Valorization of Fruit and Vegetable Waste for Bioactive Compound and Their Application in Food Industry

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Abstract

The current generations are wasting the food in large quantities because the production of fruits and vegetables has become significantly increasing but the waste utilization is still lacking. To narrow down the wastage of fruits and vegetables and the carbon footprint, the researchers working effectively to utilizing the underused waste like skin, pomace, seed, kernels, rind, leaves. The fruit waste contains many bioactive compounds such as flavonoids, dietary fiber, phenols, phytochemical, polysaccharides, carotenoids, anthocyanin, etc. Recent findings of valorization of fruit and vegetable waste had a great impact on the world using different extraction methods, to extract the bioactive compounds and apply them in food sectors such as food additives, adsorbents, natural colorants, indicators, fermentation processes, functional foods, pharmaceuticals, packaging industry, storage of fresh and processed foods, compost, and animal feed. The waste utilization also helps in generating employment opportunities, reducing food waste, creating novel by-products, and bringing a great revolution in the food industry.

Introduction

The fruits and vegetables generally rich in many vitamins, minerals, organic compounds, polysaccharides, fibers, proteins, fats, phytochemicals, flavonoids, etc. Bioactive compounds found in fruits and vegetables can be incorporated into our regular diet. The waste materials such as peels, seeds, stem, pulp, and pomace also contain beneficial compounds. Unfortunately, these compounds are often wasted due to underutilization or low usage of these waste materials. According to the Food and agricultural organization (FAO), food waste is one of the causes for the release of carbon footprint accounting for 3.3 billion tons of carbon-dioxide in 2023. Valorization of fruit waste by extracting the bioactive components of anti-oxidants, antimicrobial properties, anthocyanin, betalain, etc., using different techniques like traditional methods, high-pressure extraction methods, ultrasound-assisted extraction method, novel green extraction and soxhlet extraction methods. These bioactive compounds are used in pharmaceutical industry, food industry, by-products can be used for feeding animals or being used as compost production of methane gas, incineration of waste and some components are used in food preservation.

Bioactive compounds from fruit and vegetable waste

The bioactive compounds vary between each fruit and vegetable waste converts the waste into high value-added products where these compounds are extracted by various method of extraction and it has been listed in the below (Table.1).

Traditional method of extraction

The bioactive compounds in fruit and vegetable waste can be extracted using conventional method such as Soxhlet extraction, maceration, percolation, decoction, solid-liquid extraction, hydro distillation. Maceration method, the samples are ground, mixed with solvents, and continuously agitated using agitator to out filter contaminants. This is commonly used simple method, but it may take long time and only heat sensitive material are suitable for this technique. The Soxhlet method is a continuous and efficient extraction technique that combines reflux and percolation extraction to separate bioactive components from fruit and vegetable waste. It works on the principle solvent reflux and siphoning, requires less solvent, takes less time, can expose materials to high temperatures, and is cost-effective

Extraction of Novel green-emerging method

Over the past few years, new emerging technologies were developed and practiced. These non-conventional methods are time-saving, reduce solvent usage, and improve energy efficiency compared to conventional extraction methods. The emerging novel techniques include Supercritical Fluid Extraction (SFE), Microwave-Assisted Extraction (MAE), Enzyme-Assisted (EAE), Pulsed Electric Field Extraction (PEFE), High-pressure method and

Ultrasound-Assisted Extraction method (UAE). Since emerging technologies are advanced and have many advantages, they are considered to be the most promising methods for extraction.

Table 1. Bioactive compounds in fruit waste and methods for their extraction

Fruit waste	Bioactive compounds	Extraction methods
Banana peel	Gallocatechin, catechin, tannin, phenolics	Homogenization, conventional method
Avocado peel	Flavonoids, procyanidins, phenolic components	Soxhlet extraction
Mango peel	Phenolic acid, anti-bacterial properties	Ultrasound-assisted, enzyme-assisted extraction
Citrus peel (secondary metabolites)	Terpenoids, coumarins, Flavanones, polyethoxylated flavones	Conventional solvent extraction
Apple seed, red pitaya seed, pomegranate seed, grape seed	Polyphenols, tannin, flavonoids, ascorbic acid and phenylpropanoids	Supercritical fluid extraction, homogenisation
Mango waste	Catechin, epicatechin, kaempferol	Soxhelt, percolation and maceration
Pomegranate by-products	Punicalagin, ellagic acid, hydrolysable tannins	homogenisation
Rambutan by - products	Ellagitannins, capsaicins, di-hydrocapsaicin	Maceration
Mango by-products	Phenolics acids, sterols, carotenoids, tocopherols	Percolation
Kiwi leaves	Alcoholic, actinidin and hydroalcoholic extracts	Ultrasound assisted extraction
Papaya peel	Papain, phenolic components	Ultrasound assisted extraction
Chaya and papaya stalks	Papain	Enzyme-assisted extraction
Major constitutent	Vanones, flavones, terpenes, citral, aldehydes, ester, quinones, capsaicin, tocopherols	Conventional method of extraction

Extraction of Supercritical fluids (SFE)

The process of separating bioactive compounds from fruit waste using the supercritical fluid, which has the characteristics of solvation powder, surface tension, and diffusion. When the solvent is subjected to high temperature and pressure for a certain period, it reaches the supercritical state above its critical point. Supercritical fluid is the combination of carbon and water which forms carbon-di-oxide and is maintained at the temperature of 31^0C. This method is used to extract essential oil, flavonoids, carotenoids, phenolic compounds, and alkaloids from pomegranate peel, tomato skin, pineapple waste, and vegetable waste.

Pressurized liquid extraction technique (PLE): Using this method the bioactive compounds extracted from the fruits waste of beet waste, pomegranate peel, feijoa peel extracts, etc. and the component such as ferrulic acid, pectin, anti-oxidants, phenolic compound, anthocyanin, sinapaldehyde and others. The principle PLE is application of high pressure to the solvent and maintaining it in the liquid state beyond its boiling point. These extracted bioactive components are identified using Liquid Chromatography-mass spectrometry (LC-MS).

Ultrasound - Assisted Extraction (UAE)

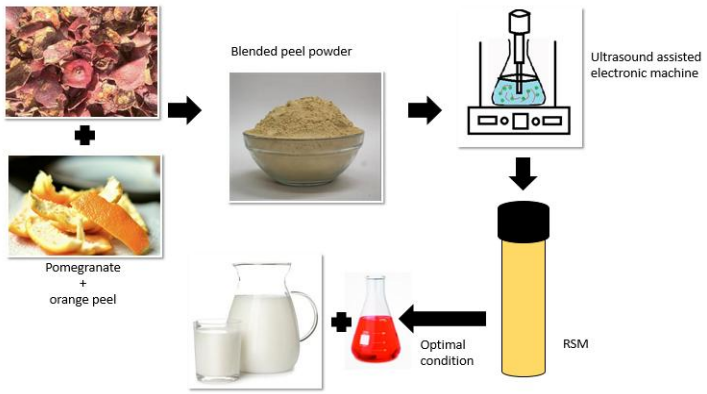

Fig. 2. Ultrasound Assisted Electronic Machine process

The process of applying intense ultrasonic waves with the frequency of 20 kHz and 100MHz which is not audible to humans. The UAE method takes less duration, easy to operate, less solvent usage, less temperature, etc. From the peel waste pectin can be extracted after the cell was rupturing of waste materials and their process is shown in the (fig 2). The fruit waste used here is pomegranate peel, rind, and sunflower head, orange peel, grapefruit peel, tomato waste, grape pomace, durian rind, eggplant peel, jackfruit peel, mango peel, etc.

Bioactive compounds used in food industry

The fruit and vegetable waste suitable for varies use in the food sectors includes processing industry, preservation, food fortification, pharmaceutical industry, and compost unit, by extracting their bioactive compounds. These compounds are infused to produce by-products and become industrialized. Some of the byproducts get degraded quickly and are utilized as animal feed. After the potato chips, the peels are processed, the peels are collected, and the anti-oxidant using a suitable method which is used as a supplement in fresh-cut fruits to avoid browning reactions during storage. The fruit pomace also contains useful bioactive compounds that can be utilized by adding flavor to baked foods, pomace brandy, pomace oil, blended products, beef substitutes, etc. In dairy industry, the fruit pomace is used as natural texturizer and stabilizer in skimmed milk at different concentrations. To improve the lipid stability of cooked chicken they are packaged in vacuum packaging infused with grape extract. The peel waste also used in packaging technology as the green apple peel extract contains phenolic components and anti-oxidant property that is being incorporated with ethanolic extracts of freeze-dried apple peel and aqueous extracts of fresh apple skin to make active packaging of edible film of methylcellulose.

Future challenges

This waste utilization also helps in generating employment opportunities, reducing food waste, creating novel by-products, and bringing a great revolution in the food industry. These newly emerging technologies need to gain higher potential in the market and also for export. The machines and installation costs are higher and researchers should have an interest in creating novel products using these bioactive compounds from the waste of fruits and vegetables and further mitigate the supply-demand. The technology used for the extraction process is advanced compared to the conventional method hence, there will be a need for a skilled person to operate. There are several generations of job opportunities in the food sector for bio-based products and these bioactive compound-based by-products can also be used in the medical and packaging industry.

Conclusion

The study focusses on the waste utilization of fruit and vegetable for its various properties like anti-oxidants, anti-microbial, anti-browning, adsorbent, natural pigment, enzyme. The major concern is to extract the bioactive compound from the sustainable waste to reduce the carbon footprint and greenhouse. To mitigate these problems novel technologies has been developed are more rapid process with better extraction quality, more efficient, higher production of co-products. Due to this new technology, generation of employment opportunities for the unemployed graduates is getting increased, better utilization of raw materials but while processing removes the toxic compounds such as heavy metals, pesticides and other chemicals. After removal of such compounds the subjected to the extraction of bioactive compounds and their extracts are used as supplements, coloring agents, food additive, and also in fortified foods.

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