Integrated biorefinery approach towards production of sustainable chemicals and fuel from passion fruit rind

Short Abstract: Agro-industrial waste represents significant potential for the production of biofuels and value-added chemicals, supporting sustainable waste management and resource sustainability. Passion fruit, a tropical fruit, produces over 60% of its weight as byproducts that are rich in bioactive compounds. This study focuses on investigating the antioxidant properties of yellow passion fruit rind from Northeast India and its prospective application in nutraceuticals, food, and biofuels. Polyphenolic compounds from yellow passion fruit rind (YPFR) were extracted utilising green methods, specifically ultrasound-assisted extraction (UAE) and supercritical fluid extraction (SFE). Each extraction technique was optimised by Response Surface Methodology (RSM) and statistically ($p < 0.05$) validated substantial correlations between the process variables and extraction efficiency. The extracts from SFE and UAE demonstrated significant concentrations of phenolics, flavonoids, and carotenoids, which contributed to their enhanced antioxidant activity. Gas chromatography-mass spectroscopy showed UAE's efficacy for extracting a broader range of compounds. High-performance liquid chromatography profiling revealed the selectivity of SFE. Both extracts demonstrated significant antibacterial activity. Thus, it highlights the potential of YPFR as a sustainable source of bioactive compounds. Further, phytochemicals were extracted from YPFR utilising sunflower (SFO) and soybean oil (SBO) as solvents through UAE. The extract-enriched oils exhibited markedly increased carotenoid, phenolic and flavonoid levels, thereby enhanced antioxidant activity. The extract-enriched oils demonstrated increased resistance to lipid oxidation (29.53 - 46.44%) with an enhancement in induction time at 140 °C and improved thermal stability; however, the structural integrity of the oils was preserved. The carbohydrate content (41.3%) in spent passion fruit rind (SPFR) exhibited potential for bioethanol production. The dilute acid pretreatment of SPFR released 122.02 mg/g db of xylose which was detoxified to reduce inhibitor concentration and fermented with *Pichia (Scheffersomyces) stipitis* yielding 9.7 g/L of ethanol. However, the residual biomass obtained following dilute acid pretreatment (PUH-PFR) was treated with 2% NaOH, which removed 92.35% lignin with negligible cellulose loss (7.33%). The enzymatic saccharification of the cellulosic fraction released 67.19 g/L of glucose, which yielded 30.12 g/L of ethanol upon fermentation with *Saccharomyces cerevisiae*. This approach illustrates the possibilities of utilising passion fruit rind waste for sustainable bioethanol production and environmental sustainability.

Keywords: Bioethanol, edible oil, extraction, fermentation, passion fruit rinds, phytochemicals, Sustainable.