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Utilization of Agroindustry Residues Using Supercritical Fluids

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PURPOSE OF THE ABSTRACT

The agroindustry generates a substantial number of residues during the production and processing of agricultural products. Often considered waste, these residues include fruit peels, seeds, husks, and other organic materials that still contain valuable compounds. The efficient management of these by-products is crucial for environmental sustainability, and realizing biocircular economy principles. One promising approach for any biowaste valorization is the use of supercritical fluid (SCF) technology, which allows for its transformation to secondary metabolites and biochemical in an environmentally friendly manner.
Supercritical fluids exhibit unique properties, making them highly effective for extraction and processing applications. When subjected to temperature and pressure conditions above its critical point, a substance reaches its supercritical state, behaving as both a liquid and a gas. The most used supercritical fluid is carbon dioxide ($scCO_2$) due to its non-toxicity, low critical temperature (31.1°C), and ease of removal after processing. Additionally, CO_2 is generally recognized as safe (GRAS) (1) by regulatory agencies, making it ideal for applications in food, pharmaceuticals, and cosmetics.
One of the most significant applications of SCF technology in agroindustry residue utilization is the extraction of bioactive compounds such as polyphenols, carotenoids, essential oils, and lipids. These compounds possess antioxidant, antimicrobial, and anti-inflammatory properties, making them highly valuable in various industries. For example, citrus peels, which are often discarded as waste, contain essential oils rich in limonene, a compound widely used in flavorings, fragrances, and even biodegradable solvents (2). Using $scCO_2$, these oils can be efficiently extracted without harmful organic solvents.
Similarly, coffee and tea industry residues contain significant amounts of polyphenols and caffeine, which can be recovered and repurposed for nutraceutical and cosmetic applications. The residues from wine industries, such as grape seeds, are yet another potential candidate for those applications. The SCF method provides high selectivity

and purity while maintaining the bioactivity of the extracted compounds, enhancing their commercial value (3,4). Beyond extraction, supercritical fluids can modify and enhance biodegradable materials derived from agroindustry residues. For instance, $scCO_2$ can be employed in impregnating bio-based polymers with natural antioxidants, extending their shelf life and improving their functional properties. Agricultural waste, such as rice or corn, can be treated with SCF to develop biodegradable packaging materials that replace conventional plastic products.

The use of SCF technology in agroindustry residue valorization offers a multitude of environmental and economic advantages. It significantly reduces reliance on chemical solvents, thereby minimizing toxic waste and environmental pollution. Moreover, the efficient extraction and utilization of bioactive compounds foster biocircular economy, where waste is transformed into high-value products. This strategy not only benefits industries seeking sustainable raw materials but also creates additional revenue streams for agricultural producers, underscoring the practicality and economic viability of SCF technology.

Two compelling examples, namely spent coffee grounds and grape seeds, will be presented. By harnessing SCFs to extract valuable bioactive compounds and enhance biodegradable materials, industries can significantly reduce waste, enhance efficiency, and develop environmentally friendly products. As the demand for sustainable practices continues to rise, the integration of SCF technology into agro-industrial processes will be pivotal in shaping a more sustainable and resource-efficient future.

FIGURES

FIGURE 1

FIGURE 2

KEYWORDS

Supercritical Carbon Dioxide | Biomass | Fatty acids | Agroindustry residues

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