Antioxidant Molecules from Plant Waste

Subjects: Others

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The fruit, vegetable, legume, and cereal industries generate many wastes, representing an environmental pollution problem. However, these wastes are a rich source of antioxidant molecules such as terpenes, phenolic compounds, phytosterols, and bioactive peptides with potential applications mainly in the food and pharmaceutical industries, and they exhibit multiple biological properties including antidiabetic, anti-obesity, antihypertensive, anticancer, and antibacterial properties. The aforementioned has increased studies on the recovery of antioxidant compounds using green technologies to value plant waste, since they represent more efficient and sustainable processes. In this review, the main antioxidant molecules from plants are briefly described and the advantages and disadvantages of the use of conventional and green extraction technologies used for the recovery and optimization of the yield of antioxidant naturals are detailed; finally, recent studies on biological properties of antioxidant molecules extracted from plant waste are presented here.

terpenes phytosterols phenolics peptides

1. Introduction

According to the Food and Agriculture Organization of the United Nations [1], globally, agriculture produces 8.65 billion tons of food per year. Along the agricultural food supply chain, a large amount of waste of fruits, vegetables, cereals, and pulses is produced, mainly during post-harvest, processing, and household consumption [2][3]. The levels of agricultural waste vary from region to region. For example, the United States of America generates about 15 million tons of fruit and vegetable waste, while China generates 32 million tons [4]. Cereals waste represents 10–12% of North America and Europe's total production, while Asia is up to 18% [5]. In Mexico, the processing of fruits, vegetables, and cereals generates about 76 million tons of waste per year [6].

The main agricultural wastes of peels, pomace, seeds, leaves, resin, and others are produced each year and are commonly disposed of in the environment, causing serious pollution and environmental problems. However, these wastes represent one of the main sources of low-cost antioxidants molecules, including terpenes, phytosterols, phenolic compounds, and peptides [7][8][9][10]. The antioxidant molecules could be used as food additives, pharmaceuticals, or therapeutic agents, because they have been shown to play an important role in the prevention and adjunctive treatment of diseases such as diabetes, cancer, hypertension, and metabolic syndrome [11][12][13][14][15].

Therefore, the revaluing of plant-derived waste is a topic of interest to the scientific community. The attention has been focused on studying the recovery technologies for antioxidant molecules, especially those that are friendly to the environment, also known as green extraction technologies or non-conventional technologies such as enzyme-aided extraction, ultrasonic and microwave-assisted extraction, pressurized liquid extraction, and supercritical fluid extraction. These green technologies have replaced conventional technologies such as maceration and hydrodistillation, due to their high yield, reduced extraction process time, and mild conditions that prevent or reduce the degradation of the antioxidant molecules maintaining their quality, but above all, because the compounds of interest are recovered from sustainable processes [16][17][18].

2. Plant Waste as Source of Bioactive Compounds

Waste from inedible parts of plants such as peel, leaves, stem, seed, and root can be generated during the harvesting, post-harvesting, or processing [19]. They constitute a low-cost source of antioxidant molecules, including terpenes, polyphenols, phytosterols, and peptides, which exhibit antidiabetic, anti-obesity, antihypertensive, anticancer, and antibacterial properties [12][20][21][22][23]. However, these residues might have a negative impact on the environment. In this regard, as an effort to reduce the environmental consequences of plant waste and their potential exploitation, studies have focused on giving added value to plants waste through green extraction of antioxidant molecules, for intensifying their use as functional additives, or as a therapeutic alternative in the treatment or prevention of chronic diseases such as cardiovascular diseases, diabetes, and cancer [24].

Peels and pomace of fruits such as mango, apple, grape, pomegranate, pineapple, banana, and orange are the main waste of the agri-food industry, which might present a greater content of phenolic compounds than the edible portion [19][25]. On the other hand, the oil industry of almond, rapeseed meal, and coconut; the processing of cereals (mainly wheat, rice, and oat); and the pitting process of fruits such as olive, plump, tomato, and peach generate large amounts of protein-rich residues, which have recently been used for the production of bioactive peptides [9][26][27][28][29][30][31][32][33]. Terpenes have been extracted mainly from essential oils from leaves, resins, and cones of trees such as *Pinus taeda*, *Pistacia lentiscus*, etc. [34]. Oils from fruits (e.g., melon, mango, orange, berries, papaya, apple, passion fruit, and guava seeds) and cereals (e.g., wheat, oat, and rice) are generally known to be the best natural sources of dietary plant sterols known as phytosterols [35][36][37].

3. Conclusions and Future Perspectives

The use of non-conventional extraction technologies or green technologies to obtain antioxidant molecules such as terpenes, phenolic compounds, phytosterols, and bioactive peptides from plant waste has increased in recent years in order to exploit and give added value to this type of waste, reduce environmental impact, obtain high quality extracts, safe products, reduce energy and solvent consumption, and increase the yield of the final product. Likewise, the number of studies focused on optimizing the conditions of the recovery process of this type of molecule has augmented, due to the nature of the plant material and the structural chemical differences (hydrophilicity and lipophilicity) presented by the antioxidant molecules discussed here, which have been widely

studied due to their potential to prevent or treat cardiovascular diseases and others related to metabolic syndrome. However, although there is a wide variety of studies on the potential benefit of antioxidant molecules on human health, clinical studies are needed to confirm the findings reported both in vitro in animal models.

Extraction of antioxidant molecules by SFE represents a viable option for its potential use at an industrial scale. Antioxidants obtained by SFE maintain their chemical structure and functional properties. Furthermore, the solvent CO_2 used in SFE is safe and available. Additionally, SFE is already being used in industrial processes, such as coffee decaffeination, which reveals its scalable potential.

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