blood), and obesity	Cooked as vegetables	Tsering et.al, 2017; Kaur et al., 2012 Wairagu et al., 2013
220.	**English:** Broken Bones Tree, Indian Trumpet Flower, Tree Of Damocles **Hindi:** Bhut-Vriksha, Dirghavrinta **Manipuri:** Shamba **Marathi:** Tayitu, Tetu **Tamil:** Cori-Konnai, Palai-Y-Utaicci, Puta-Puspam **Malayalam:**Palaqapayyani , **Telugu:** Manduka-Parnamu, **Kannada:** Tattuna **Konkani:** Davamadak **Bengali:** Sona **Oriya:** Tatelo **Assamese:** Toguna **Sanskrit:** Aralu, Shyonaka	*Oroxylum indicum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Order Lamiales Family Bignoniaceae Genus Oroxylum Species Oroxylum indicum	Asia	Chrysin, baicalein, baicalein-7-O-glucoside, baicalein-7-O-diglucoside (Oroxylin B), dihydroiso-α-lapachone, 7-O-methylchrysin, 5-hydroxy- 4′,7-di methoxy flavone, dihydro oroxylin A, oroxylin A, chrysin and baicalein	Moisture (%) 88.9 Total Ash 18.00 Acid insoluble ash 2.5 Water soluble ash 5.11	Gastric or peptic ulcer, treat rheumatism and wounds, possessing analgesic, antitussive and anti-inflammatory potencies	Cooked as vegetables	Jambey Tsering et.al, 2017; Li-Juan Chen, 2003; T.Hari Babu, 2010; Yuan Yuan, 2008; http://bioinfo.bisr.res.in/project/domap/plant_details.php?plantid=0091&bname=Oroxylum%20indicum; Aparna et al., 2013
221.	**English:** Wight's Sow-Thistle **Bengali:** Ban Palang **Tangkhul:** Kameo Meikachi **Nepali:** Dudhe, Mulaapaate, Ban Raayo	*Sonchus wightianus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Asterales Family Asteraceae Genus Sonchus Species Sonchus wightianus	Euroasia, around the Mediterranean and tropical Africa	1-hexacosanol, β-Sitosterol, β-Sitosterol 3-O-β-D glycoside, Hexadecanoic methyl ester	Moisture (%) 53 Total ash 19.65 Acid insoluble ash 0.9 Water soluble extractives 42.4	Applied to swellings, while its latex is used for the treatment of eye diseases, used in indigestion and as a febrifuge, while its roots act as a vermifuge, used in jaundice, deafness, gout, cough, bronchitis, asthma, eye diseases, appendicitis, tonsillitis and in sore throat	Cooked as vegetables	Jambey Tsering et.al, 2017; Sonchus wightianus, 2011 Bolleddu et al., 2018
222.	**English:** Large-Flowered Pink Sorrel, Lilac Oxalis, Pink Wood Sorrel **Nepali:** Chari Amilo	*Oxalis debilis*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Oxalidales Family Oxalidaceae Genus Oxalis Species Oxalis debilis	South America and grown throughout India	Linoleic, linolenic, oleic, palmitic acid, and stearic acids), flavonoids, isovitexine, and vitexine-2-O-β-D-glucopyrunoside	NF	Cancer, rheumatoid arthritis, liver diseases andbatherosclerosis as well as in degenerative processes associated with ageing, Antioxidant, anticancer, anti-inflammatory, analgesic, antimicrobial, antiamoebic, antifungal, astringent, cardio relaxan, depurative, diuretic, febrifuge, stero-idogenic, stomachic and styptic	Cooked as vegetables	Jambey Tsering et.al, 2017, Aniruddha Sarma, 2015; ELEENA PANDA, 2016

223.	**English:** Mountain Sorrel, Wood Sorrel, Alpine Sorrel, Alpine Mountainsorrel **Ladakhi:** Lamanchu, Chu-Lchum	*Oxyria digyna*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Polygonaceae Genus Oxyria Species Oxyria digyna	Asia, Europe, North America	(-)-epigallocatechin, (-) -epigallocatechin-3-gállate, (-) -epicatechin,(-)-epicatechin-3-gallate,quercetin-3-0-a-L-rhamnoside, tiliroside, kacmpferol-3-O-β-D-glucopyranoside, querctine, annphenone, trans-N-(p-hydroxyphenethyl) ferulamide, cis-N-(p-hydroxyphpnethyl)feinlamide(ll) , icariol A2, (.+)-lyoniresinol , and helonioside B	NF	Treatment of noxious heat,pain in leg and traumatic injury ,diarrhea	Cooked as vegetables	Jambey Tsering et.al, 2017; LI Xing-yu, 2007
224.	**English:** Mile-A-Minute Vine, Mile-A-Minute Weed, Devil's Tail, Giant Climbing Tearthumb	*Polygonum perfoliatum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Polygonaceae Genus Polygonum Species Polygonum perfoliatum	Eastern Asia, occurring from eastern Russia and Japan in the north, and the range extending to the Philippines and India in the south	3,4-dihydro-4-(4′-hydroxyphenyl)-5,7-dihydroxycoumarin; 3,4-dihydro-5-hydroxy-7-methoxy-4-(4′-methoxyphenyl)coumarin; 3,4-dihydro-5-hydroxy-4-(4′-hydroxyphenyl)-7-methoxycoumarin; and 3,4-dihydro-5,7-dihydroxy-4-(4′-methoxyphenyl)coumarin; Five diferuloyl esters of sucrose, 6′-acetyl-3,6-diferuloylsucrose (helonioside B); 2′,4′,6′-triacetyl-3,6- diferuloylsucrose; 1,2′,4′,6′-tetraacetyl-3,6-diferuloylsucrose; 1,2′,6′-triacetyl-3,6-diferuloylsucrose; and 2′,6′-diacetyl-3,6-diferuloylsucrose, were isolated, along with the 1,3,6-tri-p-coumaroyl-6′-feruloylsucroses, vanicoside A and vanicoside B; Quercetin-3-O-β-D-glucuronide	Moisture (%) 85.24 Crude Protein 12.90±0.08 Crude fibre 34.10 ± 0.42 Vitamin C (mg) 11.03 ± 0.09 Carotene 175.50±0.71 Iron 187.15±1.98 Calcium 983.51±5.00	Used for the treatments on reliving cough, fever, antidote	Cooked as vegetables	Tsering et.al, 2017;Sun et al., 1999; Sun et al., 2000; Dongsheng Fan et al., 2011 Narzary et al., 2015 Xu et al., 2020
225.	**Common Name:** Chinese Buttercup	*Ranunculus cantoniensis*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Ranunculanae Order Ranunculales Family Ranunculaceae Genus Ranunculus Species Ranunculus cantoniensis	Pakistan, Kashmir, India. S.F. China	3-O-α-L-arabinopyranosyl-(1→2)-β-D-galactopyranosyl-7-O-β-D-glucopyranosylkaempferol; 3-O-α-Larabinopyranosyl-(1→2)-{4-O-[(E)-caffeoyl]β-D-galactopyranosyl})-7-O-β-D-glucopyranosylquercetin; 3- O-{2-O-[(E)-caffeoyl]-α-L-arabinopyranosyl(1→2)-β-D-galactopyranosyl})-7-O-β-D-glucopyranosylkaempferol (4c); 3-O-{2-O-[(E)-caffeoyl]-α-L-arabinopyrannosyl-(1-2)-β-D-galactopyranosyl}kaempferol Apigenin, Jacein, jacedin-5-O-β-D-glucoside, centaurein, R(+)-Dalbergi phenol, R(+)-4methoxydalbergione, apigenin-4'-O-α-L-arabinopyranoside, apigenin-7-O-β-D-glucopyranosyl-4'-O-α-Lrhamnopyranoside, apigenin-8-C-α-L-arabinopyranoside, apigenin-8-C-β-D-galactopyranoside, tricin-7-O-β-Dglucopyranoside, 7-O-methylherbacetin 3-O-[2-O-E-feruloyl-fl-D-glucoside, β-sitosterol, stigmasterol -4 - ene-3 ,6 - dione, stigmastero	NF	Treat skin diseases, arthritis, gout, nerve pain, flu (influenza), swine flu, and meningitis.	Cooked as vegetables	Jambey Tsering et.al, 2017 Aslam et al., 2012 Bhatti et al., 2015

226.	**English**: Cane Buckthorn **Hindi:** Chadua, Chato, Chentuli, Chhedula **Oriya:** Kontus	*Rhamnus virgata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Rosales Family Rhamnaceae Genus Rhamnus Species Rhamnus virgata	E. Asia - Himalayan regions of southern China, India, Nepal, Bhutan and Thailand.	Physcion-8-O-β-gentiobioside, rhamnetin, quercitin and rhamnazin	Carbohydrate 57.74 ± 3.06 Ca(mg) 635.0 ± 7.01 Mg 445.0 ± 7.00 K 5600.0 ± 0 Na 280.0 ± 42.43 P 515.0 ± 7.01 Fe 28.70 ± 0.70	Antioxidant, antimicrobial, laxative, effects, emetic, purgative properties mostly used in the treatment of parasitic infections, spleen affection and leg swelling	Cooked as vegetables	Jambey Tsering et.al, 2017; http://temperate.theferns.info/plant/Rhamnus+virgata; KALIDHAR, et al. 1984; Abbas et al, 2019 Idris et al., 2019
227.	**English:** Tree Rhododendron **Hindi:** Burans, Lal Buransh **Tamil:** Billi **Malayalam:** Kattupoo Varasu **Kannada:** Pu **Nepali:** Lali Gurans **Tangkhul:** Kokluiwon	*Rhododendron arboreum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Equisetopsida Order Ericales Family Ericaceae Genus Rhododendron Species Rhododendron arboreum	Bhutan, China, India, Myanmar, Nepal, Sri Lanka, Pakistan and Thailand	Ericolin(arbutin), ursolic acid, α-amyrin, epifriedelinol, a new triterpenoid named campanulin, quercetin & hyperoside, hyperoside (3-D -galactoside of quercetin), ursolic acid and epifriedelinol, a triterpenoid compound, contain the flavone glycoside and dimethyl ester of terephthalic acid and certain flavonoids; Quercetin 3-O- beta -D-glucopyranosyl [1->6]-O- alpha -L-rhamnopyranoside, pectolinarigenin 7-Orutinoside, 7,2'-dimethoxy-4',5-methylenedioxyflavanone	NF	Used in gout & rheumatism, possesses oxytocic, estrogenic, and prostaglandin synthetase-inhibiting activity, are said to be poisonous (causes intoxication in large quantities) as well as medicinal and applied on the forehead to alleviate headache	Cooked as vegetables	Tsering et.al, 2017; SRIVASTAVA et al., 2012;Prakash et al, 2008 Kumar et al., 2019
228.	**English:** Nepal Dock **Assamese:** Pahari Palang **Bengali:** Pahari Palang **Hindi:** Amlya, Amlora, Bhilmora, Malorijangli Palak **Manipuri:** Torongkhongchak **Tamil:** Sukkankeerai **Nepali:** Halahale, Jangali Palak	*Rumex nepalensis*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Polygonaceae Genus Rumex Species Rumex nepalensis	, South-west Asia, Turkey, Bhutan and South Africa	physcion-1-O-β-D-glycopyranoside, nepodine, rhein, physcion-8-O-βD-glycopyranoside	Moisture (%) 96.5 Ash 8.11 Protein 13.95 Fats 17.54 Crude fiber 15.38 Carbohydrate 41.52	Purgative, antioxidant, antifungal, antibacterial, antihistaminic, anticholinergic, antibradykinin antiprostaglandin, antipyretic, antiinflammatory, antialgal, insecticidal, analgesic and CNS depressant properties	Cooked as vegetables	Tsering et.al, 2017;Shaikh et al., 2018; Jain et al., 2018; Shafiq et al.,2017 Dastagir et al., 2007
229.	**Local Name (Arunachal Pradesh):** Gilgal	*Baliospermum calycinum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Malpighiales Family Euphorbiaceae Genus Baliospermum Species Baliospermum calycinum	Southeast Asia	NF	NF	Cathartic, pungent, thermogenic, purgative, anthelmintic, and diuretic, dropsy, anascara, and jaundice, Decoction of leaves is used for treating asthma and used for external application in rheumatism.	Cooked as vegetables	Tsering et.al, 2017 Bijekar et al., 2014

230.	**Local Name (Arunachal Pradesh):** Sudum Meko	*Begonia griffithiana*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Cucurbitales Family Begoniaceae Genus Begonia Species Begonia griffithiana	Asia	Beta-sitosterol, beta-amyrin, daucosterol, stigmasterol, stigmasterol-3-O-beta-D-glucopyranoside and 4', 5', 7-trihydroxy-flavone-6-O-beta-D-glucopyranoside.	NF	Rheumatic, bronchitis, asthma, and other diseases	Leaves cooked as vegetable	Nyitan et.al, 2018 Zhang et al., 1997
231.	**Local Name (Arunachal Pradesh):** Rumdum	*Blumea fistulosa*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Asterales Family Asteraceae Genus Blumea Species Blumea lacera	Asia	(Z)-lachnophyllum ester, (Z)-lachnophyllic acid, germacrene D, (E)-β-farnesene, bicyclogermacrene, (E)-caryophyllene, and (E)-nerolidol. Also detected in the oil were (E)-lachnophyllic acid and (E)-lachnophyllum ester.	NF	Treats sinusitis, colic pain, cough, kidney stones, flu, or as a diuretic.	Leaves as sour vegetable; boiled with smoked meat	Nyitan et.al, 2018 Jawi et al., 2021 Satyal et al., 2015
232.	**Local Name (Arunachal Pradesh):** Gaam Oying	*Glochidion multiloculare*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Malpighiales Family Phyllanthaceae Genus Glochidion Species Glochidion multiloculare	Bhutan, India, Myanmar, Nepal and Bangladesh	Glochidonol, glochidiol, glochidone, lupeol, daucosterol, stigmasterol	Moisture (%) 69.36 Ash 3.30 Crude Protein 9.23 Crude Fat 3.56 Vit C (mg/100g) 61.3	Haemorrhoids, diarrhoea, dysentery, anaemia, jaundice, dyspepsia, insomnia, leukorrhagia, common cold, sore throat, toothache, carbuncle, furuncle, rheumatic arthralgia, Abortifacient, indigestion, chest pain	Leaves cooked as vegetable	Jami Nyitan et.al, 2018; Hasan et al., 2012; M.Sekendar Ali, 2014 Bhardwaj et al., 2009
233.	**English:** Thickhead, Fireweed, Redflower Ragleaf **Nepali:** Anikale Jhar **Manipuri:** Tera Paibi **Tangkhul:** Revival	*Crassocephalum cripidioides*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Asterales Family Asteraceae Genus Crassocephalum Species Crassocephalum crepidioides	Asia, Africa, Australia, Malaysia, China, Nepal and Sri Lanka	α-caryophyllene (10.29 %), β-cubebene (13.77 %) and α-farnesene (13.27 %), thymol (43.93 %), α-caryophyllene (15.16 %) and 4-cyclohexybutyramide (20.94 %), α-phellandrene, p-cymene, pinene, myrecene, limonene and E-β-ocimene, E)-β-farnesene (30.6%), α-humulene (10.3%), β-caryophyllene (7.2%), cis-β-guaiene (6.1%) and α-bulnesene (5.3%). The oil was constituted mainly of sesquiterpene hydrocarbons (77.6%), followed by oxygenated sesquiterpenes (8.7%), oxygenated monoterpenes (3.5%), monoterpene hydrocarbons (2.8%) and phenyl derivatives (0.6%)	Moisture(%) 85.08±0.19 Crude Protein 27.17±0.51 Crude Fibre 8.13±0.06 Ash 17.31±0.02	Remedy for acute hepatitis and fever, possess cancer chemo preventive actions and anti-inflammatory properties	Tender leaves cooked as vegetable	Nyitan et.al, 2018; O et al., 2012; JOSHI et al., 2014 Adanlawo et al., 2007

234.	**English:** Hill Gynura **Manipuri:** Terapaibi **Marathi:** Kusimbi	*Gynura cusimbua*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Asterales Family Asteraceae Genus Gynura Species Gynura cusimbua	Asia	myrcene (31.0%), β-phellandrene (12.43%), eugenol (6.34%), α-humulene (6.20%), dodecyl acrylate (6.09%), α-copaene (5.61%), phytol (3.21%), germacrene D (3.0%), cryptone (2.04%), 2,4-ditertbutylphenol (1.62%), α-pinene (1.33%), α-cadinene (1.26%), caryophyllene oxide (1.24%) and β-caryophyllene (1.08%), myrcene (31.0%), β-phellandrene (12.43%) and α-pinene (1.33%) were the main components, while oxygenated monoterpene hydrocarbons (10.87%) contained eugenol (6.34%) and cryptone (2.04%), α-humulene (6.20%), α-copaene (5.61%), germacrene D (3.0%), α-cadinene (1.26%) and β-caryophyllene (1.08%), as major compounds while dodecyl acrylate (6.09%), phytol (3.21%), 2,4-ditertbutylphenol (1.62%) and caryophyllene oxide (1.24%)	Moisture (%) 7.08 Carbohydrate(µg) 0.053-0.2 Protein 4.51 Lipida 0.023	Used as a heat-clearing properties for the treatment of fevers and detoxifying effect in patients with infectious diseases, smoothing intestine and relieving constipation, treatment of coronary heart diseases and hypoglicemia	Leaves cooked with roasted meat	Jami Nyitan et.al, 2018; Virendra S. Rana, 2007; Qinge Ma, 2017 Paungpronpitag et al., 2010
235.	**English:** Asian Plantain, Chinese Plantain **Kannada:** Sirapotla Gida	*Plantago asiatica*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Plantaginaceae Genus Plantago Species major	Asia	Isoacteoside, decaffeoylacteoside, tetradecanoic acid, and bis (2-ethythexyl) benzene-1,2-dicarboxylate. Asiatica revealed polyphenols such as phenylethanoid glycosides	Moisture (%) 90 Carbohydrate 63.71 Crude Protein 18.75 Crude Fat 1.67 Crude Ash 6.48 Total Dietary Fibre 22.68	Constipation, improves digestion	Whole plant cooked as vegetable	Jami Nyitan et.al, 2018 Park et al., 2011 Zeng et al., 2015
236.	**English:** Popolo-Kikania, Small-Flowereed Nightshade, Apple Of Sodom, American Black Nightshade, American Nightshade, Black Nightshade, Common Nightshade **Irula:** Kakkae Dagu **Malayalam:** Tudavalam, Mullakuthakkali **Others:** Manatakkali **Tamil:** Manathakali, Sirungunni, Kaasithazhai, Milaguthakkali **Assamese:** Laskosi, Koisi	*Solanum americanum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Solanales Family Solanaceae Genus Solanum Species Solanum americanum	South America	Gentisic acid, luteolin, apigenin, kaempferol, and m-coumaric acid.	Moisture (%) 86.75±3.28 Ash 17.40±1.27 Crude Protein 11.33±0.05 Crude Lipid 20.08±0.90 Crude Fibre 19.87±1.42 Carbohydrate 31.82±1.37	Digestive, liver tonic	Leafy shoot cooked as vegetable	Jami Nyitan et.al, 2018 Umar et al., 2008 Haung et al., 2010

237.	**English:** Hare's-Lettuce, Milk Thistle, Sow Thistle **Hindi:** Dudhi **Manipuri:** Khomthokpi **Nepali:** Dudhe Kaandaa, Chhote Jhaar **Rajasthani:** Aakadio	*Sonchus oleraceus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Asterales Family Asteraceae Genus Sonchus Species Sonchus oleraceus	Eurasia and northern Africa	Lupeol(I), α-amyrin(II), β-amyrin (III), ursonic acid(IV), oleanolic acid(V), and betulinic acid(VI)	Moisture (%) 85.37 ± 4.25 Ash 14.25± 0.25 Protein 17.50 ± 0.08 Fat 7.0 ± 0.23 Carbohydrate 46.0 ± 0.07 Crude fibre 15.25 ± 0.1	Treats flatulence and body pain, Fresh leaves decoction is taken orally for Body weakness, constipation	Tender leaves as vegetable as well as chutti, or as salad	Jami Nyitan et.al, 2018; Ballabh et al., 2007; Arshad Mehmood Abbasi, 2013 Jimoh et al., 2010
238.	**English:** Indian Prickly Ash **Kannada:** Jummina, Arempala, Kadumenasu **Malayalam:** Kothumurikku, Mullilavu, Mullilam **Marathi:** Chiphal, Chirphala, Kokli **Tamil:** Iraccai, Iraccaimaram, **Telugu:** Morapu, Raccamanu	*Zanthoxylum rhesta*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Sapindales Family Rutaceae Genus Zanthoxylum Species Zanthoxylum rhesta	India east to the Philippines and south to northern Australia	Sabinene, carophyllene oxide, spathulenol, α-pinene, 4-terpineol, 3-elemene, β-phellandrene, 3-pinene, γ-terpinene and myrcene were the predominant compounds	Moisture (%) 49.2±0.35 Ash 3.5±0.36 Crude Fibre 4.8±0.30 Crude Fat 4.0±0.50 Crude Protein 1.0±0.45 Carbohydrate 1.32±0.04	Stomach bloating; pregnancy termination; anti-helminthic	Leaves cooked as vegetable	Nyitan et.al, 2018 Varsha et al., 2018 Santhanam et al., 2016 Xu et al., 2005
239.	**Local Name (Arunachal Pradesh):** Sokho	*Spiradiclis bifida*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Class Magnoliopsida Order Gentianales Family Rubiaceae Genus Spiradiclis Species Spiradiclis bifida	Asia	NF	NF	NF	Leaves cooked as vegetable	Jami Nyitan et.al, 2018
240.	**Common Name:** Bale Chabo, Long Pipla	*Piper pedicellatum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Class Magnoliopsida Order Piperales Family Piperaceae Genus Piper Species Piper pedicellatum	Arunachal Pradesh, Manipur and Nagaland states of Northeast India.	Catechin, gallic acid, courmaric acid and protocatechuic acid of the leaf extract	Moisture (%) 89.44±0.11 Ash 13.12±0.07 Crude fat 0.60±0.05 Crude fibre 1.99±0.02 Protein 21.22±0.03 Carbohydrate 63.06±0.06	Stimulant for the digestive and respiratory systems, as a rejuvenating agent, longevity enhancer and tonic for the immune system and also used for treatment of tuberculosis, bones fracture etc.	Leaves cooked as vegetable	Jami Nyitan et.al, 2018 Seal et al., 2017 Tamuly et al., 2012 Varshney et al., 2012

241.	**Common Name (China):** Chinese Onion, Chinese Scallion, Glittering Chive, Japanese Scallion, Kiangsi Scallion	*Allium chinence*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Lilianae Order Asparagales Family Amaryllidaceae Genus Allium Species Allium chinence	China	NF	Moisture (%) 87.13 Carbohydrate 66 Protein 16.23 Fats 2.44 Crude fibre 3.96 Moisture content 5.52 Ash content 5.85	Used in stomachic and fever	Leaves are used in curry for flavouring	Leafy and Edible Plants of North-East India Rhetso et al., 2020 Ibrahim et al, 2019
242.	**Common Name:** Giant Taro	*Alocasia macrorrhiza*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Lilianae Order Alismatales Family Araceae Genus Alocasia Species Alocasia macrorrhiza	Rainforests of Island Southeast Asia, New Guinea, and Queensland	Glycosmisic acid, N-trans-feruloyltyramine, grossamide, protocatechuic acid(4), borneol acetate, vanillic acid, methyl 4-hydroxybenzoate, β-daucosterol and β-sitosterol	Moisture (%) 74.04 Carbohydrate 23.16 Protein 2.1 Fat 0.1 Ash 1.2 Fibre 1.8	Stypitic and astringent	Leaves cooked as vegetable	Leafy and Edible Plants of North-East India Kumoro et al., 2014 Zhu et al., 2012
243.	**Common Name:** Sour Currant Shrub	*Antidesma diandrum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Malpighiales Family Phyllanthaceae Genus Antidesma Species Antidesma Diandrum	Northern Australia to the Philippines, China, and India	β-friedelinol, lupeol, squalene, polyprenol, β-sitosterol, long-chain hydrocarbons, β-sitosterol and triacylglycerols	NF	Used in bile complication and blood dysentry	Leaves are eaten and made for preserve	Leafy and Edible Plants of North-East India Dechayont et al., 2017 Jadhav et al., 2014
244.	**Common Name:** Prosea	*Antidesma thwaitesianum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Malpighiales Family Phyllanthaceae Genus Antidesma Species Antidesma thwaitesianum	Southeast Asia	Caffeic galloylglucoside, Caffeic acid, Deoxycaffeic acid, 5-O-caffeoyl shikimic acid, Methyl gallate, HHDP-galloyl glucopyranoside, p-Coumaroyl-D-glucoside, 3-Hydroxy-adipic acid, 3-Hydorxy-3-methylglutaric acid, D-(-)-gulono-gamma-lactone, Gallic acid, (R)-2-methylmalate, Galloyl glucoside, Ethyl malate, Malic acid, Tartaric acid, Lactic acid, Hexose, flavonoid, quercetin	NF	Give relief for fever and body pain, syphilitic ulcers and also remedy for indigestion	Leaves cooked as vegetable	Leafy and Edible Plants of North-East India Chusri et al, 2015 Dechayont et al., 2017

245.	**Common Name:** Coral Berry	*Ardisia crispa*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Ericales Family Primulaceae Genus Ardisia Species Ardisia crispa	Asia	Bauerenol, amyrin and bergenin	NF	Used to treat scurvy, Antimetastatic and antitumor	Leaves cooked as vegetable	Leafy and Edible Plants of North-East India Nordin et al, 2017; JINDAL et al., 2012 Mohamad et al., 2012 Ishak et al, 2014
246.	**Common Name (North-East):** Theilang-Rong	*Ardisia floribunda*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Ericales Family Primulaceae Genus Ardisia Species Ardisia floribunda	Africa, Asia	5,6,3′,4′,5′-pentamethoxyflavone (cerrosilin B, 4, 162 mg), and 5,6,2′,3′,4′-pentamethoxyflavone	NF	Reduces effects of snake envenomation are immediate and prominent local tissue damage (including myonecrosis, dermonecrosis, hemorrhage, and edema), coagulation disorders (consumption coagulopathy and spontaneous systemic bleeding), cardiovascular alterations (hypotension, hypovolemic shock, and myocardial damage), renal alterations (which could evolve into acute kidney injure), neurotoxic action (descending paralysis, progressing from ptosis and external ophthalmoplegia to bulbar, respiratory muscle, and total flaccid paralysis), generalized rhabdomyolysis with myoglobinuria, and intravascular haemolysis	Leaves cooked as vegetables	Leafy and Edible Plants of North-East India Heneka et al, 2005; Silva et al.,2017 Chandran et al., 2014
247.	**English:** Shoebutton Ardisia	*Ardisia elliptica*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Ericales Family Primulaceae Genus Ardisia Species Ardisia elliptica	Asia	α-amyrin, β-amyrin, Syringic acid, quercetin, isorhamnetin	NF	Used as an anodyne, detoxicant, febrifuge, for backaches, diphtheria, dog and snake bites, sore throat, toothache, traumatic injuries, pain in the thighs, used for treatment of scurf. The juice is put in ears to treat ear ache, used for broken bones, sprains, cough and other pulmonary diseases	Leaves cooked as vegetable	Leafy and Edible Plants of North-East India PHADUNG KIT, 2006; Feng et al., 2012 Al-Abd et al., 2017
248.	**English:** Shoebutton Ardisia, Duck's Eye, Ellliptical-Leaf Ardisia **Hindi:** Bisi **Marathi:** Kadna, Katapenga, Bugadi, Dikna, Nilbedsi **Tamil:** Manipudbam, Kozhikkottai, Narikandam **Malayalam:** Kaka-Njara **Kannada:** Bodhina Gida, Shuli, Bode, Sore **Bengali:** Banjam **Oriya:** Kuti **Nepali:** Damaai Phal	*Ardisia solanacea*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Ericales Family Primulaceae Genus Ardisia Species Ardisia solanacea	Tropical Himalaya (Kumaun to Sikkim), India, Ceylon, Burma, W. China, Malaya	1naphthyl ester acetoxyacetic acid, 5hydroxymeth-2-furancarboxaldehyde and 2,4bis(1,1-dimethylethyl)-phenol.	Moisture (%) 67 Carbohydrate 7.3 Crude Protein 31.25 Crude Lipid 0.00067 Crude Fibre 6.6 Ash 25.31	Reduces alleviation of liver cancer, swelling, rheumatism, earache, cough, fever	Eaten as raw	Leafy and Edible Plants of North-East India Mares et al, 2011 Ishak et al, 2014 Chandran et al., 2014

249.	**English:** Pouch Birthwort	*Aristolochia saccata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Magnolianae Order Piperales Family Aristolochiaceae Genus Aristolochia Species Aristolochia saccate	Asia	Aporphinic, tetrahydroprotoberberinic, benzyltetra-hydroisoquinolinic, and bisbenzyltetrahydroisoquinolinic alkaloids and other nitrogenated derivatives (phenantrenoids, aristolactams, and porphyrins), Quinones, coumarins, flavanoids, lignoids (phenylpropanoids, neolignans, and lignans), terpenoids are kaurane, clerodane, and labdane diterpene derivative	NF	Used as sources of abortifacient, emmenagogue, sedative, analgesic, anticancer, anti-inflammatory, antifeedant, muscle relaxant, antihistaminic, and antiallergic drugs, for intestinal worms, in the treatment of cholera, stomach ache, abdominal pain, rheumatism, malaria , wounds and skin diseases, and also useful in treatment of different types of poisonous bites and stings	Leaves cooked as vegetable	Leafy and Edible Plants of North-East India By S. Kumar Christodoulakis et al., 2019
250.	**English:** Indian Birthwort, Dutchman's Pipe **Assamese:** Beli-Kol, Pan-Pipuli **Others:** Garudakkodi, Perumarundhu Kodi	*Aristolochia tagala*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Magnolianae Order Piperales Family Aristolochiaceae Genus AristolochiaL. Species Aristolochia tagala	E. Asia - Indian subcontinent, China, Myanmar, Thailand, Cambodia, Vietnam, Malaysia, Indonesia, Philippines, northern Australia	Gentisic acid, pyragallol, 2-methyl resorcinol, orcinol, catechol, , berberine, Quercetin 3-O-rutinoside, kaempferol 3-O-rutinoside, quercetin3-O-rutinoside-O-glucoside, isorhamnetin-3-O-rutinoside	NF	Used in fits, fever, malaria, rheumatism, stomach-ache, applied to the swollen abdomen or limbs, or dysentery, high blood pressure, beri-beri and swollen feet, possess biological properties such as antiapoptosis, antiaging, anticarcinogen, antiinflammation, antiatherosclerosis, cardiovascular protection and improvement of endothelial function, as well as inhibition of angiogenesis and cell proliferation activities	Leaves cooked as vegetable	S. Kumar; http://tropical.theferns.info/viewtropical.php?id=Aristolochia+tagala; Dey et al., 2012; REMYA et al., 2016 Christodoulakis et al., 2019
251.	**Common Name:** Toothed Dock	*Rumex hastatus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Polygonaceae Genus Rumex Species Rumex hastatus	Asia	Luteolin (24.67±2.90 mg/g of extracts), Kaempherol (17.03±1.67 mg/g of extracts), Luteolin-7-O-glucoside (14.73±2.17 mg/g of extracts), Rutin (8.24±1.43 mg/g of extracts)	Moisture (%) 77.1 ± 1.4 Protein 13.4 ± 0.7 Carbohydrate 43.2 ± 1.8 Fats 2.6 ± 0.1 Fibre 12.4 ± 0.9 Ash 5.5 ± 0.6	Cure jaundice, leaves of the plant are rubbed against the sting of Urtica dioica. Leaves are applied on wounds and cuts also; fresh leaves are roots are crushed and mixed in water. This extract is taken orally for Jaundice	Young leaves cooked in diluted milk as vegetables;	Mehmood Abbasi, 2013 Ahmed et al., 2019 Sahreen et al., 2011
252.	**Common Name:** Toothed Dock	*Rumex dentatus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Polygonaceae Genus Rumex Species Rumex dentatus	Asia	Helonioside A, gallic acid, isovanillic acid, p-hydroxycinnamic acid, succinic acid, n-butyl-beta-D-fructopyranoside, quercetin, hexadecanoic acid 2, 3-dihydroxy propyl ester, beta-sitosterol and daucosterol.	Moisture (%) 95.95 Protein 13.75 Carbohydrate 52.05 Fats 12.50 Fibre 9.03 Ash 8.65	Used as an astringent, fresh leaves are applied topically Stinging nettle	Young leaves cooked in diluted milk as vegetables	Mehmood, 2013 Dastagir et al., 2007 Zhu et al., 2006

253.	**Common Name:** Ribwort Plantain Bhatti	*Plantago lanceolata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Plantaginaceae Genus Plantago Species Plantago lanceolata	Asia and Africa	Isorhamnetin 3-O-α-L-1C4-rhamnopyranosyl-(1→6)-β-D-4C1-glucopyranoside-4′-O-β-D-4C1-glucopyranoside (3-O-β-rutinoside-4′-O-β-D-4C1-glucopyranoside), quercetin 3-O-β-rutinoside-4′-O-D-4C1-glucopyranoside, isorhamnetin 3-O-β-rutinoside, isorhamnetin 3,4′-di-O-β-D-4C1-glucopyranoside, isorhamnetin 3-O-β-D-4C1-glucopyranoside, quercetin 3-O-β-D-4C1-glucopyranoside, quercetin 3-O-α-L-4C1-arabinopyranosyl-(1→2)-β-D-4C1-glucopyranoside, isorhamnetin 3-O-β-D-4C1-xylopyranosyl-(1→2)-β-D-4C1-glucopyranoside (i.e. 3-O-sambubioside), as martynoside, acteoside (verbascoside, acetoside, kusaginin), plantamajoside, campneoside II (R,S-β-hydroxyacteoside) and lavandulifolioside	Moisture (%) 86.6 ± 3.21 Protein 2.12 ± 0.27 Carbohydrate 2.81 ± 0.44 Fibre 3.71 ± 0.55 Lipids 0.33 ± 0.06 Ash 2.67 ± 0.59 Vitamin C(mg) 13.6 ± 1.3	Cure jaundice, internal body inflammation, and constipation. Poultice of leaves is applied on boils to help ripen and burst them. The leaf extract is effective against bronchitis, Fresh leaves paste is applied topically for Sores	Young leaves cooked in diluted milk as vegetables	Mehmood, 2013 Guerrero et al., 2010 Budzianowska & Budzianowski, 2020
254.	**Common Name:** Spring Vetch Auli Pali	*Vicia sativa*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Fabales Family Fabaceae Genus Vicia Species Vicia sativa	Asia and Europe	apigenin 4`-O-β-D-glucopyranoside, apigenin 6,8-di-C-β-D-glucopyranoside, apigenin 6-C-α-L-arabinopyranoside-8-C-β-D-glucopyranoside, kaempferol-3-O- β-L-dirhamnopyranosyl (1→2, 1→6)- β -D-glucopyranoside, kaempferol 3-O-(4-β-D-xylopyranosyl)-α-L-rhamnopyranoside-7-O-L-rhamnopyranoside , kaempferol-3-O- α-L-rhamnopyranosyl (1→6)- β-D-glucopyranoside, Luteolin-7-O- β-D-glucopyranoside, quercetin 3-O-β-D-glucopyranoside and quercetin 3,7 di-O-glucopyranoside	NF	As astringent, leaves paste is applied topically for Scorpion sting	Cooked in water as vegetable	Mehmood, 2013 Liu et al., 2020 Grela et al., 2020 Gamal-Eldeen et al., 2004
255.	**Common Name:** Broad Bean/Horse Bean Sarphound	*Vicia faba*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Fabales Family Fabaceae Genus Vicia Species Vicia faba	Asia, Europe and Australia	kaempferol 3-O-(2″-α-l-rhamnopyranosyl-6″-acetyl-β-d-galactopyranoside)-7-O-α-l-rhamnopyranoside, kaempferol 3-O-(6″-acetyl-β-d-galactopyranoside)-7-O-α-l-rhamnopyranoside, quercetin 3-O-(6″-acetyl-β-d-galactopyranoside)-7-O-α-l-rhamnopyranoside and their deacylated derivatives, Nigellic acid	Moisture (%) 92 Crude Protein 30.57 Ash 3.61 Crude Fat 3.22 Crude fibre 2.73 Carbohydrate 59.87	Cure kidney stones and eye infection, Fresh leaves decoction is taken orally for Kidney pain, eye infection	Fresh leaves are boiled in water and cooked as vegetables	Abbasi, 20 Mortuza et al., 2009 Buraczewska et al., 1997 Lorente et al., 1989 Lehmann et al., 1988
256.	**Common Name:** Yellow Melilot Sinjii	*Melilotus indicus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Fabales Family Fabaceae Genus Melilotus Species Melilotus indicus	Tropical regions and desert	Catechin, epicatechin, taxifolin, quercetin, quercetin 3-O-β-D-glucopyranoside, and quercetin 3-O-α-L-rhamnopyranoside, isorhamnetin 3-O-β-D-glucopyranoside and isorhamnetin 3-O-β-D-rutinoside., phenol, flavonoid	NF	Treatment of bowel compliment and diarrhea, Fresh leaves paste is applied topically for joint swelling	Cooked as vegetables	Abbasi et al., 2013 Sonju et al., 2017

257.	**Common Name:** White Sweat Clover Safed Sinjii	*Melilotus alba*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Fabales Family Fabaceae Genus Melilotus Species Melilotus alba	Europe to Tibet	Coumarins, melilotin,anthraquinone glycosides, tannin, bis hydroxycoumarin, 2-(β-D-Glucosyloxy)-Cinnamic Acids, kaempferol 3-0-galactosyl-(l-*6)-glucoside 7-O-rhamnorhamnoside (melitin) and quercetin 3-rhamnosyl-(l-*-6)-galactoside 7-O-rhamnoside (clovin).	Moisture (%) 85.89 Total ash 11.25±0.25 Acid insoluble ash 2.11±0.12 Water soluble ash 6.86±0.19 Volatile oil 0.59±0.02	Swelling and inflammation joints	Cooked as vegetables	, Al-Snafi et al., 2020 Nicollier and Thompson, 1982 OBA et al., 1981
258.	**Common Name:** Phagwar	*Ficus palmata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Rosales Family Moraceae Genus Ficus Species Ficus palmata	Asia	furanocoumarin derivatives, rutin, germanicol acetate, vanillic acid and psoralenoside methyl ether.	Moisture (%) 76.8 Protein 1.35 Crude Fibre 18.90 Crude Fat 1.07 Ash 0.92 Carbohydrate 19.84	Fresh leaves are boiled in the milk of goat and taken Orally for Bowel complaints	Cooked in diluted milk	, Abbasi et al., 2013 Kumari et al., 2018 Alqasoumi et al., 2014
259.	**Common Name:** Trakani Phagwar	*Ficus carica*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Rosales Family Moraceae Genus Ficus Species Ficus carica	Europe and Asia	Oxalic, citric, malic, quinic, shikimic, fumaric acids, quinic and shikimic acids, myristic, pentadecylic, palmitic, margaric, *cis*-10-heptadecenoic, stearic, oleic, elaidic, linoleic, arachidic, heneicosylic, behenic, tricosylic, and lignoceric.	Moisture (%) 16.19±0.03 Ash 1.90±0.02	Cure skin infection, warts, used to cure gastric problems, inflammation and cancer, Fresh leaves are crushed and paste is applied topically for Boils	Cooked in diluted milk	Abbasi et al., 2013 Khan et al., 2011 Badgujar et al., 2014
260.	**Common Name:** Benghal Day Flower/Wild Tulip Kkar Moona	*Tulipa stellata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Lilianae Order Liliales Family Liliaceae Genus Tulipa Species Tulipa stellata	Europe and Asia	4-hydroxybenzoic, 2,5-dihydroxybenzoic, gallic, vanillic, syringic, salicylic, protocatechuic, trans-cinnamic, p-coumaric, caffeic, ferulic, chlorogenic and sinapic acids, as well as quercetin, rutin, luteonin, catechin and vitexin, Malonic, succinic, acetic and citric acids were the major organic acid	NF	Cardiac stimulant, Respiratory ailment	Cooked in diluted milk along with other vegetables	Bashir et al, 2018, TOUSEEF HUSSAIN TRAK, 2017 Krzymi ´nska et al., 2020
261.	**Common Name:** Patience Dock	*Rumex patientia*		Kingdom Plantae Phylum Tracheophyta Class Magnoliopsida Order Caryophyllales Family Polygonaceae Genus Rumex L Species Rumex patientia	Southern Europe, Bulgaria, North Macedonia and Serbia.	Nepodin, nepodin-8-O-beta-D-glucopyranoside, chrysophanol-8-O-beta-D-glucopyranoside, emodin-6-O-beta-D-glucopyranoside, emodin-8-O-beta-D-glucopyranoside, 1, 3, 5-trihydroxy-7-methylanthraquinone, physcion-8-O-beta-D-glucopyranoside	Moisture (%) 96.8 Ash 24.28 Protein 24.44 Fat 6.08 Fibre 9.80 Carbohydrate 32.22	Cold, tonsillitis, cough, inflammation, intestineache, stomachache	Leaves are used for making chutney in some areas of Ladakh, Decoction and make soup	Basant Ballabh, 2007 Ullah et al., 2017 Liu et al., 2011 GÜNEŞ and ÖZHATAY , 2011

262.	**Common Name:** Horse Mint	*Mentha longifolia*		Kingdom Plantae Phylum Tracheophyta Class Magnoliopsida Order Lamiales Family Lamiaceae Genus Mentha L. Species Mentha longifolia	native to Europe excluding Britain and Ireland, western and central Asia	pulegone (54.41%), isomenthone (12.02%), 1,8-cineole (7.41%), borneol (6.85%), and piperitenone oxide (3.19%), carvone (50.47%), 1,8-cineole (9.14%), and limonene (4.87%), menthone, isomenthone, menthol, carvone	Moisture (%) 88.5 Ash 8 Protein 8.23 Fibrers 38.5 Carbohydrate 12.22 Lipid 6 Iron(mg) 2.9012 ± 0.030 Zinc 0.4936 ± 0.067 Copper 0.1474 ± 0.033 Manganese 0.2330 ± 0.025 Sodium 5.888 ± 0.077 Potassium 242.32 ± 0.407 Magnesium 25.098 ± 0.020	The leaves are crushed and an extract prepared with warm water. The extract is taken to cure asthma, the leaves are made into fine. powder and decoction prepared, decoction of one cup is taken during indigestion and Diarrhoea	Used as chutney, dried leaves used to flavour local dishes	Basant Ballabh, 2007; TRAK, 2017 Khan et al., 2011 Mkaddem et al., 2009
263.	**Common Name:** Fuzzy Himalayan Mint **Nepali:** Bhotepaati	*Elsholtzia eriostachya*		Kingdom Plantae Phylum Tracheophyta Class Magnoliopsida Order Lamiales Family Lamiaceae Genus Elsholtzia Species Elsholtzia eriostachya	East Asia	NF	Moisture (%) 60.43 Carbohydrate 89.26 Total Fat 0.5 K 23 Ca 5.25 Mg 4.15	Treats Cold and cough, ½ glass decoction of whole plant used to remove intestinal parasites	Raw as chutney and dried for flavouring	Basant Ballabh, 2007 Guo et al., 2012 Pal et al., 2019 Dutt et al., 2011 Devi et al., 2013 ZAMAN et al., 2022
264.	**Common Name:** Dense Himalayan Mint	*Elsholtzia densa*		Kingdom Plantae Phylum Tracheophyta Class Magnoliopsida Order Lamiales Family Lamiaceae Genus Elsholtzia Species Elsholtzia densa	East Asia	Limonene, *β*-caryophyllene, *ρ*-cymene, *trans*-phytol, *α*-terpineol, linalool, acetophenone, 1,8-cineole, *ρ*-cymen-7-ol, 1-*O*-cerotoylgly-cerol, and palmitic acid. Furthermore, acetophenone, *ρ*-cymen-7-ol, and 1-*O*-cerotoylgly-cerol, 4-Pyridinol, Thymaol	NF	Treats common cold, fever, headache, stomach problems, joint ache and high blood pressure, skin disorder, Musculoskeletal disorder, Otorhinolaryngology disorder, Digestive disorder, Urinary Disorder, Skin Disorder, Respiratory disorder	Raw as chutney and dried for flavouring	Basant Ballabh, 2007 Liang et al., 2021 Zhou et al., 2019 Soelberg & Jäger, 2016
265.	**Common Name:** Foxglove	*Digitalis purpurea*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Plantaginaceae Genus Digitalis Species Digitalis purpurea	Temperate Europe	Purpurea glycosides A and B, glucogitaloxin, Digitoxin, gitoxin and getaloxin	B 0.816 Cr 0.730 Mn 11.80 Co 0.065 Ni 0.919 Cu 0.858	Reduces cardiac problems, leaf paste applied to sores and wounds	Leaves are cooked as vegetable	TOUSEEF HUSSAIN TRAK, 2017 Bhatt, 2020 Negi et al., 2012
266.	**Common Name:** Common Quince	*Cydonia oblonga*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Rosales Family Rosaceae Genus Cydonia Species Cydonia oblonga	Western Asia	3-, 4-, and 5-O-caffeoylquinic acids, quercitin 3-galactoside, rutin, and 3,5-dicaffeoylquinic acid while in peel kaempferol 3-glucoside, kaempferol 3-rutinoside, kaempferol glycoside, quercitin glycosides acetylated with *p*-coumaric acid, and two acetylated glycosides of kaempferol	NF	Antidiabetic, antidioxidant, antihemolytic, antihyperglycemic, antihyperlipidemic.	Leaves are cooked as vegetable	TOUSEEF HUSSAIN TRAK, 2017 Sharma et al., 2011 Ashraf et al., 2016 Sajid et al., 2015

267.	**Common Name:** Common Mallow	*Malva neglecta*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Malvales Family Malvaceae Genus Malva Species Malva neglecta	Most of Europe, including Britain, south and east to N. Africa and Asia.	Tri-O-galloylquinic acid, epicatechin, ferulic acid, 3-O-caffeoylquinic acid, 5-O-caffeoylquinic acid, 3,4-di-O-caffeoylquinic acid, 3,5-di-O-caffeoylquinic acid and 4,5-di-O-caffeoylquinic acid	Moisture(%) 79.1 Ash 15.6±2.2 Protein 16.9±3.4 Vit C(mg) 83.5±26.2 K(mg) 2828.6±764.7 Mg(mg) 408.5±63.1 Fe(mg) 19.2±14.7 Zn(mg) 8.1±2.3	Used as a laxative, anti-ulcerogenic activity, Wounds and cuts, abscessed diseases, rheumatism	Leaves are cooked as vegetable	TOUSEEF HUSSAIN TRAK, 2017 Aksoy et al., 2019 Al-Snafi, 2019 Akkol et al., 2022 KILIÇ, 2016 Cakilcioglu & Turkoglu, 2010
268.	**Common Name:** Common Maidenhair Fern	*Adiantum capillusveneris*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Polypodiophytina Class Polypodiopsida Subclass Polypodiidae Order Polypodiales Family Pteridaceae Genus Adiantum Species Adiantum capillus-veneris	Eurasia, the Levant in Western Asia, and Australasia	Rutin, quercetin, quercetin-3-O-glucoside, querciturone, isoquercitrin, nicotiflorin, naringin, astragalin, populnin, procyanidin, prodelphinidin, and kaempferol-3-sulfate, Alkaloids (0.53%)	Moisture(%) 91.7 Fats 0.20 Fiber 67.23	Leaves of the plant is mixed with cardamom and boiledin water and is given to cure cough, cold, and fever in infants. The dried powdered fronds are mixed with milk and given as a remedy for fever to infants, curing herpes.	Leaves are cooked as vegetable	TOUSEEF HUSSAIN TRAK, 2017 Snafi, 2015 Al-Snafi, 2015
269.	**Common Name:** Bell Rhododendron **Hindi:** Burans, Semru	*Rhododendron companulatum*		Kingdom Plantae Phylum Tracheophyta Class Magnoliopsida Order Ericales Family Ericaceae Genus Rhododendron L Species Rhododendron campanulatum	Northern India, Bhutan, and Nepal	gallic acid, quercetin, and campanulin	NF	Leaves of the plant are effective as it is given in chronic rheumatism, syphilis and sciatica. Leaves are mixed with tobacco and are used as snuff to cure cold;	Leaves are cooked as vegetable	TOUSEEF HUSSAIN TRAK, 2017 Qiang et al., 2011
270.	**Common Name:** Himalayan Arnebia **Nepali:** Mahaarangee, Ulte Bhutkesh	*Arnebia benthamii*		Kingdom Plantae Phylum Tracheophyta Class Magnoliopsida Order Boraginales Family Boraginaceae Genus Arnebia Forssk. Species Arnebia benthamii	North-West Himalaya	NF	NF	The extract is prepared out of the herb and is used in abdominal pain, in high fever and in wormicide. The leaves of the plant are used in fever and heart ailments. The herb is extensively collected from the higher reaches and sold to the crude herbal medicine dealers by nomads.	Leaves are cooked as vegetable	TOUSEEF HUSSAIN TRAK, 2017

271.	**Common Name:** Pot Marigold	*Calendula officinalis*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Asterales Family Asteraceae Genus Calendula Species Calendula officinalis	southern Europe	five phenolic acid glucosides [1′-O-p-hydroxybenzoyl-β-D-glucopyranose, 6′-O-p-hydroxybenzoyl-β-D-glucopyranose, 1′-O-protocatechuoyl-β-D-glucopyranose, 6′-O-protocatechuoyl-β-D-glucopyranose, and 1′-O-vanilloyl-β-D-glucopyranose], five phenylpropanoids [caffeic acid, 3-O-, 3,5-di-O-, 1,5-di-O-, and 4,5-di-O-caffeoylquinic acid], five coumarins [umbelliferone, aesculetin, aesculin , cichoriin, scopoletin], and nine flavonoids [quercetin, isoquercitrin, quercetin-3-O-(6′′-acetyl)-β-D-glucopyranoside, rutin, isorhamnetin, isorhamnetin-3-O-β-D-glucopyranoside, isorhamnetin-3-O-(6′′-acetyl)-β-D-glucopyranoside, narcissin and thyphaneoside	Moisture(%) 81.21 Ca(ppm) 2464 Na(ppm) 14745 K(ppm) 71617 Mg(ppm) 9060 Fe(ppm) 22.94 Cu(ppm) 1.27 Mn(ppm) 36.96 Zn(ppm) 34	Leaves are used as blood tonic and blood purifier	Leaves are cooked as vegetable	TOUSEEF HUSSAIN TRAK, 2017 Ahmed et al., 2002 Al-Snafi, 2015 Olennikov and Kashchenko, 2014
272.	**Common Name:** False Amaranth	*Digera muricata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Amaranthaceae Genus Digera Species Digera muricata	Eastern tropical Africa	α- & β-spinasterol, β-sitosterol, superoxide, peroxidase, rutin, hyperoside, palmitic acid	Moisture(%) 92.76 Ash 11.43 Carbohydrate 51.033 Fat 2.033 Mg(mg) 41.20 Fe 1.575 Mn 0.138 Cu 0.275 Ca 66.29	Paste is taken orally for constipation, used internally against digestive system disorders	Fresh leaves are cooked in water	Arshad Mehmood Abbasi, 2013 Elgailani, 2018 J Anar et al., 2013 Taran et al., 2022
273.	**Common Name:** Pakistan Wood Fern	*Dryopteris ramosa*		Kingdom Plantae Phylum Tracheophyta Class Polypodiopsida Order Polypodiales Family Dryopteridaceae Genus Dryopteris Species Dryopteris ramose	Pakistan	Oleoresin, Filicin, Iriflophenone-3-C-β-d Glucopyranoside, mangiferin and isomangiferin	NF	Gastric ulcer, constipation taken orally, anti-bacterial and anthelminthic	Leaves are cooked as vegetable and taken orally	Arshad Mehmood Abbasi, 2013 Bir et al., 2006; Singh et al., 2003 Alam et al., 2021 Ishaque et al., 2022
274.	**Common Name:** Spanish Needles	*Bidens bipinnata*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Asterales Family Asteraceae Genus Bidens Species Bidens bipinnata	Asia and North America	Quercetin, quercetin-3-0-alpha-L-rhamnoside, keampferol-3-O-beta-D-glucopyranoside, keampferol-3-O-alpha-L-rhamnoside, 3', 5-dyhydroxy-3, 6, 4'-trimethoxyl -7-O-beta-D-glucopyranoside flavonoid, 7, 8, 3', 4'-tetraflavanone, (2S)- and (2R)-isookanin-7-O-beta-D- glucopyranoside (7a/7b), (2S)- and (2R)-3'-methoxy-isookanin-8-O-beta-D-glucopyranoside (8a/8b), 6, 7, 3', 4'-tetrahydroxyaurone, maritimetin, esculetin, 3-O-caffeoyl-2-methyl-d-erythrono-1, 4-lactone, (7S, 8R) balanophonin-4-O-beta-D-glucopyranoside, eugenyl-O-beta-apiofuranosyl-(1''-6') -O-beta-glucopyranoside, and (+)-syringaresinol-4'-O-beta-D-glucopyranoside.	NF	Fresh leaves extract is applied topically for Leprosy and skin cuts	Leaves are cooked as vegetable	Arshad Mehmood Abbasi, 2013 Wang et al., 2014

275.	**Common Name:** Chicory	*Cichorium intybus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Asterales Family Asteraceae Genus Cichorium Species Cichorium intybus	Europe and introduced into the United States late in the 19th century	alpha-amyrin, taraxerone, baurenyl acetate and beta-sitosterol	NF	Fresh leaves decoction is taken orally for fever, gas trouble, and body swelling	Leaves are cooked as vegetable	Arshad Mehmood Abbasi, 2013 Madan et al.,2018
276.	**Common Name:** Creeping Launaea	*Launaea procumbens*		Kingdom Plantae Phylum Tracheophyta Class Magnoliopsida Order Asterales Family Asteraceae Genus Launaea Species Launaea procumbens	Pakistan	1-H- pyrazole, 1-H-imidazole, β -amyrin, α -amyrin and lupeol	NF	Fresh leaves are grinded along with sugar and extract is taken orally for Painful micturation	Leaves are cooked as vegetable	Arshad Mehmood Abbasi, 2013 Rawat et al., 2016
277.	**Common Name:** Weed Silene And Large Sand Catchfly	*Silene conoidea*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Caryophyllaceae Genus Silene Species Silene conoidea	Subtropical and temperate zones of western Eurasia, and some parts of the Himalayas	(4”-O-α-L-rhamnopyranosyl)-C-β-D-glycopyranosyldiosmetin, 8 (4”-O-α-L-rhamnopyanosyl)-C-β-D-glucopyranosylapigeninand Conoidene (2,2’-(1,3-butadiene-1,4-diyl)bis[3-methoxy-5-(2-propen-1-yl) furan), conoidene 1,4-di-[3-methoxy-5-(2-propenyl)-furan]-1,3 butadiene, 8-C-(4-O-α-L-rhamnopyranosyl)-β-D-glucopyranosylapigenin, α-Spinasterol and α-spinosterolglucoside	Fe 0.045±0.018 Zn 0.040±0.011 Cu 0.014±0.006 Mn 0.005±0.002 Cr 0.024±0.012 Cd 0.499±0.231 Pb 0.013±0.007	Fresh leaves paste is applied topically for Skin infection	Leaves are cooked as vegetable	Abbasi, 2013 Ullah et al., 2019 Ali et al., 2006 Ullah et al, 2009
278.	**Common Name:** Dwarf Morning-Glory	*Evolvulus alsinoides*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Solanales Family Convolvulaceae Genus Evolvulus Species Evolvulus alsinoides	Tropical and warm-temperate regions of Australasia, Indomalaya, Polynesia, Sub-Saharan Africa and the Americas.	Evolvine, β-sitosterol, stearic, oleic and linoleic acid, betaine, pentatriacontane and triacotane	Moisture(%) 90 Total Ash 8.5 ± 0.0	Leaves are crushed and mixed along with water. This juice is taken orally for Indigestion, constipation	Leaves are cooked as vegetable	Abbasi et al., 2013
279.	**Common Name:** Common Henbit	*Lamium amplexicaule*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Lamiaceae Genus Lamium	Europe, Asia and northern Africa	Sesquiterpene hydrocarbons, notably germacrene D (18.5% - 34.9%) and (E)-caryophyllene (2.5% - 11.9%) and and monoterpene hydrocarbons, α-pinene (2.2% - 16.2%), β-pinene (2.0% - 10.6%), as well as 1-octen-3-ol (3.5% - 8.0%).	NF	Fresh leaves paste is applied topically for Joints swelling	Leaves are cooked as vegetable	Abbasi et al, 2013 Jones et al., 2012

				Species Lamium amplexicaule						
280.	**Common Name:** Oregano	*Origanum vulgare*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Lamiaceae Genus Origanum Species Origanum vulgare	North America	Four phenolic acids (gentisic, chlorogenic, *p*-coumaric and rosmarinic acids) and six flavonoids (hyperoside, isoquercitrin, rutin, quercitrin, quercetin and luteolin)	Moisture(%) 93.5 Proteins 7.9 Lipids 0.67 Carbohydrates 70.89 Mineral 5.3	Fresh leaves are chewed for toothache and mouth gums	Leaves are cooked as vegetable	Abbasi et al., 2013 Negrea et al., 2018 Oniga et al., 2018
281.	**Common Name:** Small-Flowered Mallow, Cheeseweed Mallow, Little Mallow, Marshmallow	*Malva parviflora*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Malvales Family Malvaceae Genus Malva Species Malva parviflora	Northern Africa, Europe and Asia	β- amyrin, α-amyrine, mixture of β-sitosterol and stigmasterol, cholesterol, campasterol, ergosterol and β-sitosterol-O-glucoside.	Moisture(%) 78.64±0.09 Crude Protein 44.77±0.54 Crude Fat 3.39±0.08 Total sugars 5.41±0.08 Crude Fiber 9.81±0.08 Total Ash 10.47±0.54 Carbohydrate 41.37±0.68	Fresh leaves decoction is taken orally for constipation, cough, fever	Leaves are cooked as vegetable	Abbasi, 2013 Abdalla et al., 2016 Sahzly et al., 2013
282.	**Common Name:** California Burclover	*Medicago polymorpha*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Fabales Family Fabaceae Genus Medicago Species Medicago polymorpha	Mediterranean basin	Apigenin, apigenin-7-O-β-D-glucopyranoside, apigenin-7-O-β-D-glucuronopyranoside methyl ester, apigenin-7-P-β-D-glucuronopyranoside butyl ester, luteolin, isoformononetin, isoliquiritigenin, echinocystic acid-3-O-[-O-α-L-rhamnosyl-(1 → 2) - α-L-arabinoside], coumestrol, adenine, xanthine, n-nonyl triacontanol, daucosterol, and β-sitosterol.	Moisture(%) 82 Protein(%) 28.5 Dietary Fiber 24.6-28.4 Fat 4-6	Fresh leaves are cooked in water and taken orally for Constipation, indigestion	Leaves are cooked as vegetable	Abbasi et al., 2013 Liu etal., 2015 Yan et al., 2012
283.	**Common Name:** Mountain Fleece	*Polygonum amplexicaule*		Kingdom Plantae Phylum Tracheophyta Class Magnoliopsida Order Caryophyllales Family Polygonaceae Genus Bistorta Species Bistorta amplexicaulis	China, the Himalayas, and Pakistan.	Friedelin, beta-sitosterol, simiarenone, angelicin, psoralen, palmitic acid, (-)-epicatechin, and quercetin, essential oils, Geraniol (19.91%), β-Linalool(19.63%), Citronellol (16.22%), Heptan-2-ol (5.66%)	NF	Fresh leaves are boiled in water along with sugar and decoction is taken orally for Fever, joint pain, flue	Leaves are cooked as vegetable	Abbasi et al, 2013 Ren et al., 2009 Prasad et al., 2018

284.	**Common Name:** Knotgrass	*Polygonum aviculare*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Polygonaceae Genus Polygonum Species Polygonum aviculare	Europe	Quercitrin hydrate, caffeic acid, and rutin	Moisture(%) 62.29 Crude Protein 9.56 Ash 6.99	Fresh leaves decoction is taken orally for diarrhoea and dysentery	Leaves are cooked as vegetable	Abbasi et al., 2013 Kamalak et al., 2010
285.	**Common Name:** Chicken Weed	*Portulaca quadrifida*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Portulacaceae Genus Portulaca Species Portulaca quadrifida	Africa and tropical Asia	NF	Moisture(%) 62.17 Ash content 8.2 Crude Proteins 6.4 Crude Fiber 12.16 Fat Content 0.83 Carbohydrate 73.23	Fresh leaves are slightly wormed and applied topically for joint swelling	Leaves are cooked as vegetable	Abbasi, 2013 Samreen et al., 2016
286.	**Common Name:** Goose Grass	*Galium aparine*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Gentianales Family Rubiaceae Genus Galium Species Galium aparine	Southwest Asia	Quercetin, luteolin, apigenin, hesperetin, linarin, kaempferol-3-neohesperidose, tamarixetin-3-rutinoside and hesperidin. alkaloids (2.76±0.03), saponins (0.99±0.03), flavanoids (6.36±0.03), tannins (16.96±0.01)	NF	Fresh leaves paste is applied topically for Wounds healing, Extract of fresh leaves is taken orally for jaundice	Leaves are cooked as vegetable	Abbasi, 2013 Al-Snafi, 2018 Li et al., 2010
287.	**Common Name:** Wall Speedwell, Corn Speedwell, Common Speedwell, Rock Speedwell, Field Speedwell	*Veronica arvensis*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Lamiales Family Plantaginaceae Genus Veronica Species Veronica arvensis	Eurasia, North Africa	Cornoside aglycone and rengyolone, luteolin, apigenin, chrysoeriol, delphinidin, tricin, 6-hydroxyflavones	NF	Fresh leaves decoction is taken orally for Skin infection, blood purifier	Leaves are cooked as vegetable	Abbasi et al., 2013 Salehi et al., 2019

288.	**Common Name:** Diverse-Leaf Hogweed	*Pimpinella diversifolia*		Kingdom Plantae Phylum Tracheophyta Class Magnoliopsida Order Apiales Family Apiaceae Genus Pimpinella L. Species Pimpinella diversifolia	E. Afghanistan to China and Indo-China	Essential oils present (specific compounds not found)	NF	Dried leaves are grinded along with salt and powder is taken orally for Gas trouble, indigestion	Leaves are cooked as vegetable	Abbasi et al., 2013 Melkani et al., 1990
289.	**Common Name:** Bristlefruit Hedge Parsley.	*Torilis leptophylla*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Asteranae Order Apiales Family Apiaceae Genus Torilis Species Torilis leptophylla	Europe, Africa and parts of Asia	α-Pinene, 1-Octen-3-ol, β-Pinene, Myrcene, Octanal, ρ-Cymene, Limonene, 1,8-Cineole, γ-Terpinene, Octanol, Linalool, Nonanal, 1-Octen-3-ol-acetate, trans-Thujone, Camphor, (E)-2-Nonenal, Lavandulol, ρ-Methyl-Acetophenone, Octanol acetate, Dec-9-en-ol, Bornyl acetate, Thymol, δ-Elemene, α-Copaene, β-Bourbonene, β-Cubebene, β-Elemene, trans-α-Ambrinol, β-Caryophyllene, β-Gurjunene, trans-α-Bergamotene, α-Humulene, (E)-β-Farnesene, γ-Muurolene, Germacrene D, Bicyclogermacrene, trans-β-Guaiene, α-Bulnesene, β-Bisabolene, Cubebol, Sesquicineole, δ-Cadinene, Kessane, Spathulenol, Caryophyllene oxide, β-Copaen-4-á-ol, β-Oplopenone, Humulene epoxide II, trans-iso-Longifolanone, Cedr-8-(15)-en-9-α-ol, 14-Hydroxy-9-epi-β-caryophyllene, Khusinol, Foeniculin, cis-14-Muurol-5-en-4-one, β-Acoradienol, 14-Hydroxy-δ-cadinene, (Z,E)-Farnesyl acetate, 6,10,14-Trimethyl-2-pentadecanone, (E,E)-Farnesyl acetate, Hexadecanoic acid	NF	Taken orally with water for Gastrointestinal disorders	Leaves are cooked as vegetable	Abbasi et al, 2013 Saeed et al., 2012 Saeed et al., 2012 Masoudi et al., 2012
290	**Common Name** (Bodo): Jwglaori	*Blumea lanceolaria*		Kingdom Plantae Class Magnoliopsida Order Asterales Family Asteraceae Genus Blumea Species Blumea lanceolaria (Roxb.) Druce	Tropical and sub-tropical zones of Asia, especially the Indian Subcontinent and Southeast Asia	Chloroacetic acid, tetradecyl ester, 3, 7, 11, 15-tetramethyl-2-hexadecen-1-ol and Z, z-6,28-heptatriactontadien-2-one, 1-Heptacosanol	Moisture (%) 88.87 ± 0.52 Ash 1.96 ± 0.001 Crude Fat 0.31 ± 0.0006 Crude Protein 1.84 ± 0.0001 Carbohydrate 7.00 ± 0.52 Crude Fibre 1.23 ± 0.003	Stomach ulcers, wounds and cut	Contain aromatic smell & are eaten as vegetable	Narzary et al., 2015 Mishra et al., 2015 Pang et al., 2014 Khakhalary et al., 2022 Tlau et al., 2020
291	**Common Name:** Malabar Spinach **Local Name:** Poi	*Basella rubra*		Kingdom Plantae Class Equisetopsida C. Order Caryophyllales Family Basellaceae Genus Basella Species Basella alba L.	Indian subcontinent, Southeast Asia and New Guinea	Rutin, Quercetin, Scopoletin, Coumarin, β-xanthin and β-cyanin pigments and Caffeic, Homo-protocatechuic-, Chlorogenic-, trans- and cis-p-coumaric-, p-hydroxy-benzoic-, phloretic-, trans-and cis-sinapic-, cinnamic-acids; and the fruit consists of β-cyanin, gomphrenin I, gomphrenin II, and gomphrenin III	Moisture (%) 85.26 Ash 2.80 Crude Protein 5.15 Crude Fat 0.86 Vit C (mg) 83.7	Gastro-protective activity, ulcer healing, anti-inflammatory activity, wound healing activity. Basella alba is reported to improve testosterone levels in males, thus boosting libido. Decoction of the leaves is recommended as a safe laxative in pregnant women and children.	Cooked as vegetable	Bhardwaj et al., 2009 Singh et al., 2016
292	**Common Name:** Red Ginger **Local Name:** Kekir	*Zingiber sp.*		Kingdom Plantae Class Liliopsida Order Zingiberales Family Zingiberaceae Genus Zingiber Species Zingiber zerumbet (L.)	Southeast Asia especially in Thailand, China, the Indian Subcontinent, and New Guinea	6-gingerol, 8-gingerol, and 10-gingerol, terpene components in ginger, such as β-bisabolene, α-curcumene, zingiberene, α-farnesene, and β-sesquiphellandrene	Moisture (%) 73.67 Ash 1.21 Crude Protein 2.80 Crude Fat 2.26 Vit C (mg) 24.3	Used for arthritis, cramps, sprains, sore throats, rheumatism, muscular aches, pains, vomiting, constipation, indigestion, hypertension, dementia, fever and infectious diseases.	Cooked as vegetables	Bhardwaj et al., 2009 Shahrajabian et al., 2019 Mao et al., 2019

293.	**Common Name** (Bodo): Parukia	*Cryptolepis sinensis*		Kingdom Plantae Class Magnoliopsida Order Gentianales Family Apocynaceae Genus Cryptolepis Species Cryptolepis sinensis	Taiwan, China	isoscopoletin,(+)-3-hydroxy-β-ionone,(3R, 6R, 7E)-3-hydroxy-4, 7-megastigmadien-9-one, ficusic acid,(+)-pinoresinol,(+)-8-hydroxypinoresinol,(+)-syringaresinol, diaaurantiamide acetate, loliolide,(–)-balanophonin, chrysoeriol, 9-hydroxy-10E, 12Z-octadecadienoic acid methyl ester, and ficusesquilignan A.	Moisture (%) 81.96 ± 0.45 Ash 1.97 ± 0.001 Crude Fat 0.64 ± 0.001 Crude Protein 2.92 ± 0.003 Carbohydrate 12.48 ± 0.45 Crude Fibre 2.67 ± 0.003	Used for the treatment of malaria, rheumatism, urinary tract infections, upper respiratory tract infections and intestinal disorders	Used as vegetable	Narzary et al., 2015 Mensah et al., 2013
294.	**Common Name:** Akarkara **Local Name:** Marsang	*Spilanthus acmella*		Kingdom Plantae Class Magnoliopsida Order Asterales Family Asteraceae Genus Spilanthes Species Spilanthes acmella (L.)	Tropical and subtropical countries mainly India and South America.	lipophilic alkylamides or alkamides, unsaturated hydrocarbons (alkenes and alkynes), such as spilanthol, affinin (2E,6Z,8E)-N-isobutyl-2,6,8-decatrienamide and amide derivatives, anandamide (N-arachidonoyl-ethanolamine)	Moisture (%) 88.13 Ash 1.86 Crude Protein 3.26 Crude Fat 1.19 Vit C (mg) 12.1	Used in gum infection, inflammation, sore throat, toothache, wound healing	Cooked as vegetables	Bhardwaj et al., 2009 Byrappa et al., 2016 Prachayasittikul, et al., 2013
295	**Common Name:** Ginger **Local Name:** Takeng	*Zingiber officinalis*		Kingdom Plantae Class Liliopsida Order Zingiberales Family Zingiberaceae Genus Zingiber Species Zingiber officinale Roscoe	India or southeast Asia	6-gingerol, 8-gingerol, and 10-gingerol, terpene components in ginger, such as β-bisabolene, α-curcumene, zingiberene, α-farnesene, and β-sesquiphellandrene	Moisture (%) 79.12 Ash 0.40 Crude Protein 2.10 Crude Fat 1.20 Vit C (mg) 18.1	Used for arthritis, cramps, sprains, sore throats, rheumatism, muscular aches, pains, vomiting, constipation, indigestion, hypertension, dementia, fever and infectious diseases.	Cooked as vegetables	Bhardwaj et al., 2009 Shahrajabian et al., 2019
296.	**Common Name** (Bodo): Dousrem	*Tetrastigma angustifolium*		Kingdom Plantae Family Vitaceae	Assam to Myanmar	NF	Moisture (%) 87.46 ± 0.71 Ash 1.15 ± 0.001 Crude Fat 0.52 ± 0.0007 Crude Protein 1.86 ± 0.0006 Carbohydrate 8.99 ± 0.71 Crude Fibre 1.28 ± 0.001	Antimicrobial activity (*Staphylococcus aureus, Bacillus cereus, Escherichia coli and Proteus vulgaris*)	Eaten as vegetable	Narzary et al., 2015 Junejo et al., 2016; Narzary et al., 2018
297	**Common Name** (Bodo): Lapasaiko	*Antidesma acidum*		Kingdom Plantae Class Equisetopsida C. Order Malpighiales Juss. Family Phyllanthaceae Genus Antidesma Species Antidesma acidum Retz.	Jawa to south-central China and Pakistan	Clauszoline B, clauszoline H, mukonal, 7-methoxymukonal , and heptaphyline and three coumarin derivatives, 5-demethyltoddaculin, xanthoxyletin, and alloxanthoxyletin	Moisture(%) 87.57 ± 0.96 Ash 1.32 ± 0.002 Crude Fat 0.70 ± 0.003 Crude Protein 1.47 ± 0.0006 Carbohydrate 8.92 ± 0.96 Crude Fibre 1.19 ± 0.007	Curing headache, jaundice, stomach pain etc.	Used as vegetable	Narzary et al., 2015 Kiem et al., 2016
298	**Common Name:** Wild Brinjal **Local Name:** Koppi	*Solanum torvum*		Kingdom Plantae Class Magnoliopsida Order Solanales Family Solanaceae Genus Solanum Species Solanum torvum	West Indies	Neochlorogenin 6-O-β-D-quinovopyranoside, neochlorogenin 6-O-β-D-xylopyranosyl-(1→3)β-D-quinovopyranoside, neochlorogenin 6-O-α-L-rhamnopyranosyl-(1→3)-β-D-quinovopyranoside, solagenin 6-O-β-D-quinovopyranoside, solagenin 6-O-α-L-rhamnopyranosyl-(1→3)-β-D-quinovopyranoside, isoquercetin, rutin, kaempferol and quercetin.	Moisture (%) 76.34 Ash 0.56 Crude Protein 4.82 Crude Fat 0.95 Vit C (mg) 17.6	It treats cold, anemia, improves brain function, reduce weight, treat diabetes, improce heart function.	Used as vegetable	Bhardwaj et al., 2009 Jaiswal et al., 2012 Luo et al., 2011
299	**Common Name:** Wild Brinjal **Local Name:** Koppir	*Solanum khasianum*		Kingdom Plantae Class Magnoliopsida Order Solanales Family Solanaceae Genus Solanum Species Solanum aculeatissimum Jacq.	Eurasia	(+)-pinoresinol, (+)-syringaresinol, (+)-medioresinol, scopoletin, tetracosanoic acid and beta-sitosterol .	Moisture (%) 73.13 Ash 1.77 Crude Protein 6.33 Crude Fat 2.45 Vit C (mg) 20.0	Used to treat pneumonia, aching teeth, stomach ache, tonsillitis, wing worms, pain, inflammation and fever, tumor, inflammation, and also as hepaprotective, diuretic, antipyretic	Cooked as vegetables	Bhardwaj et al., 2009

300	**Common Name** (Bodo): Ontaibajab	*Lippia javanica*		Kingdom Plantae Class Magnoliopsida Order Lamiales Family Verbenaceae Genus Lippia Species Lippia javanica	Eastern and southern Africa	Myrcenone, carvone, piperitenone, ipsdienone, and linalool	Moisture (%) 84.53 ± 1.40 Ash 3.15 ± 0.003 Crude Fat 0.27 ± 0.007 Crude Protein 4.38 ± 0.0005 Carbohydrate 7.65 ± 1.39 Crude Fibre 2.63 ± 0.002	Used to treat colds, cough, fever, malaria, wounds, diarrhoea, chest pains, bronchitis, and asthma	Eaten as vegetable with meat or fish	Narzary et al., 2015 Maroyi et al., 2017
301.	**Common Name:** Garden Cress, Garden Pepper Cress, Pepper Grass, Pepperwort, **Assamese**: Halim Shaak **Bengali**: Halim Shaak **Gujarati:** Asheliyo **Hindi:** Chansur,Halim **Kachchhi:** Aaserio **Kannada:** Allabeeja, Kurtige Gida **Konkani:** Aaliv **Malayalam:** Asali **Marathi:** Ahaliv **Nepali:** Chamsur **Odia:** Halima **Persian**: Tara Tezak **Rajasthani:** Asaliyo **Sanskrit:** Chandrashura, Raktaraji **Tamil:** Ali **Urdu:** Chansur, Halim, Halon	*Lepidium sativum*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Brassicales Family Brassicaceae Genus Lepidium L Species Lepidium sativum L.	Asia: Afghanistan, Bhutan, China, India, Japan, Kazakhstan, Kyrgyzstan, Nepal, Pakistan, Russia, Tajikistan, Turkmenistan, Uzbekistan, Vietnam; Africa; Europe; North America; South America.	Campesterol, cis-vaccenic acid, 2-naphthalenol, 1-nitro-2-propanol,1-deoxy-d-mannitol, allyl isothiocyanate, and paromomycin	Moisture (%) 82.3 Protein 5.8 Ash 2.2 Total Fat 1 Carbohydrate 8.7 Calcium 0.36 Phosphorus 0.11 Iron (mg) 28.6 Vitamin A 3.3IU Riboflavin(mg) 0.15 Niacin (mg) 0.08 Ascorbic acid (mg) 39 Nickel (µg) 4 Cobalt (µg) 1.2 Iodine (µg) 11 Thiamin (µg) 70	Crushed leaves show antibacterial actibity against *Bacillus cereus, Micrococcus pyrogenes* var. aureus, diuretics, aperient and aphrodisiac properties and are recommended in inflammation, bronchitis, rheumatism and mascular pain, asthma, cough, and bleeding piles	salad, sprouts, and spicy seasoning	The wealth of India-A dictonary of Indian Raw materials and industrial products, Council of scientific and industrial Research, NewDelhi, Vol VI, 1963, PP.70-73; Nadkarni, et al., 1954, Indian Materia Medica Sidhu et al., 2011; Painuli et al., 2022
302.	**Gonglu, Shalgam, Turnip**	*Brassica rapa*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Brassicales Family Brassicaceae Genus Brassica L. Species Brassica rapa	Asia: China, India; Africa; North America; South America.	Mono-, di-,tri- and tetraglucosides of quercetin, kaempferol and isorhamnetin as well as esters of hydroxycinnamic acids with malic acid, glycosides, and quinic acid, isorhamnetin derivatives; kaempferol 3-O-sophoroside-7-Oglucoside, kaempferol 3-O-(feruloyl/caffeoyl)-sophoroside-7-O-glucoside, kaempferol 3,7-di-Oglucoside, isorhamnetin 3,7-O-diglucoside and sinapic acid; kaempferol 3,7-di-O-glucoside, kaempferol-3-Oglucoside, isorhamnetin 3,7-O-diglucoside and hydroxycinnamoyl gentiobiosides, being kaempferol-3-O-glucoside and quercetin-3-O-(sinapoyl)-sophotrioside-7-O-glucoside	Moisture (%) 93.56 Protein 1.41 Ash 1.1 Total Fat 1.91 Soluble Dietary Fibre 0.47 Insoluble dietary fibre 1.44 Carbohydrate 1.78 Energy (KJ) 67	Reduces acne, pimples, and cooling agent as well. Paste of crushed leaves is applied on burnt skin; anticancer and moderate antioxidant activity against human lung cancer; headaches, chest complaints, rheumatisms, oedemas, gonorrhoea, syphilis, and rabies; antitumor, antihypertensive, antidiabetic, antioxidant, antiinflammatory, hepatoprotective, and nephroprotective effects	Young turnip leaves boiled with salt and eaten as spinach, Take leaves, seed and then ground it to make powder. This power is recommende d for cancer treatmen	Ali et al., 2020; Cartea et al., 2010; Rahman et al., 2022; Paul et al., 2019

303.	**Common Name:** Kenaf, Deccan Hemp, Brown Indian Hemp **,** **Hindi:** Patsan, San **Manipuri**: Sougri **Marathi:** Ambari **Tamil:** Palungu, Pulimanji **Malayalam:** Kanjaru **Telugu:** Pimdikura, Gonkura **Kannada:** Pundi,Gogu Pundrike Holada Pundrike, Dirin Da Ran**i** **Bengali:** Patsan, Ambari **Oriya:** Kanuriya **Konkani:** Ambadi **Gujarati:** Sheria **Sanskrit:** Machika, Maryurika, Ambika, Sahasravatamulika	*Hibiscus cannabinus*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Malvales Family Malvaceae Genus Hibiscus L. Species Hibiscus cannabinus L.	African origin; in most countries south of the Sahara, but greatest morphological diversity is found in East Africa, southern Asia	Diterpenes (36.18%), (E)-phytol (28.16%) and (Z)-phytol (8.02%). Aldehydes (20.32%), n-nonanal (5.70%), benzene acetaldehyde (4.39%), (E)-2-hexenal (3.10%), and 5-methylfurfural (3.00%), Caffeic acid, Chlorogenic acid, Tannic acid, Cryptochlorogenic acid, Kaempferol, Catechin hydrate, Kaempferol glycoside, Afzelin, Isoquercitrin, Kaempferitrin, Naringin, Tiliroside, Z-phytol, 2-Pentadecanone, 6,10,14-trimethyl, 2,6,10,14,18,22-Tetracosahexaene, Hydroxycitric acid, Methoxycitric acid, Tetradecanoic acid, Hexadecanoic acid, 9-Octadecenoic acid, 9,12-Octadecadienoic acid, 9,12,15-Octadecatrienoic acid,	Moisture (%) 74.2 Protein 24 Ash 6.30 Total Fat 4.2 Crude Fibre 13 Ca (mg) 214 P(mg) 39 K (mg) 157 Mg (mg) 30 Zn (mg) 16.2 Fe (mg) 34	Treat Guineaworm sores, dysentery, bilious, blood and throat disorder, cataract, ulcer, showed antisecretory activity, anaemia and fatigue, antibacterial, antitumor, anti-inflammatory, hepatoprotective, antiulcer, antityrosinase, antihyperlipidemia, and antioxidant activities.	food additives, sed as a potherb or added to soups. The leaves have an acid flavour like sorrel	Kobaisy et al., 2001 Silambujan aki et al., 2010; Sim et al., 2021;
304.	**Common Name:** Betel Vine, Betel **Hindi:** Paan, Nagar-Bel **Kannada:** Veeleya,Veeleyada Ele Taamboola **,** **Malayalam:**Beetla, Vettila**,** **Manipuri:** Kwa **Marathi:** Khavayache-Pan, Naagavaela **Nepali:** Paan **Sanskrit:** Tambula, Nagavalli **Tamil:** Vettilai, Akilatam, Vetrilai **Urdu:** Desi Paan **Mizo:** Panruang	*Piper betle*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Magnolianae Order Piperales Family Piperaceae Genus Piper L. Species Piper betle L.	East Africa and tropical countries of Asia	Phenylpropene compounds, eugenol acetate and eugenol, chavibetol (22.0%), estragole (15.8%), β-cubebene (13.6%), chavicol (11.8%), and caryophyllene (11.3%), Eugenol (63.39%) and acetyleugenol (14.05%), Eugenol (36.2%), chavibetol acetate (16.9%), 4-allylphenyl acetate (9.4%) and 4-allylphenol, chavibetol (53.1%), chavibetol acetate (15.5%), allypyrocatechol diacetate (0.71%), camphene (0.48%), chavibetol methyl ester (methyl eugenol 0.48%), eugenol (0.32%), ß-pinene (0.21%), a-limonene (0.14%), safrole (0.11%), 1,8-cineole (0.04%) and allypyrocatechol monoacetate, Eugenol, hydroxychavicol, safrole, β-phellandrene, 4-terpineol, eugenol, chavitol acetate, allylpyrocatechol diacetate, 4-allyl-2-methoxy-phenolacetate (31.47%), 3-allyl-6-methoxyphenol (25.96%), and 4-allylpheny acetate (5.21%)	Moisture(%) 85-90 Protein 3-3.5 Fat 0.4-1.0 Minerals 2.3-3.3 Fiber 2.30 Carbohydrate 0.5-6.10 Energy (kcal) 44 Iodine (µg) 3.4 Iron 0.005-0.007 Calcium 0.2-0.5 Potassium 1.1-4.6 Nicotinic acid(mg) 0.63-0.89 Vitamin C 0.005-0.01 Vitamin A(mg) 1.9-2.9 Thiamine(µg) 13-70 Riboflavin 1.9-30 Phosphorus 0.05-0.6	Anthelmintic, antibacterial, antifungal, antiseptic, aphrodisiac, astringent, carminative, expectorant, galactofuge, laxative, sialagogue, stimulant, stomachic and tonic. Leaf preparations and the leaf sap are applied to wounds, ulcers, boils and bruises. Heated leaves are used as a poultice on the chest against cough and asthma, on the breasts to stop milk secretion, and on the abdomen to relieve constipation. leaves are used to treat nosebleed, ulcerated noses, gums and mucous membranes, while the extract from the leaves is applied for wounds in the ears and as an infusion for the eye. A decoction of the leaves is used for bathing a woman after childbirth or is drunk to lessen an unpleasant body odour. The essential oil obtained from the leaves is antibacterial and antifungal. It has shown anthelmintic activity against tapeworms and hookworms. It has been used to treat affections of the mucous membrane of the nose, throat and respiratory organs.	mixture of betel leaves and other ingredients is used as a masticatory, which acts as a gentle stimulant and is taken after meals to sweeten the b	Shah et al., 2016 Madhumita et al., 2020
305.	**Common Name:** Beet Greens	*Beta vulgaris*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Caryophyllanae Order Caryophyllales Family Amaranthaceae Genus Beta L. Species Beta vulgaris L	eastern Mediterranean or the Middle East, can be found in all African countries, more in the cooler parts of East and southern Africa	vitexin, a C-glycoside of apigenin, orientin, the luteolin analog of vitexin, lutexin, barbaloin, deoxyvitexin,Vitexin, glucoside of quercctin	Moisture (%) 86.68 Protein 2.38 Ash 2.69 Total Fat 0.75 Soluble Dietary Fibre 3.64 Insoluble dietary fibre 1.43 Carbohydrate 3.86 Energy (KJ) 145	Stomach troubles, reduced fasting blood glucose levels, antioxidant, anti-inflammatory and anti-carcinogenic properties, gastrointestinal health	Cooked as vegetables	Al-Qura'n, 2005; Gardner et al., 1967; de Oliveira et al., 2021

306.	**Common Name:** Brussels Sprout	*Brassica oleracea L. var. gemmifera*		Kingdom Plantae Subkingdom Tracheobionta Superdivision Spermatophyta Division Magnoliophyta Class Magnoliopsida Subclass Dilleniidae Order Capparales Family Brassicaceae Genus Brassica L. Species Brassica oleracea Variety Brassica oleracea L. var. gemmifera DC. - brussels sprouts	West and Mid Europe, Japan, and North America	Glucoiberin, Glucoraphanin, Progoitrin, Gluconapin, Sinigrin, Glucoalysin, Glucobrassicin, Neoglucobrassicin, 4-Methoxyglucobrassicin, Myristic acid, Pentadecanoic acid, Palmitic acid, Heptadecanoic acid, Stearic acid, Palmitoleic acid, Margaroleic acid, Oleic acid, Vaccenic acid, Linoleic acid, α-Linolenic acid, cis-11, 14-Eicosadienoic acid, Arachidonic acid, Docosahexaenoic acid	Moisture(%) 84.07 Ash 1.13 Protein 3.45 Crude Fat 0.30 Dietary Fiber 5.26 Digestible Carbohydrates 5.76	Cancers of the stomach, lungs, kidney, breast, bladder, and prostate, high blood pressure, high cholesterol, heart disease, and diabetes	eaten raw in salads, cabbage flavour when cooked	Tian et al., 2005; Doniec et al., 2022 .
307.	**Common Name:**; Collard Greens, Kashmir, The Famous Haak Or Karam Saag	*Brassica oleracea var. viridis*		Kingdom Plantae Subkingdom Tracheobionta Superdivision Spermatophyta Division Magnoliophyta Class Magnoliopsida Subclass Dilleniidae Order Capparales Family Brassicaceae Genus Brassica L. Species Brassica oleracea Variety Brassica oleracea var. viridis	origin of Brussels sprouts lies in Belgium, spread from there to the rest of north-western Europe, where it is an important autumn and winter crop	caffeic acid, ferulic acid, quercetin, kaempferol, and isorhamnetin	Moisture (%) 89.62 Protein 3.02 Fat 0.61 Carbohydrate 5.42 Energy (kcal) 32 Ca (mg) 232 Fe 0.47 Mg 27 P 25 K 213 Na 17 Zn 0.21 Vitamin C 35.3 Thiamin 0.054 Riboflavin 0.130 Niacin 0.742 Vitamin B 60.165 Folate (µg) 129 Vitamin A(µg) 251 Vitamin E (mg) 2.26 Vitamin K(µg) 437.1	Diabetes, antioxidant, anticancer, cardiovascular system protection, gastrointestinal system protection	Cooked as vegetables, the leaves and the roots are fermented to form haak-e-aanchaar, a popular pickle	Huang et al., 2007; AŠamec et al., 2019
308.	**Common Name:** Red Cabbage	*Brassica oleracea var. capitata rubra*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Brassicales Family Brassicaceae Genus Brassica Species oleracea Variety Brassica oleracea var. capitata rubra	all of Europe, North America, Asia, China, Brazil, South Africa, Japan, and many other countries of Asia and Africa	1,5-Pentanediol, Phenol, 2,4-Bis(1,1-Dimethylethyl), 1-Heptadecanamine, N,NDimethyl, Hexadecanoic Acid, Ethyl Ester, 1-Tetradecanol, cyanidin 3-diglucoside-5-glucoside, cyanidin 3-(sinapoyl)-diglucoside-5-glucoside, cyanidin 3-(sinapoyl)(sinapoyl)-diglucoside-5-glucoside, cyanidin 3-(feruloyl)(sinapoyl)-diglucoside-5-glucoside, cyanidin 3-(p-coumaroyl)(sinapoyl)-diglucoside-5-glucoside, cyanidin 3-(sinapoyl)-glucoside-5-glucoside, cyanidin 3-(sinapoyl)-diglucoside-5-glucoside, cyanidin 3-(feruloyl)-diglucoside-5-glucoside, cyanidin 3-(p-coumaroyl)-diglucoside-5-glucoside, cyanidin 3-(sinapoyl)(sinapoyl)-triglucoside-5-glucoside, cyanidin 3-(caffeoyl)-diglucoside-5-glucoside, cyanidin 3-(feruloyl)(sinapoyl)-triglucoside-5-glucoside, cyanidin 3-(p-coumaroyl)(sinapoyl)-triglucoside-5-glucoside, cyanidin 3-(sinapoyl)-diglucoside-5-glucoside	Moisture(%) 91.94 Protein 1.39 Ash 0.71 Total fat 0.21 Insoluble dietary fibre 1.58 Soluble dietary fibre 0.62 Carbohydrate 3.54 Energy (KJ) 97	gastrointestinal disorders such as gastritis, peptic and duodenal ulcers, and irritable bowel syndrome, as well as wounds and mastitis, Antioxidant, Anticarcinogenic, Antiinfammatory	added to soups, stews, salads, and coleslaw. It's delicious raw, steamed, sauteed, and fermented. It retains the most nutrients when it's eaten raw,	Lee et al., 2018; Rajamani et al., 2018; Zielińska et al., 2015

309	**Common Name:** Cauliflower	*Brassica oleracea var. botrytis*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Brassicales Family Brassicaceae Genus Brassica Species oleracea Variety Brassica oleracea var. botrytis	Native of Europe	Methyl apigenin, Catechin, Chlorogenic acid	Moisture(%) 87.64 Protein 3.9 Ash 1.22 Total fat 0.42 Insoluble dietary fibre 2.37 Soluble dietary fibre 1.06 Carbohydrate 3.39 Energy (KJ) 148	Laxative, inflammation, anticancer, antioxidant and neuro-degenerative disease, Control diabetes	chopped cauliflower leaves and then cooked properly	Ali et al., 2020; Mariam et al., 2015
310.	**Commom Name:** Knol-Knol, Leaves	*Brassica oleracea var. gongylodes*		Kingdom Plantae Subkingdom Viridiplantae Infrakingdom Streptophyta Superdivision Embryophyta Division Tracheophyta Subdivision Spermatophytina Class Magnoliopsida Superorder Rosanae Order Brassicales Family Brassicaceae Genus Brassica Species oleracea Variety Brassica oleracea var. gongylodes	Europe	sulfur compounds (dimethyl trisulfide, methyl 2-methyl-3-furyl disulfide, and three isothiocyanates (1-isothiocyanato-3-(methylsulfanyl)propane, benzyl isothiocyanate, and 1-isothiocyanato-4-(methylsulfanyl)butane)), two lipid oxidation products (1-octen-3-one and trans-4,5-epoxy-(2E)-dec-2-enal), and 2-isopropyl-3-methoxypyrazine	Moisture(%) 86.2 Protein 3.12 Ash 1.42 Total fat 0.35 Insoluble dietary fibre 1.81 Soluble dietary fibre 0.95 Carbohydrate 6.16 Energy (KJ) 178	Diabetes, colon cancer prevention	Cooked as vegetables	Esakkimuthu et al., 2018; Sahani et al., 2013; Noor et al., 2023; Marcinkowska et al., 2021

Appendix A.2 Proximate composition and micro constituents of 34 leafy vegetables

Table A.1 Proximate composition

Sl. No	Common Name	Scientific name	Moisture (g)	Protein (g)	Ash (g)	Total Fat (g)	Total Crude Fibre	Dietary Fibre (g) Insoluble	Dietary Fibre (g) Soluble	Carbohydrate (g)	Energy (KJ)
1.	Agathi leaves	*Sesbania grandiflora*	74.43	8.01	2.42	1.35	8.6	6	2.6	5.21	295
2.	Amaranth leaves, green	*Amaranthus gangeticus*	86.85	3.29	2.52	0.65	4.41	3.21	1.2	2.28	128
3.	Amaranth leaves, red	*Amaranthus gangeticus*	85.56	3.93	2.61	0.63	4.91	3.72	1.19	2.37	140
4.	Amaranth leaves, red and green mix	*Amaranthus gangeticus*	86.37	3.09	2.55	0.53	4.6	3.23	1.37	2.87	132
5.	Amaranth spined, leaves, green	*Amaranthus spinosus*	86.37	3.54	2.94	0.36	5.1	3.89	1.2	1.61	110
6.	Amaranth spined, leaves, red and green mix	*Amaranthus spinosus*	86.64	2.8	3.2	0.34	5.57	3.82	1.75	1.45	99
7.	Basella leaves	*Basella alba*	92.68	1.57	1.09	0.45	2.21	1.64	0.57	2.01	82
8.	Bathua leaves	*Chenopodium album*	88.77	2.5	1.71	0.44	4.01	2.34	1.68	2.56	116
9.	Beet greens	*Beta vulgaris*	86.68	2.38	2.69	0.75	3.64	2.2	1.43	3.86	145
10.	Betel leaves, big (Kolkata)	*Piper betle*	84.93	2.51	2.33	0.75	2.12	1.32	0.8	7.37	202
11.	Betel leaves, small	*Piper betle*	85.92	2.62	2.59	0.75	1.97	1.17	0.8	6.16	183
12.	Brussels sprouts	*Brassica oleracea var. gemmifera*	84.39	4.26	1.47	0.5	4.29	3.35	0.94	5.09	185
13.	Cabbage, Chinese	*Brassica rupa*	93.19	1.58	0.73	0.13	2.01	1.55	0.45	2.36	75
14.	Cabbage, collard greens	*Brassica oleracea var. viridis*	89.53	3.63	0.81	0.27	2.98	2.04	0.94	2.79	126
15.	Cabbage, green	*Brassica oleracea var. capitata f. alba*	91.85	1.36	0.67	0.12	2.76	1.91	0.85	3.25	90
16.	Cabbage, voilet	*Brassica oleracea var. capitata f. rubra*	91.94	1.39	0.71	0.21	2.21	1.58	0.62	3.54	97
17.	Cauliflower leaves	*Brassica oleracea var. botrytis*	87.64	3.9	1.22	0.42	3.43	2.37	1.06	3.39	148
18.	Colocasia leaves, green	*Colocasia esculenta*	83.61	3.42	2.3	1.38	5.6	4.32	1.29	3.69	182
19.	Drumstick leaves	*Moringa Oleifera*	75.65	6.41	2.46	1.64	8.21	6.12	2.1	5.62	282
20.	Fenugreek leaves	*Trigonella foenum graecum*	86.73	3.68	1.69	0.83	4.9	3.2	1.7	2.17	144
21.	Garden cress	*Lepidium sativum*	84.02	5.62	2.48	0.8	2.6	1.77	0.83	4.48	208
22.	Gogu leaves, green	*Hibiscus cannabinus*	87.42	1.86	0.98	1.09	4.59	3.24	1.35	4.06	152
23.	Gogu leaves, red	*Hibiscus cannabinus*	87.98	1.85	0.97	1.07	3.89	2.66	1.23	4.24	153
24..	Knol-Knol, leaves	*Brassica oleracea var. gongylodes*	86.2	3.12	1.42	0.35	2.76	1.81	0.95	6.16	178
25.	Lettuce	*Lactuca sativa*	92.27	1.54	1.11	0.27	1.79	1.32	0.47	3.01	91
26.	Mustard leaves	*Brassica juncea*	88.17	3.52	1.47	0.51	3.92	3.04	0.87	2.41	127
27.	Pak Choi leaves	*Brassica rapa var. chinensis*	93.56	1.41	1.1	0.25	1.91	1.44	0.47	1.78	67
28.	Parsley	*Petroselinum crispum*	77.76	5.55	2.25	1.14	3.87	2.79	1.09	9.43	305
29.	Ponnaganni	*Alternanthera sessilis*	79.43	5.29	2.65	0.71	6.74	5.63	1.11	5.17	213
30.	Pumpkin leaves, tender	*Cucurbita maxima*	85.82	4.21	2.24	0.74	2.25	1.56	0.69	4.75	185
31.	Radish leaves	*Raphanus sativus*	91.19	2.22	1.5	0.51	1.82	1.18	0.63	2.77	109
32.	Rumex leaves	*Rumex patientia*	93.18	1.62	1.27	0.33	1.27	0.93	0.34	2.33	82
33.	Spinach	*Spinacia oleracea*	90.31	2.14	2.47	0.64	2.38	1.52	0.86	2.05	102
34.	Tamarind leaves, tender	*Tamarindus indica*	71.69	5.84	1.25	0.49	10.7	9.34	1.36	10.04	299

Table A.2 Water Soluble Vitamins

Sl. No	Common name	Scientific name	Thiamine (B1), mg	Riboflavin (B2), mg	Niacin (B3), mg	Pantothenic Acid (B5), mg	Total B6, mg	Biotin (B7), µg	Total Folates (B9), µg	Total Ascorbic Acid, mg	Total Water Soluble Vitamins (mg)
1.	Agathi leaves	*Sesbania grandiflora*	0.26	0.33	1.18	0.53	0.22	7.75	120	121	123.65
2.	Amaranth leaves, green	*Amaranthus gangeticus*	0.01	0.19	0.71	0.41	0.21	2.46	70.33	83.54	85.14
3.	Amaranth leaves, red	*Amaranthus gangeticus*	0.01	0.269	0.62	0.37	0.22	2.95	81.95	86.2	87.77
4.	Amaranth leaves, red and green mix	*Amaranthus gangeticus*	0.01	0.22	0.69	0.37	0.19	2.41	69.08	77.24	78.79
5.	Amaranth spined, leaves, green	*Amaranthus spinosus*	0.01	0.13	0.63	0.33	0.22	3.07	41.44	82.56	83.92
6.	Amaranth spined, leaves, red and green mix	*Amaranthus spinosus*	0.01	0.15	0.72	0.31	0.2	2.91	44.23	77.3	78.74
7.	Basella leaves	*Basella alba*	0.06	0.15	0.46	0.48	0.18	1.07	90.31	63.35	64.77
8.	Bathua leaves	*Chenopodium album*	0.06	0.51	0.54	0.41	0.17	1.25	42.55	41.03	42.76
9.	Beet greens	*Beta vulgaris*	0.02	0.17	0.43	0.29	0.13	4.66	11.52	35.83	36.89
10.	Betel leaves, big (Kolkata)	*Piper betle*	0.03	0.08	0.45	0.51	0.04	2.18	15.96	18.4	19.53
11.	Betel leaves, small	*Piper betle*	0.02	0.07	0.47	0.47	0.04	1.28	16.56	24.51	25.60
12.	Brussels sprouts	*Brassica oleracea var. gemmifera*	0.06	0.16	0.5	0.47	0.19	2.45	85.01	89.45	90.92
13.	Cabbage, Chinese	*Brassica rupa*	0.01	0.05	0.38	0.58	0.19	1.08	54.51	19.32	20.59
14.	Cabbage, collard greens	*Brassica oleracea var. viridis*	0.03	0.05	0.26	0.49	0.24	1.38	63.46	40.76	41.89
15.	Cabbage, green	*Brassica oleracea var. capitata f. alba*	0.03	0.05	0.24	0.24	0.13	1.41	46.36	33.25	33.99
16.	Cabbage, voilet	*Brassica oleracea var. capitata f. rubra*	0.04	0.05	0.27	0.25	0.17	1.43	34.81	43.49	44.31
17.	Cauliflower leaves	*Brassica oleracea var. botrytis*	0.05	0.05	0.21	0.34	0.23	1.38	42.99	52.84	53.76
18.	Colocasia leaves, green	*Colocasia esculenta*	0.08	0.07	0.8	0.27	0.29	12.1	159	40.71	42.39
19.	Drumstick leaves	*Moringa Oleifera*	0.06	0.45	0.82	0.39	0.87	2.26	42.89	108	110.64
20.	Fenugreek leaves	*Trigonella foenum graecum*	0.11	0.22	0.7	0.49	0.38	4.82	75.26	58.25	60.23
21.	Garden cress	*Lepidium sativum*	0.03	0.06	1.2	0.22	0.2	12.01	58.1	42.75	44.53
22.	Gogu leaves, green	*Hibiscus cannabinus*	0.13	0.06	0.58	0.7	0.33	3.38	74.94	29.65	31.53
23.	Gogu leaves, red	*Hibiscus cannabinus*	0.12	0.05	0.56	0.71	0.31	3.43	88.63	35.43	37.27
24..	Knol-Knol, leaves	*Brassica oleracea var. gongylodes*	0.06	0.15	0.86	0.27	0.28	13.57	41.55	71.11	72.79
25.	Lettuce	*Lactuca sativa*	0.05	0.09	0.17	0.11	0.08	2.15	30.69	11.91	12.44
26.	Mustard leaves	*Brassica juncea*	0.08	0.18	0.58	0.26	0.16	1.7	110	60.32	61.69
27.	Pak Choi leaves	*Brassica rapa var. chinensis*	0.02	0.22	0.66	0.31	0.96	10.25	98.5	55.6	57.88
28.	Parsley	*Petroselinum crispum*	0.19	0.1	0.36	0.2	0.19	13.47	197	133	134.25
29.	Ponnaganni	*Alternanthera sessilis*	0.02	0.1	0.32	0.21	0.19	11.18	48.42	103	103.90
30.	Pumpkin leaves, tender	*Cucurbita maxima*	0.07	0.13	1.49	0.36	0.17	3.4	33.82	12.33	14.59
31.	Radish leaves	*Raphanus sativus*	0.06	0.13	0.47	0.14	0.16	4.39	53.14	65.76	66.78
32.	Rumex leaves	*Rumex patientia*	0.03	0.14	0.33	0.25	0.09	1.3	41.01	53.76	54.64
33.	Spinach	*Spinacia oleracea*	0.16	0.1	0.33	0.22	0.15	4.14	142	30.28	31.39
34.	Tamarind leaves, tender	*Tamarindus indica*	0.12	0.03	0.79	0.3	0.14	3.29	91.82	28.22	29.70

Table A.3 Fat Soluble Vitamins

Sl. No	Common name	Scientific name	Ergocalciferol (D2), mg	Tocopherols, mg				Tocotrienols, mg				α-Tocopherol Eq, mg	Phyloquinones (K1), µg	Total Oil soluble vitamin mg
				Alpha	Beta	Gamma	Delta	Alpha	Beta	Gamma	Delta			
1.	Agathi leaves	*Sesbania grandiflora*	4.02	1.48	0.22	0.18		0.60		0.18		1.77	0.27	8.72
2.	Amaranth leaves, green	*Amaranthus gangeticus*	16.01	0.41		0.26						0.44	0.28	17.40
3.	Amaranth leaves, red	*Amaranthus gangeticus*	15.10	0.44		0.21						0.46	0.31	16.52
4.	Amaranth leaves, red and green mix	*Amaranthus gangeticus*	15.25	0.42		0.25						0.45	0.28	16.65
5.	Amaranth spined, leaves, green	*Amaranthus spinosus*	15.23	0.28		0.03						0.28	0.44	16.26
6.	Amaranth spined, leaves, red and green mix	*Amaranthus spinosus*	15.04	0.28		0.04						0.28	0.45	16.09
7.	Basella leaves	*Basella alba*	9.18	0.15		0.04		0.03				0.16	0.24	9.80
8.	Bathua leaves	*Chenopodium album*	1.01	0.25								0.25	0.22	1.73
9.	Beet greens	*Beta vulgaris*	1.65	0.15	0.17							0.21	0.07	2.25
10.	Betel leaves, big (Kolkata)	*Piper betle*	3.78	0.04		0.05		0.02				0.05	0.21	4.15
11.	Betel leaves, small	*Piper betle*	2.27	0.02		0.05		0.02				0.03	0.20	2.59
12.	Brussels sprouts	*Brassica oleracea var. gemmifera*	0.26	0.21								0.21	0.02	0.70
13.	Cabbage, Chinese	*Brassica rupa*	0.39	0.25								0.25	0.11	1.00
14.	Cabbage, collard greens	*Brassica oleracea var. viridis*	0.18	0.20								0.20	0.13	0.71
15.	Cabbage, green	*Brassica oleracea var. capitata f. alba*	0.21	0.05								0.05	0.11	0.42
16.	Cabbage, voilet	*Brassica oleracea var. capitata f. rubra*	0.19	0.03								0.03	0.12	0.37
17.	Cauliflower leaves	*Brassica oleracea var. botrytis*	4.15	0.08			0.11					0.08	0.14	4.56
18.	Colocasia leaves, green	*Colocasia esculenta*	1.70	0.07								0.07	0.32	2.16
19.	Drumstick leaves	*Moringa Oleifera*	14.33	0.30		0.05		0.02				0.31	0.48	15.49
20.	Fenugreek leaves	*Trigonella foenum graecum*	2.36	0.36								0.36	0.43	3.51
21.	Garden cress	*Lepidium sativum*	0.55	0.74								0.74	0.46	2.49
22.	Gogu leaves, green	*Hibiscus cannabinus*	4.28	0.46		0.43						0.50	0.43	6.10
23.	Gogu leaves, red	*Hibiscus cannabinus*	4.27	0.47		0.32						0.50	0.44	6.00
24.	Knol-Knol, leaves	*Brassica oleracea var. gongylodes*	0.59	0.53								0.53	0.30	1.95
25.	Lettuce	*Lactuca sativa*	0.10	0.01								0.01	0.09	0.21
26.	Mustard leaves	*Brassica juncea*	5.40	0.56		0.02						0.57	0.19	6.74
27.	Pak Choi leaves	*Brassica rapa var. chinensis*	0.10	0.03								0.03	0.04	0.20
28.	Parsley	*Petroselinum crispum*	5.55	0.35								0.35	0.32	6.57
29.	Ponnaganni	*Alternanthera sessilis*	0.65	0.52	0.02			0.04				0.54	0.57	2.34
30.	Pumpkin leaves, tender	*Cucurbita maxima*	3.19	1.24	0.28	3.25		0.02	0.03			1.69	0.24	9.94
31.	Radish leaves	*Raphanus sativus*	1.39	0.06	0.04							0.08	0.19	1.76
32.	Rumex leaves	*Rumex patientia*	0.10	0.46	0.03	0.45	0.18					0.51	0.13	1.86
33.	Spinach	*Spinacia oleracea*	0.26	1.27	0.01	0.06	0.03					1.29	0.33	3.25
34.	Tamarind leaves, tender	*Tamarindus indica*	2.62	0.69		1.18						0.81	0.25	5.55

Table A.4 Theoretical calculation of concentration of carotenoids composition in LVs

Sl. No	Common Name	Scientific Name	Zeaxanthin (mM)	beta-carotene (mM)	Lutein (mM)
1.	Agathi leaves	*Sesbania grandiflora*	13.20	314.86	305.64
2.	Amaranth leaves, green	*Amaranthus gangeticus*	3.32	183.43	169.96
3.	Amaranth leaves, red	*Amaranthus gangeticus*	2.42	184.10	152.84
4.	Amaranth leaves, red and green mix	*Amaranthus gangeticus*	3.01	182.53	150.41
5.	Amaranth spined, leaves, green	*Amaranthus spinosus*	2.56	34.37	37.88
6.	Amaranth spined, leaves, red and green mix	*Amaranthus spinosus*	3.25	31.97	35.47
7.	Basella leaves	*Basella alba*	4.57	49.70	56.18
8.	Bathua leaves	*Chenopodium album*	2.61	22.56	35.55
9.	Beet greens	*Beta vulgaris*	2.96	36.59	30.32
10.	Betel leaves, big (Kolkata)	*Piper betle*	1.25	91.80	88.03
11.	Betel leaves, small	*Piper betle*	1.63	101.37	118.32
12.	Brussels sprouts	*Brassica oleracea var. gemmifera*	0.74	7.95	34.43
13.	Cabbage, Chinese	*Brassica rupa*	0.03	0.11	1.09
14.	Cabbage, collard greens	*Brassica oleracea var. viridis*	0.05	2.16	2.81
15.	Cabbage, green	*Brassica oleracea var. capitata f. alba*	0.00	0.42	0.08
16.	Cabbage, voilet	*Brassica oleracea var. capitata f. rubra*	0.04	0.63	0.85
17.	Cauliflower leaves	*Brassica oleracea var. botrytis*	0.04	3.10	3.05
18.	Colocasia leaves, green	*Colocasia esculenta*	2.86	128.27	109.79
19.	Drumstick leaves	*Moringa Oleifera*	5.46	431.90	362.03
20.	Fenugreek leaves	*Trigonella foenum graecum*	0.57	198.54	46.11
21.	Garden cress	*Lepidium sativum*	0.35	1.97	28.33
22.	Gogu leaves, green	*Hibiscus cannabinus*	0.38	112.60	106.09
23.	Gogu leaves, red	*Hibiscus cannabinus*	0.41	108.88	95.55
24.	Knol-Knol, leaves	*Brassica oleracea var. gongylodes*	0.06	0.26	0.32
25.	Lettuce	*Lactuca sativa*	0.11	25.94	35.40
26.	Mustard leaves	*Brassica juncea*	0.16	55.33	58.60
27.	Pak Choi leaves	*Brassica rapa var. chinensis*	0.10	48.77	49.88
28.	Parsley	*Petroselinum crispum*	0.27	64.91	80.80
29.	Ponnaganni	*Alternanthera sessilis*	2.32	124.00	115.10
30.	Pumpkin leaves, tender	*Cucurbita maxima*	0.93	31.58	125.75
31.	Radish leaves	*Raphanus sativus*	0.44	52.92	33.56
32.	Rumex leaves	*Rumex patientia*	0.36	55.05	44.71
33.	Spinach	*Spinacia oleracea*	0.34	53.73	74.94
34.	Tamarind leaves, tender	*Tamarindus indica*	0.05	4.36	1.44

Table A.5 Mineral Composition

Sl. No.	Common Name	Scientific Name	Mg (mg)	Mn (mg)	Mo (µg)	Ni (µg)	P (mg)	K (mg)	Na (mg)	Zn (mg)	Al (mg)	Cd (µg)	Ca (mg)	Cr (µg)	Co (µg)	Cu (µg)	Pb (µg)	Fe (mg)	Li (µg)	Hg (µg)	As (µg)	Se (µg)
1.	Agathi leaves	*Sesbania grandiflora*	54.10	0.30	0.42	15.56	22.76	231.60	10.58	0.11	0.00	0.12	301.88	0.00	1.59	52.90	0.84	1.05	0.00	0.03	0.70	5.22
2.	Amaranth leaves, green	*Amaranthus gangeticus*	93.07	0.26	2.88	3.33	27.20	168.44	8.05	0.15	1.67	0.20	94.75	5.98	0.98	38.08	0.22	0.96	14.93	0.00	0.00	3.06
3.	Amaranth leaves, red	*Amaranthus gangeticus*	86.20	0.46	1.58	5.18	28.65	168.59	7.41	0.24	1.31	0.21	71.41	6.29	4.56	40.49	0.00	1.52	15.16	0.00	0.00	3.34
4.	Amaranth leaves, red and green mix	*Amaranthus gangeticus*	70.43	0.30	1.21	5.92	25.48	176.78	8.83	0.18	1.54	0.21	77.67	5.34	2.35	31.00	0.22	1.10	11.68	0.00	0.00	3.17
5.	Amaranth spined, leaves, green	*Amaranthus spinosus*	97.45	0.23	3.86	4.73	27.06	168.49	7.88	0.28	1.23	0.00	103.65	7.79	0.39	41.94	0.06	1.32	13.35	0.00	0.00	4.25
6.	Amaranth spined, leaves, red and green mix	*Amaranthus spinosus*	89.93	0.39	2.52	3.93	31.65	173.57	8.16	0.20	1.54	0.00	107.07	6.21	0.98	59.98	0.06	0.95	23.28	0.00	0.00	2.84
7.	Basella leaves	*Basella alba*	68.79	0.25	0.67	8.09	12.97	93.00	8.79	0.06	1.07	0.19	25.26	9.54	1.10	20.39	0.31	0.81	9.33	0.00	0.40	0.84
8.	Bathua leaves	*Chenopodium album*	22.72	0.32	0.35	1.54	13.65	126.19	5.27	0.17	0.00	0.10	59.28	0.00	0.19	17.74	0.05	0.54	0.00	0.01	0.12	0.20
9.	Beet greens	*Beta vulgaris*	57.68	0.24	4.33	3.93	13.40	156.38	55.68	0.03	0.00	1.03	43.44	0.00	0.78	25.44	0.61	1.20	0.00	0.01	0.54	6.97
10.	Betel leaves, big (Kolkata)	*Piper betle*	52.49	0.55	0.49	10.03	19.65	195.44	8.60	0.08	0.88	0.21	60.78	5.89	0.60	44.50	0.28	0.63	20.36	0.01	0.18	1.81
11.	Betel leaves, small	*Piper betle*	43.62	0.38	0.24	8.53	20.92	201.82	7.10	0.07	0.80	0.00	56.89	4.25	0.39	53.15	0.22	0.60	8.39	0.00	0.26	0.80
12.	Brussels sprouts	*Brassica oleracea var. gemmifera*	16.29	0.09	1.60	2.42	37.67	193.66	9.54	0.10	0.00	0.11	15.95	0.46	0.20	14.93	0.23	0.33	0.00	0.00	0.09	0.30
13.	Cabbage, Chinese	*Brassica rupa*	5.15	0.04	0.00	0.00	11.44	70.81	9.46	0.03	0.00	0.00	15.64	0.21	0.00	8.45	0.00	0.07	0.00	0.00	0.00	0.25
14.	Cabbage, collard greens	*Brassica oleracea var. viridis*	21.36	0.26	0.47	5.71	19.70	83.41	11.16	0.06	0.95	0.10	47.35	0.21	0.38	10.55	0.00	0.53	6.44	0.00	0.00	0.33
15.	Cabbage, green	*Brassica oleracea var. capitata f. alba*	8.16	0.04	0.23	1.67	10.59	64.88	7.09	0.03	0.00	0.00	14.05	0.84	0.18	5.14	0.00	0.07	1.57	0.00	0.00	0.15
16.	Cabbage, voilet	*Brassica oleracea var. capitata f. rubra*	12.18	0.00	0.23	0.74	7.77	55.91	11.35	0.02	0.00	0.00	13.02	0.84	0.37	3.43	0.00	0.05	1.57	0.00	0.00	0.15
17.	Cauliflower leaves	*Brassica oleracea var. botrytis*	19.73	0.10	0.71	2.53	23.12	109.14	12.06	0.05	0.19	0.10	27.52	3.07	27.08	434.85	0.00	0.00	4.93	0.00	0.00	0.15
18.	Colocasia leaves, green	*Colocasia esculenta*	29.62	0.28	1.87	5.30	22.33	123.58	6.28	0.15	0.00	0.11	64.42	0.92	0.61	54.62	0.40	0.73	0.00	0.01	0.44	0.65
19.	Drumstick leaves	*Moringa Oleifera*	53.48	0.30	4.96	5.40	46.48	134.22	5.37	0.15	0.56	0.12	103.51	5.08	0.00	91.59	0.26	1.08	36.19	0.00	0.28	1.00
20.	Fenugreek leaves	*Trigonella foenum graecum*	30.59	0.18	2.04	6.68	19.73	66.64	23.57	0.10	0.86	0.10	78.78	8.65	1.17	32.68	0.33	1.18	11.63	0.00	0.00	0.19
21.	Garden cress	*Lepidium sativum*	39.30	0.26	0.62	8.52	17.49	115.37	13.12	0.28	0.00	0.53	64.41	0.23	1.21	43.11	0.86	1.32	0.00	0.02	0.62	1.22
22.	Gogu leaves, green	*Hibiscus cannabinus*	39.60	0.42	1.43	9.74	15.49	76.07	6.14	0.11	0.97	0.00	41.36	13.42	0.78	41.43	0.00	1.57	8.24	0.00	0.00	0.34
23.	Gogu leaves, red	*Hibiscus cannabinus*	35.87	0.36	1.18	9.68	13.34	46.80	6.96	0.11	1.15	0.00	36.56	8.74	1.73	28.64	0.05	1.95	8.19	0.00	0.00	0.47
24..	Knol-Knol, leaves	*Brassica oleracea var. gongylodes*	31.90	0.15	12.69	3.56	20.59	91.68	13.52	0.07	0.00	0.41	106.46	0.00	0.98	12.79	0.34	0.52	0.00	0.02	1.23	1.54
25.	Lettuce	*Lactuca sativa*	19.52	0.07	0.45	1.85	15.42	77.33	8.26	0.08	0.36	0.29	15.33	4.17	0.37	23.89	0.21	0.53	12.49	0.00	0.21	0.76
26.	Mustard leaves	*Brassica juncea*	24.40	0.08	1.18	2.90	26.20	116.90	9.44	0.12	0.73	0.40	54.02	8.51	0.19	42.87	0.38	0.58	13.07	0.00	0.55	1.15
27.	Pak Choi leaves	*Brassica rapa var. chinensis*	20.17	0.07	2.23	4.37	8.95	68.34	15.67	0.03	1.25	294.59	39.98	5.76	0.36	10.10	0.72	0.72	7.70	0.00	0.47	0.11
28.	Parsley	*Petroselinum crispum*	26.35	0.21	2.01	9.42	32.59	153.27	29.68	0.25	0.00	0.80	92.36	0.25	0.44	38.48	3.23	1.27	0.00	0.03	0.69	1.67
29.	Ponnaganni	*Alternanthera sessilis*	42.17	0.15	0.26	8.79	23.66	147.15	21.54	0.19	0.00	0.45	121.82	0.48	2.99	41.64	0.49	0.88	0.00	0.02	0.45	2.74
30.	Pumpkin leaves, tender	*Cucurbita maxima*	40.88	0.24	3.76	5.36	24.26	126.06	6.18	0.16	2.03	0.10	78.75	11.88	0.99	53.22	0.62	1.17	15.11	0.00	0.00	0.20
31.	Radish leaves	*Raphanus sativus*	26.48	0.18	2.17	4.67	17.72	85.26	8.29	0.08	0.79	0.29	63.99	10.76	0.93	50.08	0.16	0.75	22.12	0.00	0.72	4.59
32.	Rumex leaves	*Rumex patientia*	21.61	0.16	1.68	3.66	11.22	92.22	9.31	0.08	1.25	0.10	35.06	9.91	0.36	42.25	0.26	0.71	10.82	0.03	0.39	0.73
33.	Spinach	*Spinacia oleracea*	40.13	0.23	0.92	4.72	11.64	177.00	20.48	0.08	0.62	0.00	22.72	5.96	0.38	29.64	0.05	0.59	74.99	0.00	0.00	0.29
34.	Tamarind leaves, tender	*Tamarindus indica*	24.47	0.16	0.00	0.00	39.08	165.89	8.14	0.20	0	0.00	23.28	0.54	0.00	123.01	0.00	0.71	0.00	0.00	0.00	0.43

Appendix A.3 Maximum possible (theoritical) concentration (nM) of various polyphenols in stomach (assuming 50 g of (fresh or unaltered) intake of the leafy vegetable at 100% liberation)

Scientific Name	3,4-Dihydroxy benzoic acid	3-Hydroxy benzaldehyde	Protocatechuic acid	Vannilic Acid	Gallic Acid	Cinamic Acid	O-Coumaric Acid	P-Coumaric Acid	Caffeic Acid	(-)-Epigallo catechin	(-)-Epigallo catechin 3-gallate	(+)-Catechin	(-)-Gallocatechin gallate	Syringic Acid	Sinapinic Acid	Ellagic Acid
Sesbania grandiflora	192	0	0	0	104	0	39	45	20	0	0	0	0	0	0	0
Amaranthus gangeticus	92	0	0	115	0	0	0	52	54	0	0	0	0	0	0	0
Amaranthus gangeticus	107	0	0	132	0	0	0	154	56	0	0	0	0	0	0	0
Amaranthus gangeticus	74	0	0	148	0	0	0	73	57	0	0	0	0	0	0	0
Amaranthus spinosus	0	0	0	0	0	0	0	66	402	0	0	0	0	0	0	0
Amaranthus spinosus	0	0	0	0	0	0	0	78	437	0	0	0	0	0	0	0
Basella alba	3	0	8	0	0	0	0	0	7	0	0	0	0	0	0	0
Chenopodium album	46	0	0	10	0	0	0	0	23	0	0	0	0	0	0	0
Beta vulgaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Piper betle	0	0	14	0	0	0	0	0	7	0	0	0	0	0	0	0
Piper betle	0	0	32	0	0	0	0	0	25	0	0	0	0	0	0	0
Brassica oleraceavar. gemmifera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassica rupa	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassica oleraceavar. viridis	3	0	0	0	0	0	0	0	286	0	0	0	0	0	0	0
Brassica oleraceavar. capitataf. alba	2	0	0	0	0	0	0	0	393	0	0	0	0	0	0	0
Brassica oleraceavar. capitataf. rubra	6	0	0	0	0	0	0	0	396	0	0	0	0	0	0	0
Brassica oleraceavar. botrytis	0	0	102	0	8	0	0	75	237	0	0	0	0	8	14	0
Colocasia esculenta	0	0	0	0	0	0	0	51	0	0	0	0	0	0	0	0
Moringa Oleifera	0	0	32	0	0	0	0	101	5	0	0	0	0	0	0	0
Trigonella foenum graecum	0	0	78	0	277	0	0	64	85	0	0	0	0	0	0	0
Lepidium sativum	0	0	0	0	0	0	0	5	4	0	0	0	0	0	0	0
Hibiscus cannabinus	0	0	0	0	0	0	0	44	50	0	0	0	0	0	0	0
Hibiscus cannabinus	0	0	0	0	0	0	0	55	60	0	0	0	0	0	0	0
Brassica oleraceavar. gongylodes	8	0	0	0	0	0	0	60	0	0	0	0	0	0	0	0
Lactucasativa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brassica juncea	0	0	0	0	0	0	0	265	165	0	0	0	0	0	0	0
Brassica rapa var. chinensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Petroselinum crispum	0	0	0	125	0	0	45	2	27	0	0	0	0	0	0	0
Alternantherasessilis	48	0	182	0	0	0	0	0	3	0	0	0	0	0	0	0
Cucurbita maxima	0	0	0	0	0	0	0	27	40	0	0	0	0	0	0	0
Raphanus sativus	0	0	162	0	4	0	0	28	41	0	0	0	0	260	15	0
Rumex patientia	0	0	0	0	0	0	0	11	76	0	0	0	0	0	0	0
Spinacia oleracea	0	0	262	0	0	0	0	468	0	0	0	0	0	0	0	0
Tamarindus indica	0	0	0	0	0	0	0	0	23	0	0	0	0	0	0	0

Scientific Name	Chlorogenic acid	Ferulic acid	Apigenin	Apigenin-6-C-glucoside	Apigenin-7-O-noehesperidoside	Luteolin	Kaempfero	Quercetin	Querecetin-3-β-D-glucoside	Querecetin-3-O-rutinoside	Querecetin-3-β-galactoside	Isorhamnetin	Myricetin	Resveratrol	Total Ascorbic Acid	α-Tocopherol Eq	Phyloquinones (K1)	Lutein	Zeaxanthin	beta-carotene
Sesbania grandiflora	549	32	56	0	0	16	26	30	0	0	0	68	57	0	12268	73	11	406	18.59	418
Amaranthus gangeticus	92	146	0	0	0	0	0	0	305	0	0	0	0	0	83540	440	11	264	5.45	284
Amaranthus gangeticus	63	222	0	0	0	0	0	0	304	0	0	0	0	0	86200	460	12	234	3.92	281
Amaranthus gangeticus	104	155	0	0	0	0	0	0	321	0	0	0	0	0	77240	450	11	232	4.92	282
Amaranthus spinosus	99	0	0	0	0	0	46	87	0	0	0	0	0	0	82560	280	18	58	4.19	53
Amaranthus spinosus	135	0	0	0	0	0	56	100	0	0	0	0	0	0	77300	280	18	55	5.32	49
Basella alba	56	38	175	0	0	0	0	0	0	0	0	0	225	0	63350	160	9	93	8.02	82
Chenopodium album	16	1	0	0	0	0	0	0	0	67	0	0	0	0	41030	250	9	56	4.39	36
Beta vulgaris	0	0	0	0	0	15	0	24	0	0	0	0	0	0	35830	210	3	47	4.86	57
Piper betle	342	59	0	0	0	0	0	0	0	0	0	0	0	0	18400	50	8	133	2.01	139
Piper betle	46	15	0	0	0	0	0	0	0	0	0	0	0	0	24510	30	8	182	2.65	156
Brassica oleraceavar. gemmifera	0	0	0	0	0	78	64	48	0	0	0	0	0	0	89450	210	1	52	1.19	12
Brassica rupa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19320	250	4	2	0.05	0
Brassica oleraceavar. viridis	133	0	104	0	0	98	42	84	0	0	0	0	0	0	40760	200	5	4	0.09	3
Brassica oleraceavar. capitataf. alba	127	0	98	0	0	112	166	21	0	0	0	0	0	0	33250	50	4	0	0.00	1
Brassica oleraceavar. capitataf. rubra	142	0	110	0	0	107	172	23	0	0	0	0	0	0	43490	30	5	1	0.07	1
Brassica oleraceavar. botrytis	0	156	0	0	0	16	37	35	0	0	0	0	0	39	52840	80	6	5	0.07	5
Colocasia esculenta	0	6	0	0	0	2	1	2	0	0	0	0	1	0	40710	70	13	164	4.52	192
Moringa Oleifera	29	6	0	0	0	0	0	0	0	0	0	0	0	0	108000	310	19	489	7.82	583
Trigonella foenum graecum	79	53	38	5	0	0	112	0	55	57	0	2	0	0	58250	360	17	71	0.94	307
Lepidium sativum	23	2	0	0	0	0	37	0	0	0	0	689	0	0	42750	740	18	43	0.55	3
Hibiscus cannabinus	10	250	0	0	0	0	0	21	62	14	0	0	0	0	29650	500	17	166	0.62	176
Hibiscus cannabinus	9	332	0	0	0	0	0	19	66	12	0	0	0	0	35430	500	17	150	0.68	171
Brassica oleraceavar. gongylodes	4	0	26	0	0	0	0	0	0	0	0	0	24	0	71110	530	12	0	0.09	0
Lactucasativa	182	0	79	0	0	173	7	4	8	1	118	0	4	0	11910	10	4	58	0.19	43
Brassica juncea	16	246	0	0	0	0	109	85	0	0	0	2	0	0	60320	570	8	92	0.27	87
Brassica rapa var. chinensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55600	30	2	83	0.18	81
Petroselinum crispum	77	30	1067	0	0	0	1	0	0	0	0	0	0	0	133000	350	13	112	0.40	90
Alternantherasessilis	217	0	20	0	0	311	47	33	0	0	0	0	0	0	103000	540	23	163	3.49	176
Cucurbita maxima	10	26	0	0	0	0	0	32	0	0	0	0	0	0	12330	1690	10	193	1.51	48
Raphanus sativus	0	53	0	0	0	203	513	4106	0	106	0	0	0	0	65760	80	7	55	0.76	86
Rumex patientia	193	38	0	0	0	0	669	5101	0	0	0	0	0	0	53760	510	5	74	0.63	92
Spinacia oleracea	156	0	169	0	83	22	5	29	0	0	0	0	76	0	30280	1290	13	121	0.57	87
Tamarindus indica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28220	810	10	2	0.06	6

Note: Concentration expressed in nM ; Red colour: Low concentration ; Yellow colour: Medium concentration; Green colour: Higher concentration

Appendix A.4 Enzymatic reactions identified for the targeted polyphenols

Antioxidant compounds	Biosystem	Enzyme(s)	Reaction
3,4-Dihydroxy benzoic acid	Gut microbial environment	Unspecified bacterial decarboxylase	N-Glucuronidation of azole
3,4-Dihydroxy benzoic acid	Gut microbial environment	Unspecified bacterial dehydroxylase	Carnitine conjugation
3,4-Dihydroxy benzoic acid	Gut microbial environment	Unspecified bacterial dehydroxylase	2-Acetyl hydrolysis of 1-alkyl, 2-acetyl-glycerol-3-phosphocholine
3,4-Dihydroxy benzoic acid	Gut microbial environment	Sulfotransferase	Decarboxylation of aromatic L-amino acid
3,4-Dihydroxy benzoic acid	Gut microbial environment	Sulfotransferase	Epoxidation of arene
Vannilic Acid	Gut microbial environment	Unspecified bacterial dehydroxylase	2-Hydroxylation of 1,4-disubstituted benzene
Cinamic Acid	Gut microbial environment	EC 1.6.99.1	Reduction of alpha,beta-unsaturated carbon-carbon double bond adjacent to electron withdrawing group
Cinamic Acid	Gut microbial environment	Bacterial UDP-glucuronosyltransferase	O-Glucuronidation of aliphatic acid
O-Coumaric Acid	Gut microbial environment	EC 1.6.99.1	Reduction of alpha, beta-unsaturated carbon-carbon double bond adjacent to electron withdrawing group
O-Coumaric Acid	Gut microbial environment	Bacterial UDP-glucuronosyltransferase	Aromatic OH-glucuronidation
O-Coumaric Acid	Gut microbial environment	Bacterial UDP-glucuronosyltransferase	O-Glucuronidation of aliphatic acid
P-Coumaric Acid	Gut microbial environment	EC 1.6.99.1	Phosphatidylcholine sitosterol O-acylation
P-Coumaric Acid	Gut microbial environment	Bacterial phenolic acid decarboxylase (EC 4.1.1.-)	NitrosoReduction from CyProduct
P-Coumaric Acid	Gut microbial environment	Bacterial UDP-glucuronosyltransferase	alpha-Amino acid to aldoxime
Caffeic Acid	Gut microbial environment	Unspecified bacterial dehydroxylase	Carnitine conjugation
Caffeic Acid	Gut microbial environment	Sulfotransferase	alpha-Amino acid to aldoxime
Syringic Acid	Gut microbial environment	Sulfotransferase	Epoxidation of arene
Sinapinic Acid	Gut microbial environment	EC 1.6.99.1	Reduction of alpha, beta-unsaturated carbon-carbon double bond adjacent to electron withdrawing group
Sinapinic Acid	Gut microbial environment	Bacterial phenolic acid decarboxylase (EC 4.1.1.-)	Decarboxylation of phenolic acid
Sinapinic Acid	Gut microbial environment	Bacterial phenolic acid decarboxylase (EC 4.1.1.-)	Decarboxylation of phenolic acid
Sinapinic Acid	Gut microbial environment	Unspecified bacterial dehydroxylase	4'-Dehydroxylation of substituted benzene
Sinapinic Acid	Gut microbial environment	Bacterial UDP-glucuronosyltransferase	Aromatic OH-glucuronidation
Chlorogenic acid	Gut microbial environment	EC 3.1.1.1	Hydrolysis of carboxylic acid ester
Chlorogenic acid	Gut microbial environment	Bacterial UDP-glucuronosyltransferase	Alkyl-OH-glucuronidation
Chlorogenic acid	Gut microbial environment	EC 2.1.1.6	Catechol O-methylation
Apigenin	Gut microbial environment	Sulfotransferase	Decarboxylation of aromatic L-amino acid
Apigenin	Gut microbial environment	Unspecified gut bacterial enzyme	Flavonoid C-ring reduction
Apigenin-6-C-glucoside	Gut microbial environment	Unspecified bacterial dehydroxylase	4'-Dehydroxylation of substituted benzene
Apigenin-6-C-glucoside	Gut microbial environment	Sulfotransferase	Sulfation of primary alcohol
Apigenin-6-C-glucoside	Gut microbial environment	Sulfotransferase	Sulfation of secondary alcohol
Isorhamnetin	Gut microbial environment	Unspecified bacterial dehydroxylase	2-Hydroxylation of 1,4-disubstituted benzene
Myricetin	Environmental microbial	Unspecified_microbial_bile_acid_amino_acid_n_acyltransferase	3-OH-Sulfonation of phenolic compound
Myricetin	Environmental microbial	Unspecified_microbial_bile_acid_amino_acid_n_acyltransferase	3-OH-Sulfonation of phenolic compound
Myricetin	Environmental microbial	Unspecified_microbial_bile_acid_amino_acid_n_acyltransferase	Eawag_rule_bt0173
Resveratrol	Gut microbial environment	Unspecified bacterial dehydroxylase	N-Methylation of phosphatidyl-N-monomethylethanolamine
Phyloquinones (K1)	Gut microbial environment	EC 1.6.99.1	Reduction of alpha,beta-unsaturated carbon-carbon double bond adjacent to electron withdrawing group

Appendix B

Appendix B.1 Colony forming unit calculations

The number colonies were calculated using the following formula

$$CFU\ \frac{cells}{mL} = \frac{(number\ of\ colonies\ in\ plates\ \times\ dilution\ factor)}{volume\ of\ culture\ plated}$$

Sample calculation

Average number of colonies on plates = 212

Dilution factor = 10^6

Volume of culture plated = 0.1 mL

$$CFU\ \ cells/mL = \frac{(212 \times 10^6)}{0.1} = 2.12 \times 10^9\ cells/mL$$

Appendix B.2 Sample calculation for the estimation of dry cell weight of yeast

The method for estimation of dry cell mass is as follows

Sample calculation

Weight of the cells + dry aluminium foil cup (x) = 1.14 mg

Weight of dry aluminium foil cup, weighed previously (y) = 1.04 mg

Weight of the sample (z) = 1 mL

Dry cell weight in the sample = (x-y)/z = 0.1 mg/mL

Appendix B.3 Bicinchoninic acid (BCA) method for estimation of soluble protein

A stock solution of 1000 µg/mL bovine serum albumin (BSA) was prepared for standard plot preparation. BSA solutions of the following strengths were prepared by diluting the stock: 25 µg/mL, 50 µg/mL, 100 µg/mL, 250 µg/mL and 350 µg/mL. The blank was prepared by taking 100 µL of water in the place of BSA solutions. The standard plot of absorbance was prepared against microgram of bovine serum albumin using origin software (Fig. B.3). The quantity of protein present in a sample was calculated by using calibration plot.

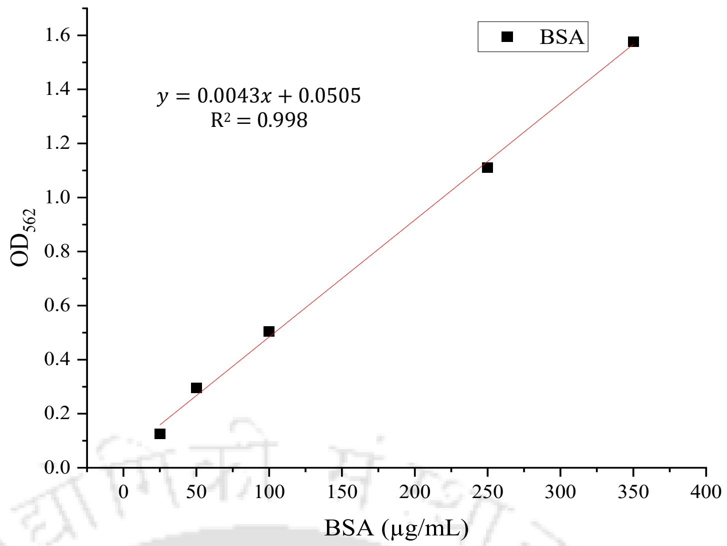


Fig. B.3 Standard plot for estimating the soluble protein

Sample calculation

For calculation of unknown soluble protein concentration of sample, standard plot calibrated equation from Fig. B.3 was used.

$$y = 0.0043x + 0.0505$$

Where,

y = Absorbance at 562 nm

x = Concentration (µg/mL)

If absorbance of unknown sample = 0.547

Therefore, the concentration of soluble protein (x) = $\frac{(0.547-0.0505)}{0.0043}$ = 115.46 µg/mL

Appendix B.4 Estimation of endogenous enzymatic activity present in yeast cells

According to Beer-Lambert's law for a UV-Visible spectrophotometric assay of chemical species,

$$A = C \times \varepsilon \times l \text{ ----------------------} \quad \text{(Eq. B.3)}$$

Where A = absorbance, C = concentration, ε = extinction co-efficient and l = pathlength (1 cm).

Activity can be calculated from the following equation

$$Activity\ (U) = \left(\frac{\left(\frac{\Delta C}{\Delta t}\right) \times V_a}{\varepsilon \times V_s \times l} \right) \times df \text{ ----------------------} \quad \text{(Eq. B.4)}$$

Where, $\Delta A = (A_t - A_0)$ = Change in Absorbance

$\Delta C = (C_t - C_0)$ = Change in Concentration (moles/mL)

$\Delta t = (T_t - T_0)$ = Time of assay (in minutes)

V_a = Reaction volume (in millilitres) of assay

df = Dilution factor

ε = Extinction coefficient

V_s= Volume (in millilitres) of sample or enzyme used

(a) Estimation of glutathione peroxidase activity (GPx)

The glutathione peroxidase activity method was validated with specific unit of enzyme and plotted in Fig. B.4a. Activity of glutathione peroxidase can be calculated according to the following equation

$$GPx\ activity\ \left(\frac{\frac{nmol}{min}}{mL}\right) = \frac{\left(\frac{\Delta A}{\Delta t}\right) \times df \times V_a}{\varepsilon \times V_s} \text{ ----------------------- (Eq. B.5)}$$

Using the following equation B.5, glutathione peroxidase can be calculated where

$$GPx\ activity\ \left(\frac{\frac{nmol}{min}}{mL}\right) = \frac{\left(\frac{0.559-0.484}{5-0}\right) \times 1 \times 1}{0.00622 \times 0.1} = 24.11 \text{ nmol/min/mL} = 24.11 \text{ mU/mL}$$

Where, ΔA =Change in absorbance at 340 nm

Δt =Time of assay (in minutes)

V_a = Total volume (in millilitres) of assay

df = Dilution factor

ε = 0.00622 $\mu M^{-1}cm^{-1}$ of β-NADPH at 340 nm

V_s= Volume (in millilitres) of sample or enzyme used

To estimate the enzymatic activity in terms of U/mg of protein the equation can be expressed as

$$\frac{U}{mg}\ of\ protein = \frac{\frac{\frac{nmol}{min}}{mL\ of\ enzyme}}{mg\ of\ of\ protein/mL\ of ezyme} \text{ ----------------------- (Eq. B.6)}$$

From the equation B.6 the unit (U) of enzyme for per mg of protein can be calculated as

$$\frac{U}{mg}\ of\ protein = \frac{24.11 mU/mL}{0.3\ mg\ /mL} = 0.08 \text{ U/mg of protein}$$

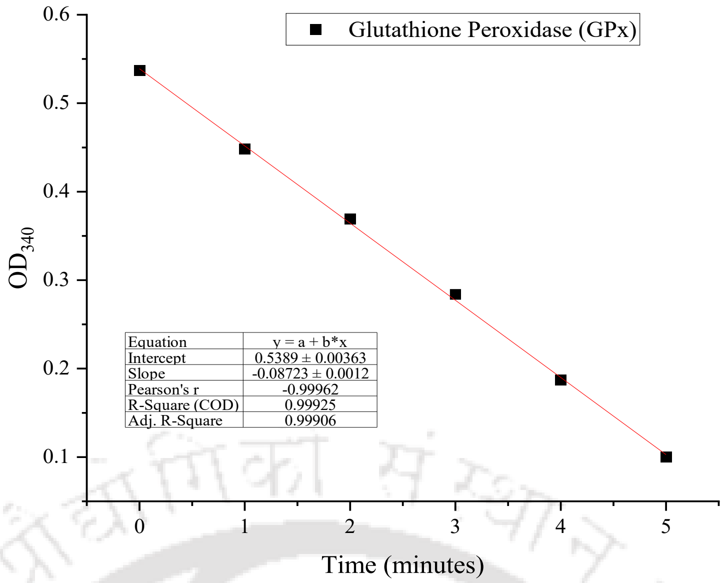


Fig. B.4a Glutathione peroxidase enzymatic activity calibration plot

(b) Estimation of glutathione reductase (GR) enzymatic activity

The glutathione reductase activity was validated with specific unit of enzyme and plotted in Fig. B.4b. Activity of glutathione reductase can be calculated according to the following equation

$$GR\ activity\ \left(\frac{\frac{nmol}{min}}{mL}\right) = \frac{\left(\frac{\Delta A}{\Delta t}\right) \times df \times V_a}{\varepsilon \times V_s} \text{ ----------------------(Eq. B.7)}$$

Where, $\Delta A = (A_t - A_0)$ = Change in absorbance at 340 nm

$\Delta t = (T_t - T_0)$ = Time of assay (in minutes)

V_a = Total volume (in millilitres) of assay

df = Dilution factor

$\varepsilon = 0.00622\ \mu M^{-1} cm^{-1}$ of β-NADPH at 412 nm

V_s= Volume (in millilitres) of sample or enzyme used

$$\frac{U}{mg}\ of\ protein = \frac{\frac{\frac{nmol}{min}}{mL\ of\ enzyme}}{mg\ of\ of\ protein/mL\ of ezyme}$$

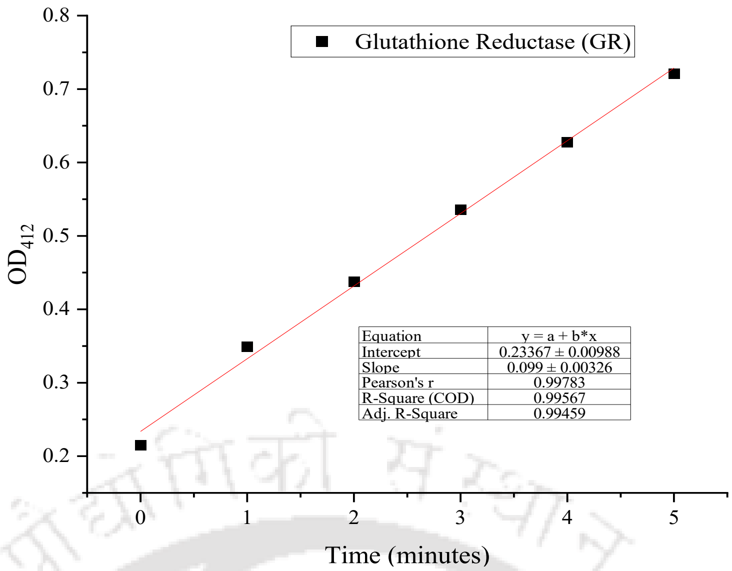


Fig. B.4b Glutathione reductase enzymatic activity calibration plot

(c) Estimation of catalase (CAT) enzymatic activity

The Catalase activity method was validated with specific unit of enzyme and plotted in Fig B.4c. Activity of catalase can be calculated according to the following equation

$$CAT\ activity\ \left(\frac{U}{mL}\right) = \frac{\left(\frac{\Delta A}{\Delta t}\right) \times df \times V_a}{\varepsilon \times V_s} \text{ ----------------------- (Eq. B.8)}$$

Where, $\Delta A = (A_t - A_0)$ = Change in absorbance at 240 nm

$\Delta t = (T_t - T_0)$ = Time of assay (in minutes)

V_a = Total volume (in millilitres) of assay

df = Dilution factor

$\varepsilon = 0.0436\ mM^{-1}cm^{-1}$ of H_2O_2 at 240 nm

V_s= Volume (in millilitres) of sample or enzyme used

The formula can also be written as

$$\frac{U}{mg}\ of\ protein = \frac{\frac{\frac{nmol}{min}}{mL\ of\ enzyme}}{mg\ of\ of\ protein/mL\ of ezyme}$$

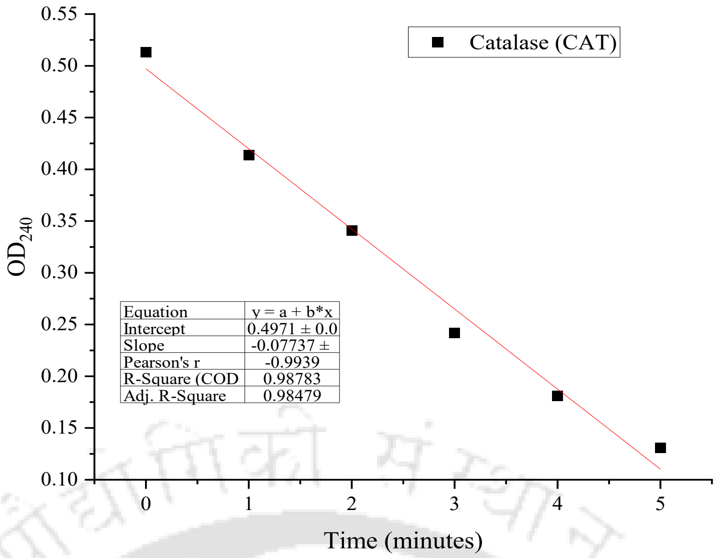


Fig. B.4c Catalase enzymatic activity calibration plot

(d) Estimation of superoxide dismutase (SOD) enzymatic activity

The SOD activity method was validated with specific unit of enzyme and plotted in Fig. B.4d. Activity of superoxide dismutase can be calculated according to the following equation

$$SOD\ \%\ inhibition = \frac{(\Delta A_{550}/\min Uninhibited - \Delta A_{550}/\min Inhibited) \times 100}{(\Delta A_{550}/\min Uninhibited - \Delta A_{550}/\min Blank)} \quad \text{---- (Eq. B.9)}$$

$$\frac{U}{mg}\ of\ protein = \frac{\%\ Inhibition \times df}{(50\%) \times (0.10) \times (mg\ of\ of\ protein/mL\ of ezyme)} \quad \text{---- (Eq. B.10)}$$

Where, df = Dilution factor

50% = Inhibition of the rate of cytochrome c reduction per unit definition

V_s= Volume (in millilitres) of sample or enzyme used

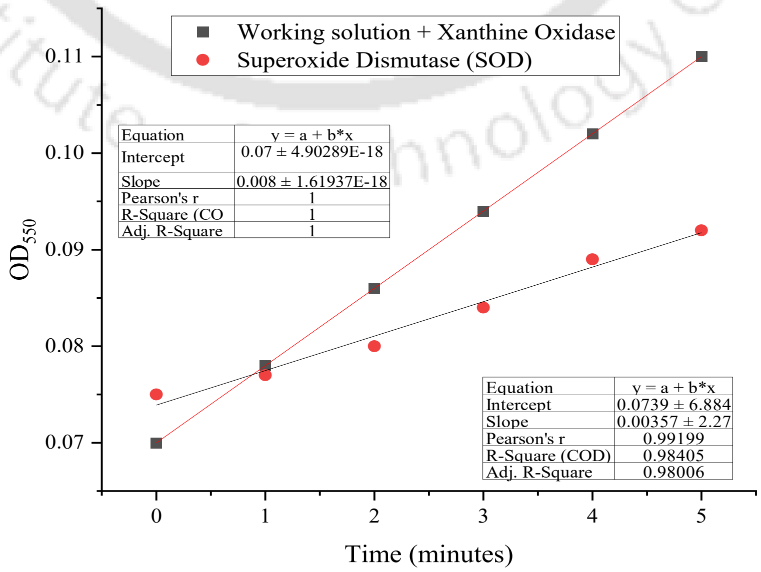


Fig. B.4d Superoxide dismutase enzymatic activity calibration plot

Appendix B.5 Iron reducing power capacity (IRP) calibration plot

A stock solution of 1000 µg/mL ascorbic acid was prepared. The diluted concentration of different strength of 10 µg/mL, 15 µg/mL, 25 µg/mL, 50 µg/mL, 75 µg/mL and 100 µg/mL was prepared from the stock solution. 100 µL of distilled water was taken as a blank to the standard solution. The quantity of the ascorbic acid concentration was calculated using the following calibration plot (Fig. B.5).

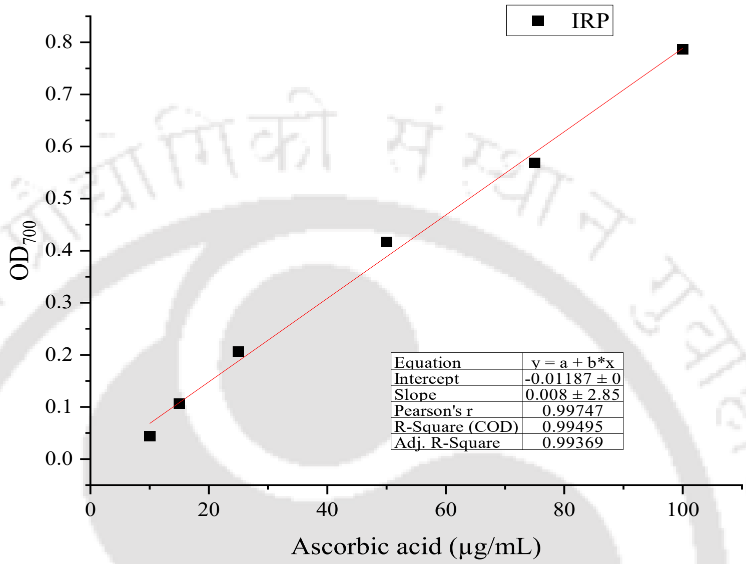


Fig. B.5 Calibration plot for estimation of iron reducing power

Appendix B.6 Radical scavenging potential (ARSA) calibration plot

A stock solution of 1000 µg/mL trolox standard was prepared. The diluted concentration of different strength of 10 µg/mL, 15 µg/mL, 25 µg/mL, 50 µg/mL, 75 µg/mL and 100 µg/mL was prepared from the stock solution. 100 µL of distilled water used as a blank to the standard solution. The quantity of the trolox concentration was calculated using the following calibration plot (Fig. B.6).

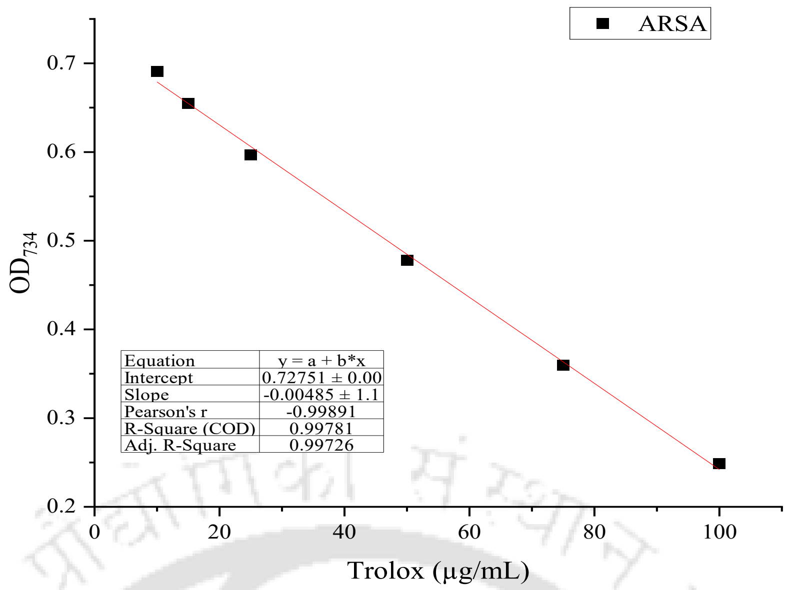


Fig. B.6 Calibration plot for estimation of radical scavenging potential

Appendix B.7 Lipid peroxidation (LPOX) calibration plot

A stock solution of 1000 µg/mL malondialdehyde standard was prepared. The diluted concentration of different strength of 10 µg/mL, 15 µg/mL, 25 µg/mL, 50 µg/mL, 75 µg/mL, 100 µg/mL was prepared from the stock solution. 100 µL of distilled water used as a blank to the standard solution. The quantity of the malondialdehyde concentration was calculated using the following calibration plot (Fig B.7).

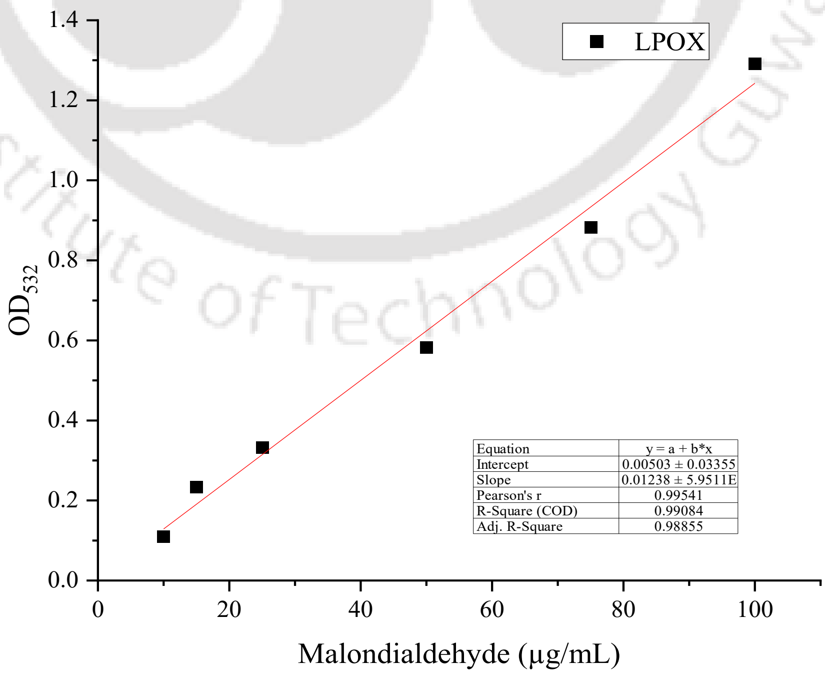


Fig. B.7 Calibration plot for estimation of lipid peroxidation

Appendix B.8 Total glutathione content (Total GSH) estimation calibration plot with HPLC

A stock solution of 1000 µg/mL reduced glutathione standard was prepared. The diluted concentration of different strength of 10 µg/mL, 15 µg/mL, 25 µg/mL, 50 µg/ml, 75 µg/mL and 100 µg/mL was prepared from the stock solution. 100 µL of distilled water used as a blank to the standard solution. The quantity of total glutathione concentration was calculated using the following calibration plot (Fig. B.8).

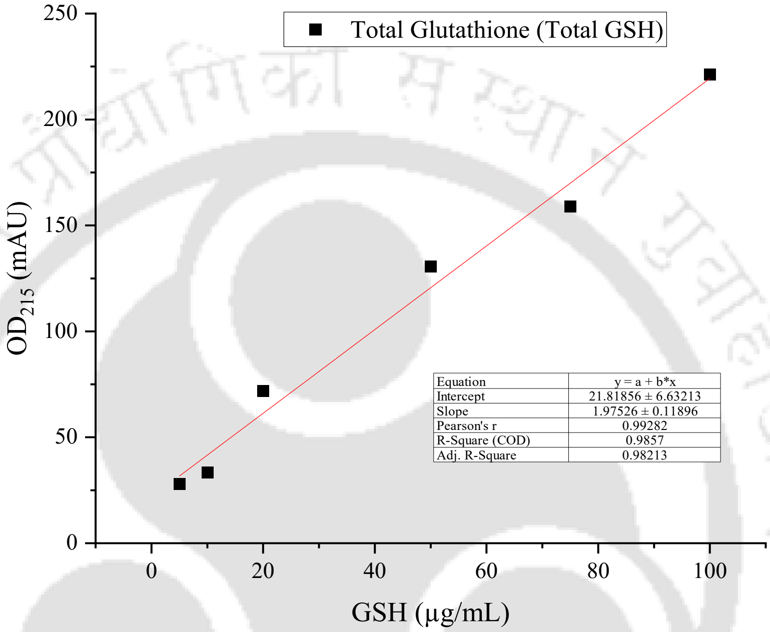


Fig. B.8 Calibration plot for estimation of total glutathione

Appendix C

Appendix C.1 Determination of moisture content (%)

The moisture content of the dry basis is the mass of the water to the mass of the dry matter estimated on the following formula

$$Moisture\ content\ on\ dry\ basis\ (\%) = \frac{M_I - M_F}{M_D} \times 100$$

M_I = Initial moisture content of the material

M_F = Final moisture content of the material

M_D = Bone dry mass of the material

Where,

M_I = 40 g; M_F = 5.2 g; M_D = 4g

Using the formula, the moisture can be calculated as follows

$$Moisture\ content\ (\%) = \frac{40 - 5.2}{4} \times 100 = 8.7\%$$

Appendix C.2 Estimation of effective moisture diffusivity

The formula of the effective diffusivity of infinite slab can be expressed as below

$$MR = \frac{M_t - M_e}{M_{cr} - M_e} = \frac{8}{\pi^2} \exp\left[-\pi^2 \frac{D_{eff} t}{L^2}\right] \text{ ---------- (Eq. C.1)}$$

Can also be written as,

$$\ln MR = \frac{\ln 8}{\pi^2} - \left[\frac{\pi^2 D_{eff}}{L^2}\right] \times t \text{ --------------- (Eq. C.2)}$$

Where, MR = Dimensionless moisture ratio

M_t = Moisture content at any time in falling rate period of drying (kg/kg)

M_e = Dynamic equilibrium moisture content with respect to drying chamber (kg/kg)

M_{cr} = Critical initial moisture content at the beginning of the falling rate period (kg/kg)

t = Time (h or min)

L = Half thickness of the slap

The plot of ln MR versus time for both oven dried (105°C) and microwave dried (720W) samples of four samples estimated the slope and intercept as shown in the Fig. C.2a and Fig. C.2b.

The plot generates an equation of

$$\ln MR = mx + c$$

Where

$$m = \frac{\pi^2 D_{eff}}{L^2} \text{--------------- (Eq. C.3)}$$

and

$$c = \frac{\ln 8}{\pi^2} \text{--------------- (Eq. C.4)}$$

and x = time (t)

We can calculate the π from the intercept (m) (leaf structure is slab surface) and the effective diffusivity (D_{eff}) can be estimated by solving the above Eq. C.3.

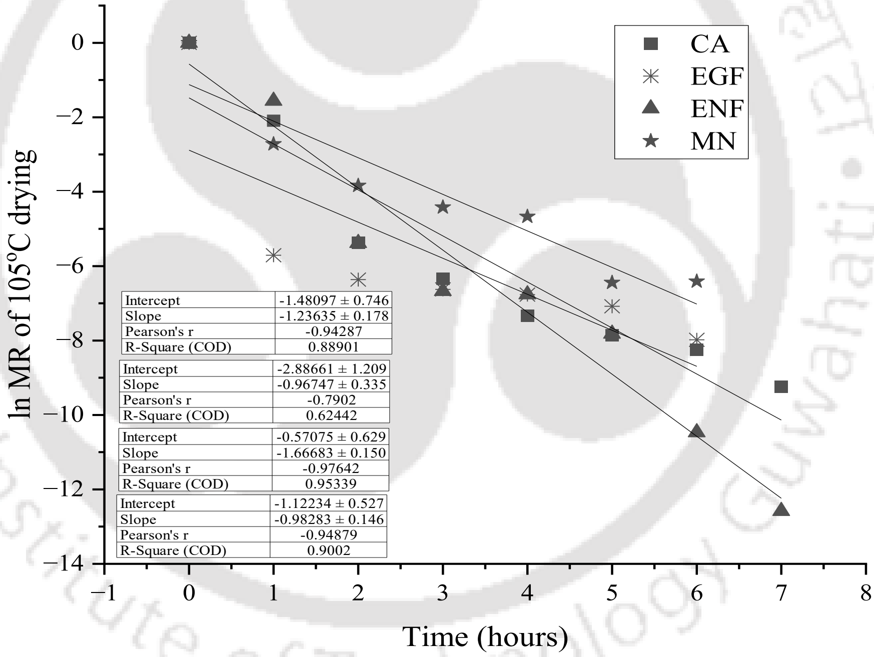


Fig. C.2a ln MR versus time plot for 105°C oven drying

Table C.2a Effective diffusivity calculations of 105°C drying

Sample Name	m	c	π =sqrt(ln8/c)	D_{eff}(m²/h) = (mL²)/ π^2	D_{eff}(m²/s)
Centella asiatica	1.236	1.481	-0.9675	6.17975E-09	1.7166E-12
Eryngium foetidum	0.967	2.887	-0.84875	3.87228E-08	1.0756E-11
Enhydra fluctuans	1.667	0.572	-1.90884	8.50254E-09	2.3618E-12
Marsilea minuta	0.983	1.122	-1.11141	2.52493E-09	7.0137E-13

Table C.2b Effective diffusivity calculations of microwave (720W) drying

Sample Name	m	c	π =sqrt(ln8/c)	$D_{eff}(m^2/h) = (mL^2)/ \pi^2$	$D_{eff}(m^2/s)$
Centella asiatica	1.1785	0.4975	1.669288	1.9787E-09	3.3E-11
Eryngium foetidum	0.8627	0.104	4.471536	1.244E-09	2.07E-11
Enhydra fluctuans	0.5812	0.0784	-5.1501	4.07286E-10	6.79E-12
Marsilea minuta	0.6275	0.2352	-2.42778	3.37852E-10	5.63E-12

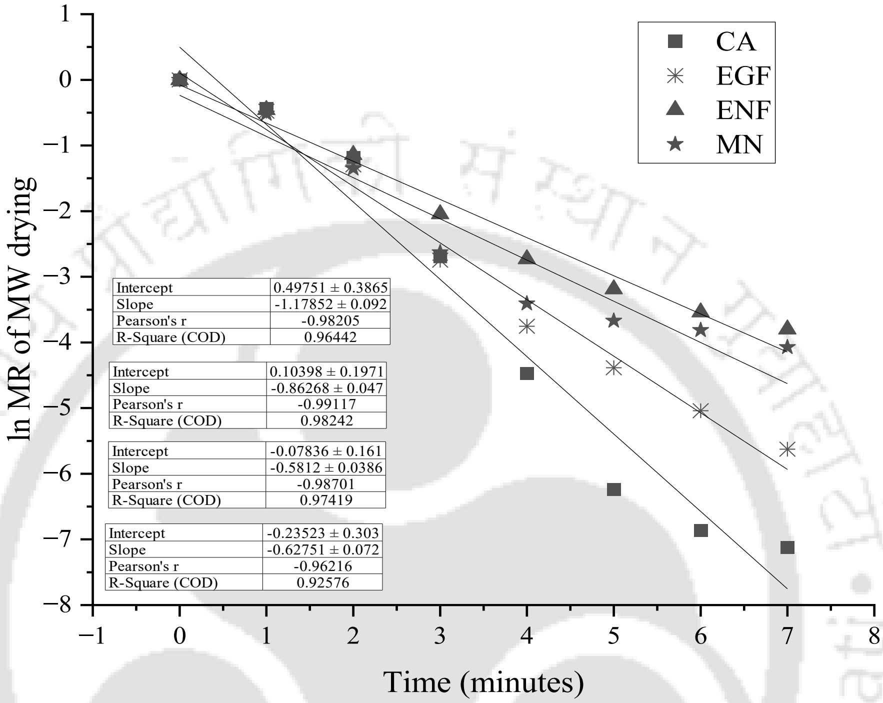


Fig. C.2b ln MR versus time plot for microwave (720W) drying

Appendix C.3 Estimation of total soluble solids (TSS)

The total soluble solids of the extracted soluble extracts are estimated form the following formula

Calculation

Weight of the extracts + dry aluminium foil cup (x) = 45 mg

Weight of dry aluminium foil cup, weighed previously (y) = 8 mg

Weight of the sample (z) = 3 mL

Soluble solids in the sample = (x-y)/z = 12.33 mg/mL

For conversion into mg of solids/g of dry powder the calculations are as follows

If 4 g dissolved in 100 mL of distilled water and recovered volume of extract is 70 mL and corresponding total soluble solids = 23.55 mg/mL

Soluble solids in sample (mg of solids/g of dry powder)

= (23.55 mg/mL × 70 mL) /4 g

= 412.12 mg/g of dry powder

Appendix C.4 Estimation of particle size with sieve analysis and calculations

The percentage of the leaves powder retained on each sieve size (2000-63 µm) shall be calculated on the basis of following formula

$$Percentage\ mass\ retained\ on\ seive = \frac{M_r}{M_T} \times 100$$

M_r = Mass of the leave powder remaining in sieve

M_T = Total mass of the leave powder

r = diameter of sieve

The mean diameter of the particles retained in r^{th} sieve was

$$\overline{d_r} = \frac{d_{r-1} + d_r}{2}$$

Therefore, the mean particle size ($\dot{d}$) calculated as

$$\dot{d} = \sum (M_r \times \overline{d_r})$$

Appendix C.5 Estimation of bulk density, tapped density and porosity calculation

Bulk Density: The bulk density is the ratio of the mass to the volume (including the interparticulate void volume) of a material. The formula can be expressed as

$$Bulk\ Density = \frac{Mass}{Bulk\ volume}$$

Using the formula bulk density of the 2 g of powder of can be calculated with pouring in measuring cylinder, if the volume indicates supposedly 6.7 mL, then the bulk density can be calculated as

$$Bulk\ Density = \frac{2\ g}{6.7\ mL} = 0.298 \text{ g/mL} = (0.298 \times 1000)\ kg/m^3 = 298 \text{ kg/m}^3$$

Tapped Density: The tapped density is calculated my mechanically tapping a measuring cylinder containing the sample. The formula can be expressed as

$$Tapped\ Density = \frac{Mass}{Tapped\ volume}$$

Using the formula, the tapped density can be calculated as

$Tapped\ Density = \frac{2\ g}{6\ mL}$ = 0.333 g/mL = $(0.333 \times 1000)\ kg/m^3$ = 333 kg/m^3

True Density: The true density is the measure of the mass per unit true volume of the material excluding the void volume. The formula can be expressed as

$$True\ Density = \frac{Mass}{True\ volume}$$

Where

True volume = (Solvent volume + Tapped volume of Powder) - Solvent volume

= (4 + 0.5) – 4 = 0.5 mL

$True\ Density = \frac{0.5\ g}{0.5\ mL}$ = 1 g/mL = $(1 \times 1000)\ kg/m^3$ = 1 kg/m^3

Apparent Porosity: The porosity is the amount of the solvent it takes to fill the tiny space of the material. The porosity percentage can be calculated as

$$Apparent\ Porosity\ (\%) = \frac{Tapped\ Density}{True\ Density} \times 100 = \frac{0.333\frac{g}{mL}}{1\frac{g}{mL}} \times 100 = 33.3\%$$

Appendix C.6 Estimation of polyphenol oxidase enzymatic activity

Estimation of polyphenol oxidase is calculated with following formula

$$PPO\ Activity\ \left(\frac{\Delta A_{435}/min}{g\ of\ powder}\right) = \left(\frac{\Delta A\ \times\ V_a}{\Delta T \times V_S}\right) \times V_p$$

Where, $\Delta A = (A_t - A_0)$ = Change in absorbance

V_a = Total volume (in millilitres) of assay

V_s= Volume (in millilitres) of sample or enzyme used

V_p= Recovered volume (in millilitres) of extract from x gram of sample

Appendix C.7 Effect of different percentages of volatilization and also effect of different degrees of incomplete drying on 90% moisture content of a sample

90 % Moisture	Loss of solid (1-15%)									
Amount of solid lost from 5 g Sample	0.005	0.01	0.03	0.05	0.07	0.09	0.11	0.13	0.15	0.2
BDM 0.5 g	0.4975	0.495	0.485	0.475	0.465	0.455	0.445	0.435	0.425	0.4
	90.05%	90.10%	90.30%	90.50%	90.70%	90.90%	91.10%	91.30%	91.50%	92.00%
	0.05%	0.10%	0.30%	0.50%	0.70%	0.90%	1.10%	1.30%	1.50%	2.00%
	0.005	0.01	0.03	0.05	0.07	0.09	0.11	0.13	0.15	0.2
	89.55%	89.10%	87.30%	85.50%	83.70%	81.90%	80.10%	78.30%	76.50%	72.00%
	4.4775	4.455	4.365	4.275	4.185	4.095	4.005	3.915	3.825	3.6
BDM 0.5 g	0.5225	0.545	0.635	0.725	0.815	0.905	0.995	1.085	1.175	1.4
	-0.45%	-0.90%	-2.70%	-4.50%	-6.30%	-8.10%	-9.90%	-11.70%	-13.50%	-18.00%

Appendix C.8 Effect of different percentages of volatilization and also effect of different degrees of incomplete drying on 10% moisture content of a sample

10% Moisture	Loss of solid (1-15 %)									
Amount of solid lost from 5 g Sample	0.005	0.01	0.03	0.05	0.07	0.09	0.11	0.13	0.15	0.2
BDM 4.5 g	4.4775	4.455	4.365	4.275	4.185	4.095	4.005	3.915	3.825	3.6
	10.45%	10.90%	12.70%	14.50%	16.30%	18.10%	19.90%	21.70%	23.50%	28.00%
	0.45%	0.90%	2.70%	4.50%	6.30%	8.10%	9.90%	11.70%	13.50%	18.00%
	0.005	0.01	0.03	0.05	0.07	0.09	0.11	0.13	0.15	0.2
	89.55%	89.10%	87.30%	85.50%	83.70%	81.90%	80.10%	78.30%	76.50%	72.00%
	4.4775	4.455	4.365	4.275	4.185	4.095	4.005	3.915	3.825	3.6
BDM 0.5 g	0.5225	0.545	0.635	0.725	0.815	0.905	0.995	1.085	1.175	1.4
	-0.45%	-0.90%	-2.70%	-4.50%	-6.30%	-8.10%	-9.90%	-11.70%	-13.50%	-18.00%

Appendix C.9 Folin's reducing power (FRP) calibration plot

A stock solution of 1000 µg/mL gallic acid standard was prepared. The diluted concentration of different strength of 10 µg/mL, 20 µg/mL, 40 µg/mL, 60 µg/mL, 80 µg/mL, 100 µg/mL was prepared from the stock solution. 100 µL of distilled water used as a blank to the standard solution. The quantity of gallic acid concentration was calculated using the following calibration plot (Fig. C.9).

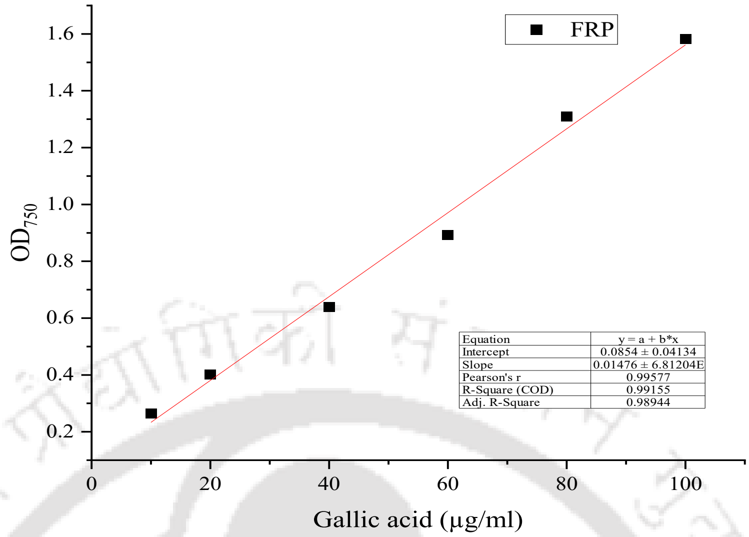


Fig. C.9 Calibration plot for estimation of folin's reducing power

Appendix C.10 Total flavonoid content (TFC) calibration plot

A stock solution of 1000 µg/mL quercetin standard was prepared. The diluted concentration of different strength of 50 µg/mL, 100 µg/mL, 250 µg/mL, 500 µg/mL, 750 µg/mL and 1000 µg/mL was prepared from the stock solution. 100 µL of distilled water used as a blank to the standard solution. The quantity of quercetin concentration was calculated using the following calibration plot (Fig. C.10).

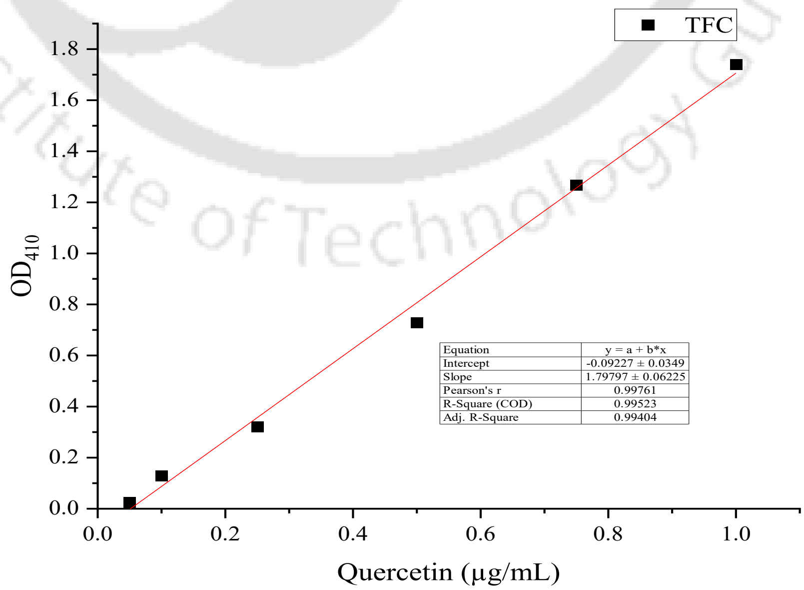


Fig. C.10 Calibration plot for estimation of total flavonoid content

Appendix D

Appendix D.1 Similarity indices calculations

a) Pearson correlation

Pearson's correlation coefficient formula is as follows,

$$\text{PC}\ (r) = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Where, r = Pearson coefficient

n= number of the pairs

$\sum xy$ = sum of products of the paired

$\sum x$ = sum of the x

$\sum y$= sum of the y

$\sum x^2$ = sum of the squared x

$\sum y^2$ = sum of the squared y

b) Euclidean distance

The Euclidean distance formula are as follows

$$\text{ED}\ (d) = \sqrt{\sum (x-y)^2}$$

Where, (x_1, y_1) = coordinates of one point.

(x_2, y_2) = coordinates of the other point.

d = distance between (x_1, y_1) and (x_2, y_2).

Appendix D.2 Estimation of colour determination

The color images were converted to the CIEL*a*b* system: L*(lightness of color (0–100)), a* (redness (+)/greenness (-)), and b* (yellowness (+)/blueness (-)). The Color difference (ΔE*) values were determined by the following formula

$$\Delta E^* = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \text{------------ (Eq. D.2)}$$

Appendix D.3 Total carbohydrate content (TCC) calibration plot

D- glucose standard is used for estimation of total carbohydrate with a stock solution of 1000 µg/mL. Different concentration of solutions was prepared by diluting the stock: 200 µg/mL, 400 µg/mL, 600 µg/mL, 800 µg/mL and 1000 µg/mL. The blank was prepared by taking water in the place of standard solutions. The standard plot of D-glucose was prepared (Fig. D.3).

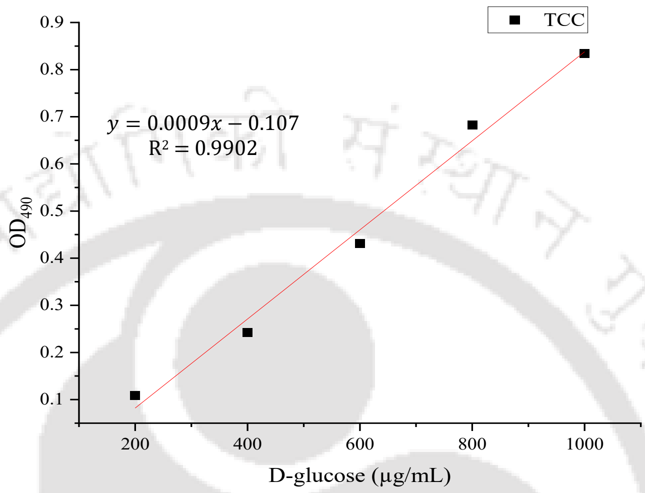


Fig. D.3 Standard plot for estimating of total carbohydrate content

Appendix D.4 Total reducing sugar (RS) calibration plot

A stock solution of 1000 µg/mL D-glucose standard was prepared. The diluted concentration of different strength of 100 µg/mL, 200 µg/mL, 400 µg/mL, 600 µg/mL, 800 µg/mL, 1000 µg/mL was prepared from the stock solution. Distilled water is used as a blank in standard solution. The quantity of the D-glucose concentration was calculated using the following calibration plot (Fig. D.4).

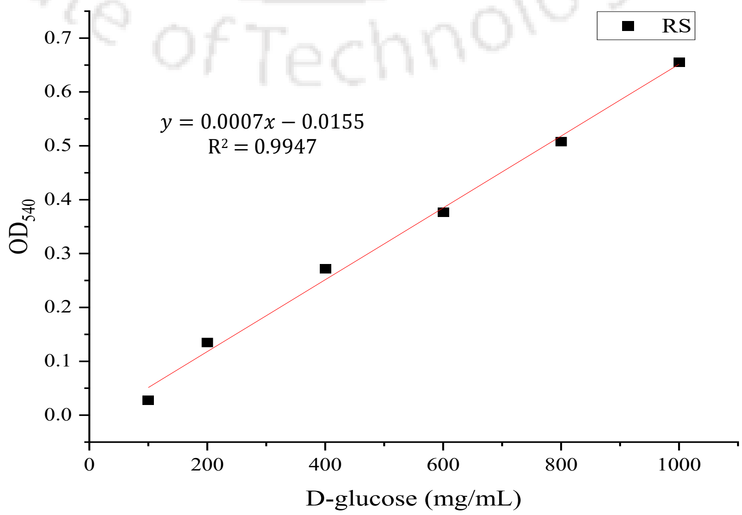


Fig D.4 Standard plot for estimating total reducing sugar

Appendix D.5 Calibration plot of total soluble protein (TSP) with lowry method

A stock solution of 1 mg/mL of bovine serum albumin was prepared as a standard. The diluted concentration of different strength of 50 µg/mL, 100 µg/mL, 150 µg/mL, 250 µg/mL and 500 µg/mL was prepared from the stock solution. Distilled water was used as a reference blank for estimating bovine serum albumin concentration in reaction mixture. The amount of BSA equivalent soluble protein was calculated using the following calibration plot (Fig. D.5).

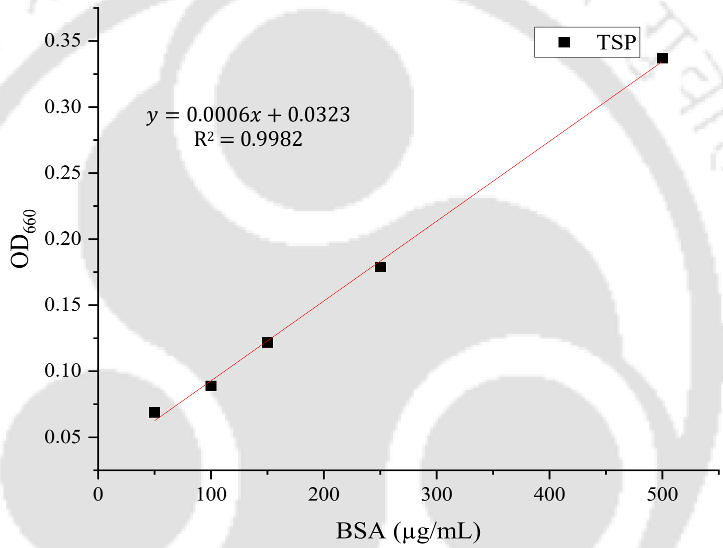


Fig. D.5 Standard plot for estimating total soluble protein using Lowry method

Appendix D.6 Sensory Score Table prescribed to the panel

Grade	Score
Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor Dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Appendix D.7 Adsorption and Desorption of *Centella asiatica* powder

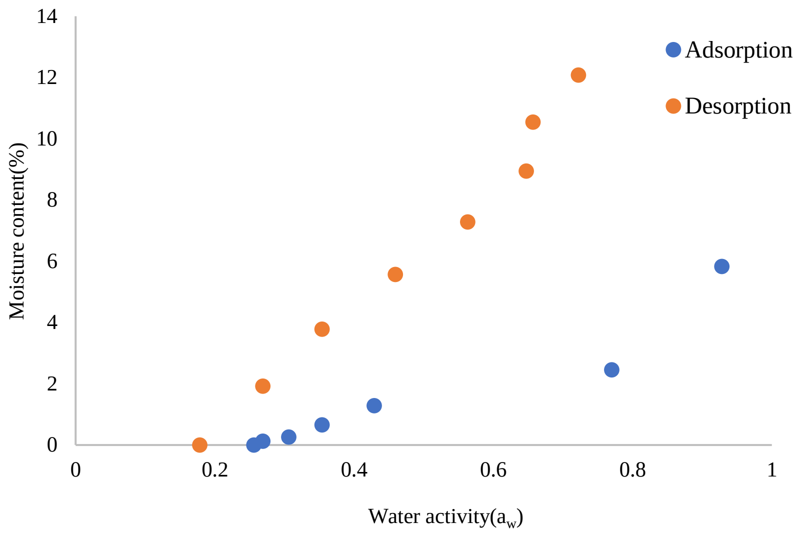


Fig. D.7 Adsorption and desorption of *Centella asiatica* powder

Appendix D.8 Change in total soluble solids during accelerated storage

Beverage	Unblended *Centella asiatica* powder TSS (mg/g d.w. of powder)			Blended *Centella asiatica* powder TSS (mg/g d.w. of powder)		
	A	**B**	**C**	**A**	**B**	**C**
	412.2±0.06	412.2±0.03	412.2±0.01	425.5±0.07	425.5±0.06	425.5±0.08
	411.8±0.06	412±0.08	412.4±0.01	425.8±0.04	425.7±0.07	426.3±0.08
Infused Beverage	411.2±0.03	412.8±0.01	411.8±0.04	425.5±0.03	426.5±0.07	426±0.01
	411.1±0.03	413±0.08	412.8±0.03	426±0.04	426.1±0.01	426.8±0.06
	412.2±0.06	412.2±0.03	412.2±0.01	425.5±0.07	425.5±0.06	425.5±0.08

Note: Note: d.w.: dry weight of powder; Results were expressed as mean ± standard error of triplicate runs.

Appendix D.9 Calculation of specific cell viability

The concentration of soluble components is described as the amount (µg) of soluble solids of CABs in total volume of treatment. The specific cell viability percentage was calculated as described in the following sample calculation

$$Specific\ cell\ viability\ (\%) = \frac{Cell\ viability\ (\%)}{Concentration\ of\ soluble\ component\ (\mu g)}$$

Appendix E

Appendix E **Pictorial assessment**

Appendix E.1 **Identification of plant specimens**

भारत सरकार / GOVERNMENT OF INDIA
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय / MINISTRY OF ENVIRONMENT, FORESTS & CLIMATE CHANGE
वैज्ञानिक –ई कार्यालय / OFFICE OF SCIENTIST - E
भारतीय वनस्पति सर्वेक्षण / BOTANICAL SURVEY OF INDIA
पूर्वी क्षेत्रीय केन्द्र / EASTERN REGIONAL CENTRE
शिलांग–793 003 / SHILLONG-793003

दूरभाष /Telephone: 0364- 2223971, 2223618 ई-मेल / e-mail-bsibsishll@yahoo.co.in Telefax: 0364 -2224119

संख्या /No.: BSI/ERC/ Tech/2021-22/ 388 दिनांक /Dated: 07.01. 2022

सेवा में/To,

Dr. Siddhartha Singha
Assistant Professor
Centre for Rural Technology complex
Indian Institute of Technology Guwahati
Assam - 781039

विषय/Sub.: Identification and authentication of plant specimens-reg.

Respected Sir,

With reference to your letter regarding the subject cited above, I am to inform you that your plant specimens have been identified and confirmed as below-

Sl.	Name of the Species	Family	Specimen No.
1.	*Centella asiatica* (L.) Urb.	Apiaceae	1
2	*Enydra fluctuans* Lour.	Asteraceae	2
3	*Eryngium foetidum* L.	Apiaceae	3
4	*Marsilea minuta* L.	Marsileaceae	4

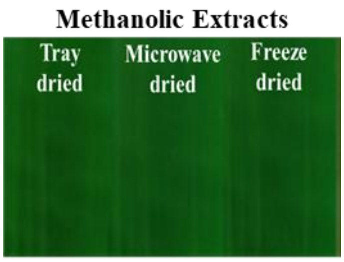
Thanking You,

भवदीय /Yours sincerely

(Dr.Deepu Vijayan)
वैज्ञानिक-'ग' एवं कार्यालय प्रभारी/ Scientist-C In-Charge

Appendix E.2 Dried plant samples in different methods of drying

Appendix E.3 Effect of drying in methanolic extraction



Appendix E.4 Effect of drying and aqueous extraction of *Marsilea minuta*

Marsilea minuta

Appendix E.5 Packaged *Centella asiatica* powder for stability study

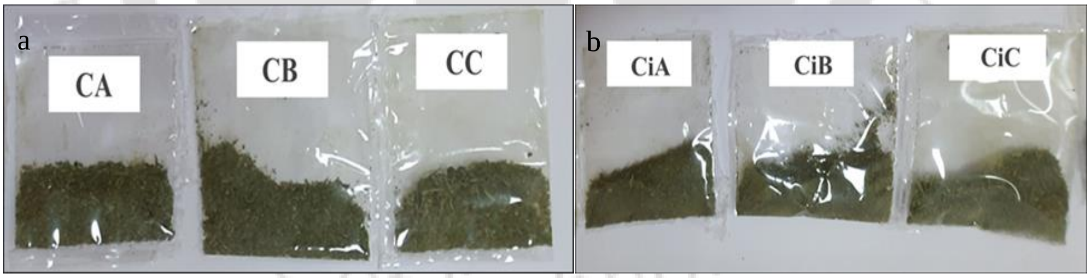


Fig. E.5 Packaged *Centella asiatica* powder for stability study of (a) unblended (b) and blended *Centella asiatica* powder. CA: Unblended *Centella asiatica* powder at 45°C+RH 82%+UV (254nm, 6 h); CB: Unblended *Centella asiatica* powder at 45°C+RH 82%; CC: Unblended *Centella asiatica* powder at 32°C+RH 61%; CiA: Blended *Centella asiatica* powder at 45°C+RH 82%+UV (254nm, 6 h); CiB: Blended *Centella asiatica* powder at 45°C+RH 82%; CiC: Blended *Centella asiatica* powder at 32°C+RH 61%.

Appendix E.6 Beverage prepared at stability study

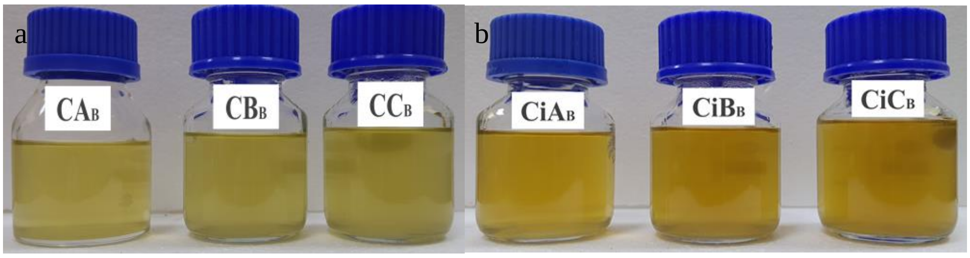
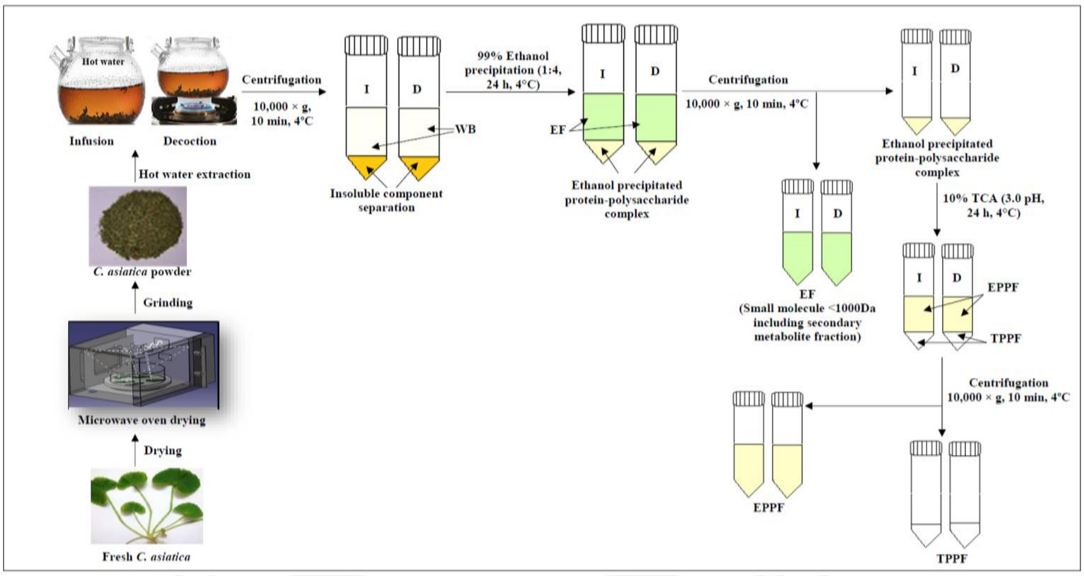


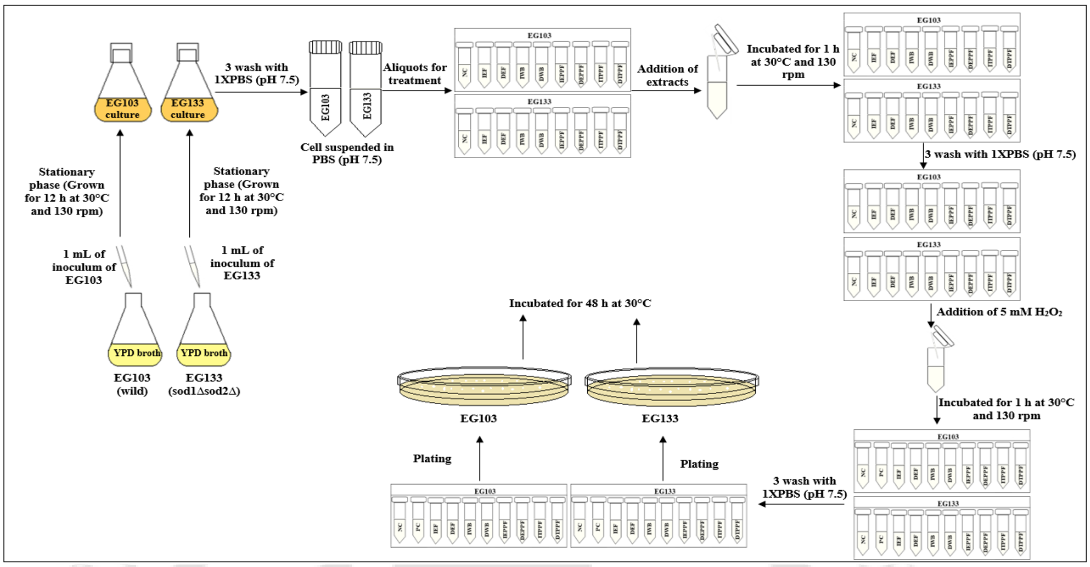
Fig E.6 Appearance of the prepared Beverages of (a) unblended and (b) blended *Centella asiatica* powder. CA_B: Beverage of unblended *Centella asiatica* powder at 45°C+RH 82%+UV (254nm, 6 h); CB: Beverage of unblended *Centella asiatica* powder at 45°C+RH 82%; CC: Beverage of unblended *Centella asiatica* powder at 32°C+RH 61%; CiA: Beverage of blended *Centella asiatica* powder at 45°C+RH 82%+UV (254nm, 6 h); CiB: Beverage of blended *Centella asiatica* powder at 45°C+RH 82%; CiC: Beverage of blended *Centella asiatica* powder at 32°C+RH 61%.

Appendix E.7 Fractionation of CABs



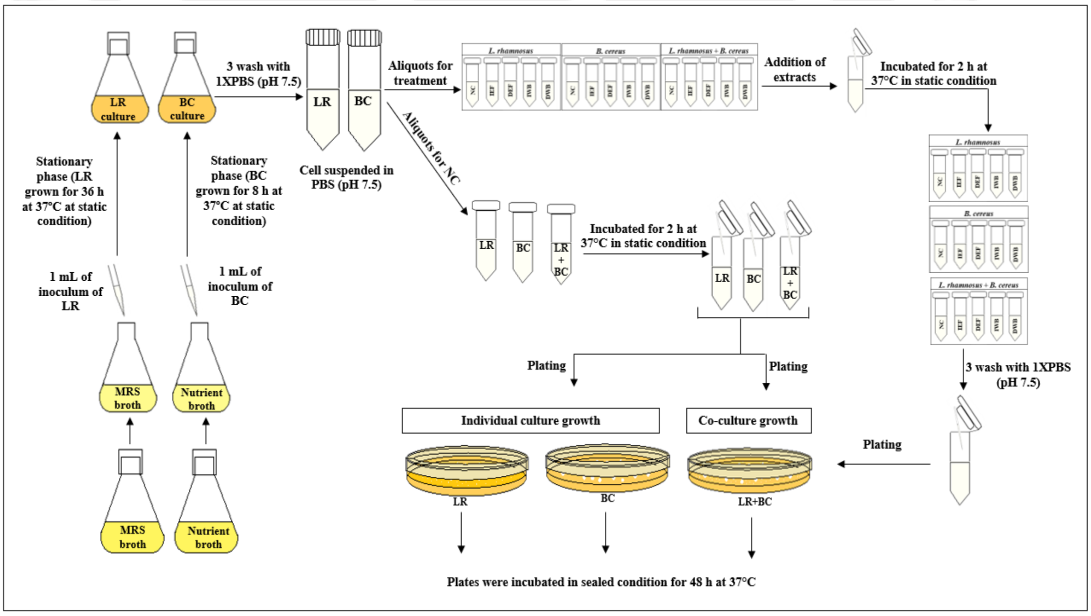
Note: I: Infusion; D: Decoction; TCA: Trichloroacetic acid; EF: Ethanol soluble fraction; EPPF: Ethanol precipitated polysaccharide fraction; TPPF: TCA precipitated protein fraction.

Appendix E.8 Assessment of oxidative stress compensation ability of the CABs in a yeast model



Note: NC: Untreated cells (100% cell viability); PC: Cells treated with 5 mM H_2O_2 (0% cell viability); IWB: Infused whole beverage; IEF: Infused ethanol soluble fraction; IEPPF: Infused ethanol precipitated polysaccharide fraction; ITPPF: Infused TCA precipitated protein fraction; DWB: Decoction whole beverage; DEF: Decoction ethanol soluble fraction; DEPPF: Decoction ethanol precipitated polysaccharide fraction; DTPPF: Decoction TCA precipitated protein fraction.

Appendix E.9 Assessment of prebiotic activity and anti-*Bacillus cereus* activity of CABs



Note: LR: *Lacticaseibacillus rhamnosus* ATCC 53103; BC: *Bacillus cereus*; NC: Untreated cells (100% cell viability); IWB: Infused whole beverage; IEF: Infused ethanol soluble fraction; DWB: Decoction whole beverage; DEF: Decoction ethanol soluble fraction.

Appendix E.10 Effect of different fractions on the viability of H_2O_2 stressed yeast cell

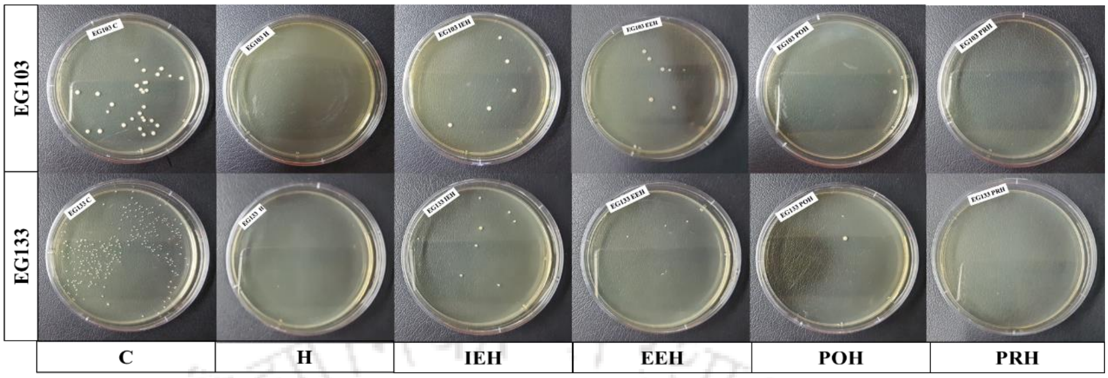


Fig. E.10a Assessment of oxidative stress reducing ability in yeast model for Infused *Centella asiatica* beverages; C: Untreated cells; H: 5 mM H_2O_2 treated cells; IEH: Whole beverage treated cells with 5 mM H_2O_2; EEH: Ethanol soluble fraction treated cells with 5 mM H_2O_2; POH: Ethanolic precipitated polysaccharide fraction treated cells with 5 mM H_2O_2; PRH: TCA precipitated protein fraction treated cells with 5 mM H_2O_2.

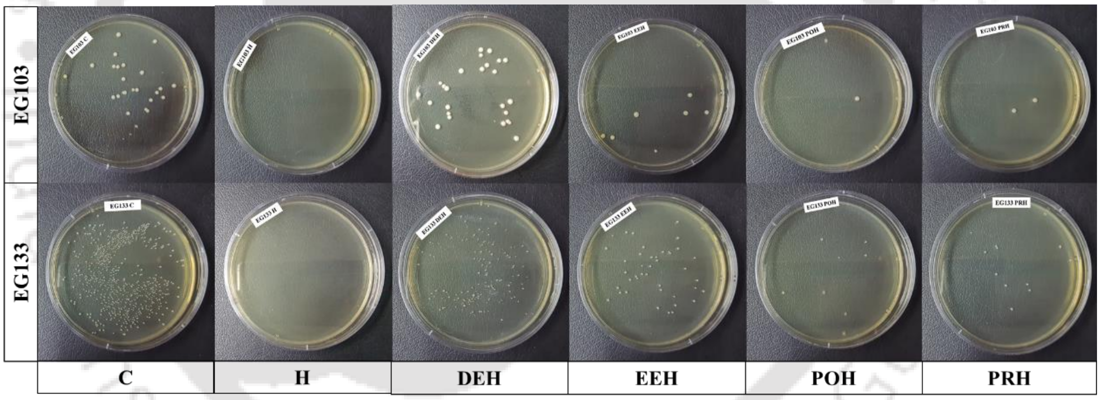


Fig. E.10b Assessment of oxidative stress reducing ability in a yeast model for decoction *Centella asiatica* beverages; C: Untreated cells; H: 5 mM H_2O_2 treated cells; DEH: Whole beverage treated cells with 5 mM H_2O_2; EEH: Ethanol soluble fraction treated cells with 5 mM H_2O_2; POH: Ethanolic precipitated polysaccharide fraction treated cells with 5 mM H_2O_2; PRH: TCA precipitated protein fraction treated cells with 5 mM H_2O_2**.**

Appendix E.11 Effect of small molecule fractions and whole beverages on prebiotic and pathogenic bacteria

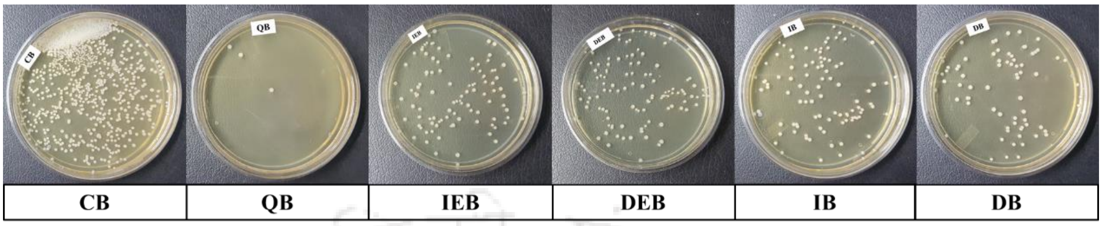


Fig. E.11a Effect of small molecule fractions and whole beverages on *Bacillus cereus* (B); C: Control (only *Bacillus cereus* (B)); QB:100 µM quercetin + *Bacillus cereus* (B); IEB: Infused Ethanolic fraction + *Bacillus cereus* (B); DEB: Decoction Ethanolic fraction + *Bacillus cereus* (B); IB: Infused beverage + *Bacillus cereus* (B); DB: Decoction beverage + *Bacillus cereus* (B).

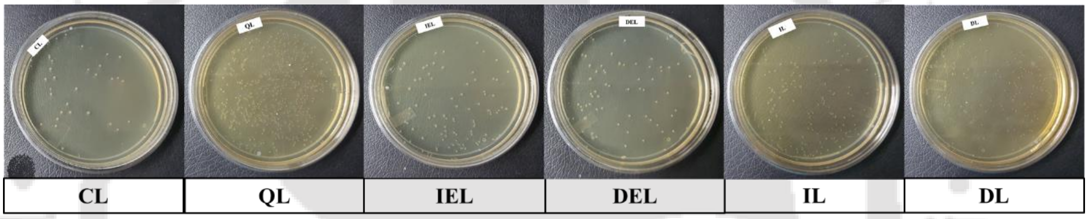


Fig. E.11b Effect of small molecule fractions and whole beverages on *Lacticaseibacillus rhamnosus* (L); CL: Control (only *Lacticaseibacillus rhamnosus* (L)); QL:100 µM quercetin + *Lacticaseibacillus rhamnosus* (L); IEL: Infused Ethanolic fraction + *Lacticaseibacillus rhamnosus* (L); DEL: Decoction Ethanolic fraction + *Lacticaseibacillus rhamnosus* (L); IL: Infused beverage + *Lacticaseibacillus rhamnosus* (L); DL: Decoction beverage + *Lacticaseibacillus rhamnosus* (L).

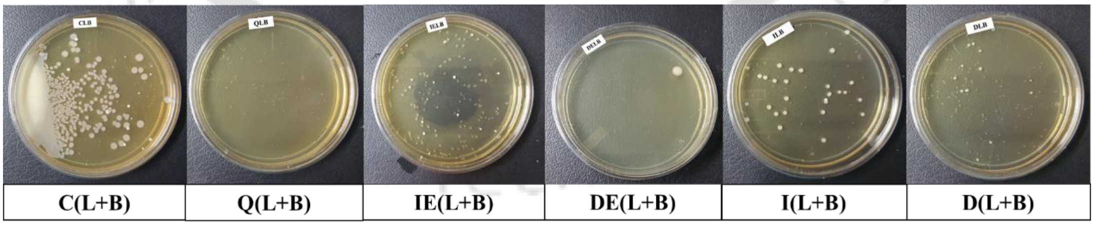


Fig. E.11c Effect of small molecule fractions and whole beverages on *Bacillus cereus* (B) and *Lacticaseibacillus rhamnosus* (L); C(L+B): Control (*Lacticaseibacillus rhamnosus* (L) + *Bacillus cereus* (B)); Q(L+B):100µM quercetin + (*Lacticaseibacillus rhamnosus* (L) + *Bacillus cereus* (B)); IE(L+B): Infused Ethanolic fraction + (*Lacticaseibacillus rhamnosus* (L) + *Bacillus cereus* (B)); DE(L+B): Decoction Ethanolic fraction + (*Lacticaseibacillus rhamnosus* (L) + *Bacillus cereus* (B)); I(L+B): Infused beverage + (*Lacticaseibacillus rhamnosus* (L) + *Bacillus cereus* (B)); D(L+B): Decoction beverage + (*Lacticaseibacillus rhamnosus* (L) + *Bacillus cereus* (B)).