Review Article

Utilization of By-Products of Fruits and Vegetables in Food Industries

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Abstract

The world's population is expanding significantly, which is driving up demand for fruits and vegetables globally. Fruits and vegetables are not consumed in their entirety by consumers, and this can lead to massive amounts of food waste being produced globally. Fruit and vegetable wastes are generated throughout the supply chain and vary greatly based on how they were processed. 10–60% of by-products, both in solid and liquid form, were produced by the processing of fruits and vegetables. Additionally, certain fruit and vegetable by-products can be used as food and functional additives in the food industry since they have a high nutritional value. Moreover, unused by-products including seed coats, hulls, peels, seeds and pomace are rich sources of useful molecules like phytochemicals, minerals and vitamins with health advantages. Utilizing fruit and vegetable waste can therefore aid in reducing food shortages, mitigating environmental damage, and boosting industry profits.

Keywords: Fruits, vegetables, wastes, processing by-products, food additives

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Introduction

According to a Food and Agriculture Organization (FAO) estimate, almost 40% of the food produced in India is wasted [1]. The Food Corporation of India also reported a 10-15% decrease in overall food production. India estimated its overall fruit and vegetable losses at 12 and 21 million tonnes, respectively, according to the Ministry of Food Processing Industries (MFPI) [2, 3]. Fruit and vegetable waste (FVW) is a word used to describe an inedible portion of produce i.e., discarded after a given stage, such as handling, collection, processing, and shipment. This concept allows fruit and vegetable waste to be regarded as a loss as opposed to waste. The FVW can be used to extract natural substances that are beneficial to the food, cosmetics, pharmaceutical, and textile sectors. Horticultural crops account for a large portion of the FVW produced [4]. Their effective application will aid in the resolution of environmental problems and serve as a sustainable method of enhancing health using enhanced foods, including health-improving ingredients [5]. Although fruit and vegetables are frequently used as sources of natural chemicals, numerous by-products (such as cores, seeds, peels, and pomaces) are discarded during processing, accounting for 25% to 30% of waste for the overall commodity category [6, 7].

When compared to the conventionally used vegetable part, these by-products exhibit an unusually high level of phytochemical compounds; as a result, they can be used in the formulation and fortification of food items. [8, 9] The production of important products like carbon dots, biosorbents, and edible films by poor nations uses FVW, particularly peels, making them sustainable and environmentally acceptable materials that can be put to good use [10]. In order to feed an expanding population, food output must increase and food costs must decrease. Cost-cutting must be done without sacrificing quality. Utilizing waste is one innovative way to decrease loss. This would contribute to lowering processing-related losses [11].

Finding natural agents with novel mechanisms of action is urgently needed due to the rising threat of infectious illnesses. Fruit and vegetable solid waste has economic value and can be used to make a variety of by-products. Peels from fruits and vegetables are discarded into the environment as horticultural waste, which can be used as a source of antimicrobics [12]. Due to ruminants' capacity to digest fiber, a number of by-products may be valuable. By-products are a well-known important source of sugars, minerals, organic acids, dietary fiber, and phenolics, which have a variety of actions, including antitumoral, antiviral, antibacterial, cardioprotective and antimutagenic properties [13]. However, the use of by-products is restricted since their nutritional and financial worth are not well understood.

Production of by-products from Fruits and Vegetables

According to statistics, by-products such as leaves, seeds, stems, branches, peels, trash from trimming, pulps, and bagasse account for 38% of the weight of the used raw material [14].

In **Figure 1**, the main by-products from different fruits and vegetables are shown.

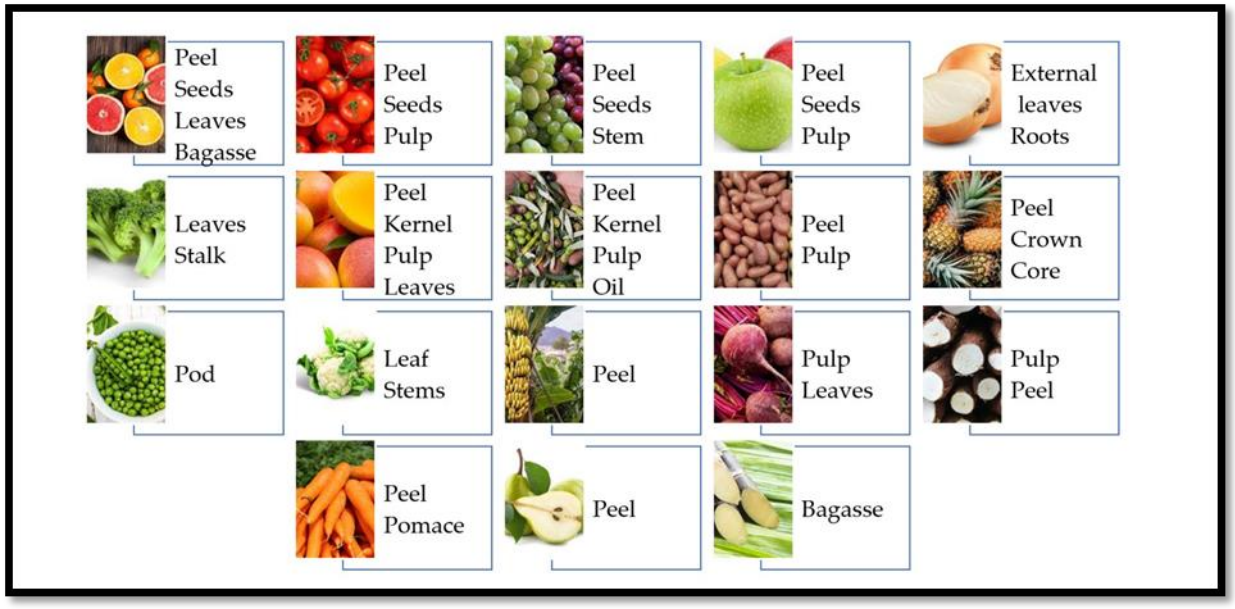

Figure 1 By-products of fruits and vegetables

By-products of Fruits

- Orange, lemon, lime and mandarin are the four principal citrus fruits that are widely grown throughout the world. The industry produces by-products such as peels, interior tissue and seeds. In the course of processing, over 50% of the fruit is converted to by-products and 15 million tonnes of peel waste are produced annually [15, 16].
- Bagasse from grapes (*Vitis* sp.) is another waste product created during the manufacturing of wine, which accounts for around 80% of all grape output. It is made up of the peels, seeds and stems of the fruit. The manufacturing of juices, jellies and raisins may also produce by-products, though in smaller amounts [17].
- Apple (*Malus domestica*) pomace, a by-product of the fruit juice sector, is made up of apple peels, seeds, stems and pulp [18].
- Mango (*Mangifera indica* L.), mostly produces peels and seeds as by-products.
- The biggest manufacturers of bagasse are the alcoholic beverage and sugar industries, which also utilize sugarcane extensively. Other residues are produced as well, including cane trash, molasses and press mud, even though bagasse is the principal by-product [19].

By-products of Vegetables

- The primary by-products of the tomato (*Lycopersicon esculentum* L.), which is the second-most significant vegetable crop in the world, are peels, seeds and pulp [20].
- Peel is the most valuable by-product of the potato (*Solanum tuberosum* L). The main outcomes of processing potatoes are chips and fries [21].
- Broccoli and cauliflower (*Brassica oleraceae* var. *italica*) both create the by-products leaf and stem. According to a production estimate for broccoli and cauliflower, 50% of the leftovers might be used as animal feed and the other 50% for bioconversion into new products.
- The pod of the pea (*Pisum sativum* L.), is one of the principal by-product that is typically rejected and burned despite having a high protein content [22].
- The by-products of the carrot (Daucus carota L.), which is a rich source of carotene, are largely pomace and peels [23].

Nutritional, Bioactive and Dietary Potential of Fruit and Vegetable By-products

In the world, about half of the produce for fruits and vegetables is wasted. The food waste contains millions of tonnes of nutrients that are being lost. Due to the presence of bioactive chemicals, these fruits and vegetables also provide

neuroprotection and a lower risk of diseases of the central nervous system, such as Alzheimer's disease (AD) and dementia. Therefore, it is crucial that every consumer makes an effort to reduce food waste, and a big part of that goal can be readily accomplished by incorporating fruits and vegetables into our diets that we previously mistakenly deemed to be inedible. Below is a detailed evaluation of their nutritional, bioactive, and dietary potential, with a summary in **Table 1** [23, 24].

Table 1 Nutrition, bioactive and potential of different fruits and vegetable by-products

Fruit or Vegetable	By-products: Nutritional and Bioactive Potential	Dietary Uses
Fruit		
Apple	peel: phenolic compounds (chlorogenic acid, procyanidin B_2)	edible, vinegar, cider
Banana	peel: crude fiber, carbohydrates, minerals	edible after cooking, flour, fermented beverage
Citrus	peel: fiber, vitamin C, limonoids, essential oils	flavoured tea, natural food additive
Mango	seeds: flavonoids, phenolic acids and fats	mango seed edible fats, flour
Vegetable		
Broccoli	stalks: phenolic compounds, sugars, pectin, free amino acids, glucosinolates	edible after cooking, natural food additives (soups, tea, flour, pasta)
Cauliflower	stem and leaves: fat, carbohydrates, dietary fiber, glucosinolates, minerals	edible after cooking, leaf powder as a supplement
Potato	peel: glycoalkaloids, polyphenols, lipids, lignin, cellulose	edible after cooking, natural food additive
Pumpkin	peel and rind: pectins, carotenoids, flavonols, vitamins	edible after cooking, natural food additive

Utilization of Fruits and Vegetables By-products

Following is a discussion of a few unique value-added products made from fruit and vegetable by-products and their uses**.**

Value-added Products

Essential Oils

Essential oils may be found in orange peels (EO). Due to its aromatic flavour, EO is frequently used in home items, alcoholic beverages, confections, soft drinks, perfumes, soaps and cosmetics. Tea blends and preparations for stomachic, carminative, and laxative effects contain oils from both sweet and bitter oranges [25, 26].

Edible Oils

The fatty acid and triglyceride profiles of the fat found in mango seed kernels are promising as a source of edible oil since they resemble cocoa butter. Guava seeds contain between 5 and 13% oil rich in important fatty acids, however, they are typically thrown away during the processing of juice and pulp. Free radical scavenging is a property of the oil [27].

Pigments

Carotenoids like lycopene are abundant in tomato peel. It might be helpful in treating chronic illnesses like cancer, coronary heart disease and others. Carotenoids are also abundant in carrot pomace. Banana bracts (leaves below the calyx) and beetroot pulp anthocyanin pigments were assessed for their potential use as natural food colourants [28].

Food Additives

Onion pomace can be utilized in snacks, whereas carrot pomace can be used in bread, cake, dressing, pickles and functional drinks. By scavenging oxygen free radicals, antioxidant chemicals derived from food industry waste products could be used to guard against oxidative damage in living systems.

Fermented Edible Products

The fermentation of fruit wastes yields a variety of alcoholic beverages, including cider, beer, wine, brandy and vinegar. Cider has previously been made from apple pomace. It has also been investigated whether dried surplus and cull fruit, such as apples, grapes and oranges, may be used to make brandy [29, 30].

The utilization of fruit and vegetable by-products as functional ingredients is covered in the section that follows:

Functional Ingredients

Bread

A typical confectionary item that is commonly consumed internationally is bread. It has been discovered that adding vegetable and fruit leftovers like tomato pomace and pea hulls boosted the bread's nutritional value [31, 32].

Cookies and Biscuits

Popular confectionery items like biscuits and cookies are frequently eaten as sweet desserts rather than savoury dishes. The lengthy shelf life and low water activity of cookies and biscuits make them excellent emergency food options [33]. The nutritional qualities of cookies and biscuits, such as dietary fiber and minerals, were improved when vegetable and fruit by-products including potato peel fiber, pomegranate peel, apricot kernel, etc. were added [34].

Noodles

The basic component of noodles is wheat flour. The amount of fiber and protein in noodles was dramatically boosted when vegetable and fruit by-products were added. It has been demonstrated that adding fruit and vegetable by-products, such as the coat of a legume seed, pomegranate peel, apricot kernel, etc., to noodles boosted their antioxidant activity because these by-products were high in fiber and phenolic compounds [35, 36].

Dairy Products

Salad dressing, cheese, and ice cream are examples of dairy products that successfully utilize vegetable and fruit by-products [37]. Additionally, they are employed as a fat substitute and a natural colorant, demonstrating the breadth of their potential as functional additives. As a natural colorant, ice cream's inclusion has shown good acceptability, but additional research may be done on novel inventions that use a thermal procedure to determine the colorant's durability [38].

Other Products

Vegetable and fruit by-products have been included in the development of various food kinds, improving the dietary fiber content. The nutritious value of traditional Indian foods was enhanced, for instance, by the addition of mango seed kernel and cauliflower by-products to idli, dhokla, and pancake [39]. The inclusion of tomato pomace enhanced the nutritional fiber content of the jam [40].

Conclusion

The efficient utilization of by-products from the production of fruits and vegetables has recently come under intense social and environmental strain as a result of the increase of food production worldwide. Due to their high nutritious content, food industry by-products provide numerous health advantages. The by-products from fruits and vegetables are loaded with health advantages, including anti-inflammatory, anti-cancer, anti-diabetic and anti-hypercholesterolemic activities. These by-products are a good source of nutraceuticals, functional foods, and bioactive chemicals. These advantages all present opportunities for the waste to be used therapeutically in the future. Utilizing by-products gives industries a second revenue stream, which boosts economic productivity. As a result, it is a strategy to address the growing issue of food security and can boost the sustainability of food. The significant amounts of fruit and vegetable wastes that have accumulated globally would be significantly reduced by the combined efforts of waste minimization and sustainable exploitation of the by-products.

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