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Food waste as a useful resource of Bioactive compounds and their Extraction

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Abstract
Extracting bioactive compounds from food waste has become a promising approach to addressing the escalating food waste crisis and the growing demand for functional ingredients with potential health benefits. This review provides a comprehensive overview of recent developments in the extraction of bioactive substances from various sources of food waste. It discusses traditional and advanced extraction methods, such as solvent extraction, pressing, supercritical fluid extraction, ultrasonic extraction, and enzyme-assisted extraction. In addition, bioactive compounds existing in food waste, including polyphenols, flavonoids, proteins, lipids, and essential oils, are being explored for their potential health benefits. Overall, this essay aims to shed light on the transformative potential of extracting bioactive compounds from food waste and highlights the importance of harnessing this intact resource to create a sustainable value-added food industry.
***Keywords*:** Food, Waste, Extraction, Polyphenols, Lipids, Enzymes, Bioactive,

1. INTRODUCTION:

The agri-food business generates significant waste in the form of shells, skins, stems, seeds and pulp, among other things, while processing raw materials. However, due to their low cost, abundance and availability, agro-food wastes may include health-beneficial substances with some market potential [1]. Waste is common in developing countries and affluent societies due to improper handling. Food waste often results from technical constraints in processing and infrastructure, such as packaging, packaging, storage, and marketing. Still, food wastage is often caused by neglect or a deliberate decision to discard food [2]. Food waste generation covers the entire food life cycle, from agriculture to industrial production and processing, retail and household consumption. In developed countries, 42% of food waste is generated by households, 39% occurs in the food industry, 14% in the food service sector and 5% in retail and distribution. Increasingly, industrial ecology concepts such as "cradle to cradle" and the circular economy are seen as the guiding principle of eco-innovation towards a "zero waste economy" in which waste is used as raw material for new products and applications. The large amount of waste generated by the food industry, in addition to the great loss of valuable materials, also creates serious management problems from both an economic and an environmental point of view. However, many of these residues have the potential to be reused in other production systems, such as through bio-refineries. This work is devoted to the use of food waste from food production [3]. It can be achieved by extracting high-quality ingredients such as proteins, polysaccharides, fibers, flavours and phytochemicals that can be reused as nutritional supplements and functional ingredients [4]**.** Natural bioactive compounds are sought after to treat and prevent human diseases. These compounds efficiently interact with proteins, DNA, and other biomolecules to produce desired results, which can be used to design natural therapeutics [5]. There is an increasing trend in today's food industry toward developing and manufacturing functional and dietary supplements. This new kind of food is gaining much attention in the food market due to the growing consumer interest in 'healthy' foods. Therefore, the pharmaceutical and food sectors are interested in obtaining new natural bioactive ingredients that can be used as pharmaceuticals, functional food ingredients or dietary supplements [6].

1.2 Bioactive Compounds in Food Waste

Fruits and vegetables are the most utilized horticulture crop. With an increase in population, there is demand for more production, but the production that gets in access becomes difficult to handle, and hence losses occur in the form of waste. Food and Agriculture Organization (FAO) claims these losses to surpass 60%. Losses also occur in the processing units, skin, seed, rind and pomace, containing good sources of potentially valuable bioactive compounds, such as carotenoids, polyphenols, dietary fibers, vitamins, enzymes, and oils. These phytochemicals can be used in various industries, such as the food industry, the development of functional or fortified foods, the pharmaceutical and pharmaceutical health industry, and the textile industry. Using waste in producing various important bioactive ingredients is an important step towards sustainable development [7]. Fruits and vegetables are the modest functional foods, rich in several biologically active components.

Fruits containing polyphenols and carotenoids have been shown to have antioxidant activity and reduce the risk of certain types of cancer [8]. Bioactive phytochemicals such as sterols, tocopherols, carotenes, terpenes, and polyphenols extracted from tomato byproducts have significant antioxidant activity. Thus, these additional valuable components isolated from such waste can be used as natural antioxidants for the preparation of functional foods or can serve as food additives to extend their shelf life [9]. Waste from the wine industry includes biodegradable solids, namely stems, skins and seeds. Bioactive compounds from winemaking byproducts have been shown to improve health-improving activity both in vitro and in vivo. These compounds act as effective anti-degenerative agents through their inclusion in functional foods, nutraceuticals, and cosmetics [10]. Bioactive peptides are biologically active regulators of a new generation that can prevent oxidation and microbial degradation of food products and can also be useful in treating various diseases. They can be recovered from residual waste and incorporated into value-added products. Their encapsulated form can be used in a controlled manner for effective use in the human body. Developing suitable methods for the large-scale extraction and purification of peptides will increase their application in the pharmaceutical and food industries [11]. Chemical composition of waste coffee waste generated in the production of instant coffee and found that the total amount of polyphenols and tannins is <6 and <4% of waste coffee waste, respectively [12]. Additional technological advances include the loss of bioactive compounds due to under-treatment in traditional extraction processes (maceration, shaking, Soxhlet, etc.) [13].

1.3 Extraction Methods for Bioactive Compounds from Food Waste

1.3.1 Solvent Extraction Method

With this extraction approach, appropriately sized raw materials are exposed to various organic solvents that absorb the soluble components of interest and other flavours and dyes, such as anthocyanins, which have anti-cancer and anti-inflammatory effects [14]. Samples are typically centrifuged and filtered to remove solids, and the extract can be used as an additive, food additive, or in the preparation of functional foods [15]. Solvent extraction is advantageous over other methods due to its low processing cost and ease of operation. However, this method uses toxic solvents, requires an evaporation/concentration step for recovery, and typically requires a large amount of solvent and a long time. In addition, the possibility of thermal degradation of natural bioactive components due to high solvent temperatures with long extraction times cannot be ignored. Solvent extraction has been improved by other methods, such as Soxhlet extraction, ultrasonic or microwave extraction and Supercritical fluid extraction (SFE), to give higher yields [16]. Ethanol is used to extract lycopene and β-carotene from tomato pomace containing dried and crushed peels (rich in lycopene and carotenes) and fruit seeds, as well as supercritical CO_2 to extract up to 50% [17].

1.3.2 Supercritical Fluid Extraction

Supercritical fluid extraction is an environmentally friendly technology commonly used to extract biologically active compounds from natural sources such as plants, food byproducts, algae and microalgae. Supercritical carbon dioxide (SC-CO_2) is an attractive alternative to organic solvents because it is non-explosive, non-toxic and inexpensive. It has the ability to dissolve lipophilic substances and is easily removed from the final products [18]. The raw material is placed in an extraction vessel equipped with temperature and pressure regulators to maintain the necessary conditions during extraction. After that, the extraction container is pumped with liquid using a pump. The products are collected through a valve at the bottom when liquid and dissolved compounds enter the separators. Finally, the liquid is recovered and recycled or released into the environment. The choice of supercritical fluids is very important for the proper functioning of this process, and a wide range of compounds can be used as solvents in this method [19]. The extraction of lipophilic compounds from sorghum, such as tocopherols, phytosterols, policosanols and free fatty acids.is possible by the SFE method. The preventive role of these compounds in many diseases like skin, cardiovascular, coronary heart disease and cancer is apparent [20]. Wheat bran oil, a rich source of antioxidants, is extracted using SC-CO_2 and soxhlet extraction. The pressure and temperature during the extraction of SC-CO_2 ranged from 10 to 30 MPa and 313.15–333.15 K, respectively. It was observed that the oil obtained by SC-CO_2 extraction had higher oxidation stability and higher radical scavenging activity compared to the oil extracted with hexane [21]. SC-CO_2 is used to extract antioxidant compounds from the petals of Crocus sativus at 62 °C for 47 minutes and a pressure of 164 bar. Extraction using these optimized conditions resulted in the recovery of 1423 mg/100 g total phenols, 180 mg/100 g total flavonoids and 103.4 mg/100 g total anthocyanins [22]. For the extraction of biologically active compounds, the supercritical method is a significant replacement for traditional organic solvent extraction methods [23].

1.3.3 Extraction by Ultrasounds:

Ultrasonic extraction is simpler and more efficient than traditional extraction methods for extracting biologically active compounds from natural resources. Ultrasound causes greater solvent diffusion into cellular materials, thereby improving mass transfer and destroying cell walls, facilitating the release of bioactive components. The extraction yield is highly dependent on the ultrasound frequency and the nature of the plant material to be extracted [24]. Different extraction times and solvents were used by mixing to extract four isoflavone derivatives, i.e., glycitin, daidzin, genistin and malonylgenistin, from soybeans. It has been found that ultrasound improves the extraction yield depending on the solvent used [25]. Ghafoor et al.[26] used the ultrasonic extraction method to extract anthocyanins and phenolic compounds from grape skins. The water-soluble polysaccharides from dried and milled byproducts were obtained from *Agaricus bisporus* through ultrasonic technology. β-Glucan was obtained from fungal byproducts of 1.01 and 0.98 g/100 g of dry weight with a particle size of 355–250 and 150–125 µm, respectively. The highest extraction yield of 4.7% was achieved with an extraction time of 15 min, an amplitude of 100 µm, and 1 h of precipitation in 80% ethanol [27].

1.3.4 Extraction Assisted by Enzymes:

Water is the main component of all natural resources; therefore, using water as a solvent instead of organic solvents to extract natural bioactive compounds is recognized as a more environmentally friendly technology, in which oil enzyme-assisted extraction is more effective[28]. Enzymatic extraction is a promising alternative to traditional solvent-based extraction methods. The enzymatic extraction of lycopene from the peel fraction of tomato processing waste found that the extraction of lycopene can be significantly improved through the use of mixed enzyme preparations with cellulolytic and pectinolytic activity and the relatively low cost of a commercial food enzyme [29]. These studies have shown that releasing biologically active compounds from plant cells by cell disruption and extraction can be optimized using enzyme preparations alone or in mixtures. It is based on the ability of enzymes to catalyze reactions under mild processing conditions in aqueous solutions [30].

1.4 Benefits of Bioactive Compounds and Nutraceuticals to Human Health:

An imbalance between the production of reactive oxygen species (ROS) and their destruction by the defence mechanisms in our body creates oxidative stress. Our body's antioxidant systems detoxify reactive intermediates and lead to a reduction in oxidative stress [31]. Nutraceuticals are commonly consumed in pharmaceutical formulations such as pills, capsules, tablets, powders, and vials [32]. Byproducts of the meat industry, such as the brain, nervous system and spinal cord, are a source of cholesterol, which, after extraction, synthesize vitamin D3[33]. In the production of oatmeal, phenolic compounds derived from natural sources, such as benzoin, catechin, chlorogenic acid, and ferulic acid, mixed with other ingredients before extrusion, can produce products that are more resistant to oxidation (slowing down the formation of hexanal). However, the treatment reduced added phenolic compounds by 24–26% [34]. A byproduct of olives, the so-called "*pate*," obtained during modern two-phase centrifugal processing, can be used as a natural source of biologically active compounds. It was characterized by hydroxytyrosol, β-hydroxyverbascoside, oleoside derivative, luteolin, etc., as potential ingredients for the preparation of nutraceuticals or the feed industry [35].

2. CONCLUSION:

In conclusion, the recovery of bioactive substances from food waste represents a paradigm shift towards a more sustainable and circular food system. By tapping into the available potential of food waste, one can discover many biologically active compounds with diverse health benefits, followed by reducing the environmental burden. As researchers and practitioners, our collective efforts in this direction promise a brighter and healthier future in which food waste becomes a valuable resource for nourishing our bodies and the planet.

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