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Valorization of fruit Byproducts: A review

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Abstract
Increasing worldwide population and consumer awareness of the health benefits of fruit consumption have contributed to an increase in demand for both fresh and processed fruits. The global fruit and vegetable processing industry produces millions of tonnes of garbage annually. As a result of the increase in the production and processing of fruits, the disposal of waste and by-product streams, which are prone to microbial degradation, has become a major concern. Inadequate waste management practises also pose grave environmental risks. In addition, the expense of drying and storing fruit processing wastes is an economic factor that prevents their future usage. Therefore, the majority of fruit debris, such as peels, pomace, seeds, stalks, and leaves, end up in landfills or rivers, causing environmental dangers. A substantial portion of fruit by products can be effectively valorized as animal feed, sources of bioactive compounds/pigments, feedstock for biofuel production, and soil amendment. Bioactive pigments can be used as food additives, antioxidants, colour intensifiers, natural colourants, or substrates for the development of high-value products. Bioactive compounds have great promise as functional additives and nutraceuticals in the food industry, as well as in pharmaceutical and cosmetic applications. These by-products, on the other hand, contain a substantial amount of dietary fibre in addition to bioactive compounds with important biological functions, such as antioxidant and antibacterial properties. Thus, the valorization of fruit processing by-products into compounds with high added value is a promising alternative not only for the management of fruit residues, but also for the manufacture of functional food products with high nutritional content and many potential health advantages.

Keywords: Processed fruits, waste management, volarization, bioactive compounds, dietry fibre, pharmaceutical

Introduction
Fruits are the most extensively consumed and lucrative products generated by horticulture crops. The term "fruit byproducts" refers to any unwanted or unconsumed fragments of fruit that occur from incorrect handling or discarding of fruit. The amount and variety of fruit by-products vary according on the fruit's commodities and physical characteristics. These include seeds, pomace, pulp, skin, leaves, and tuber, among others. Peel, seeds, and other non-edible components of fruits contain a substantial number of minerals and phytochemicals that are vital to human health [26].

Several fruit byproducts have been identified as rich sources of phenolic chemicals. One of the greatest classes of bioactive and value-added chemicals is phenolic compounds. The phenolic content of the seeds of jackfruits, mangoes, and avocados, as well as the skins of grapes, oranges, and lemons, is approximately 15% greater than that of the fruit pulp [32].

Valorization is the process of repurposing food waste into food or feed products, as well as converting or extracting food or feed ingredients. It is a sustainable method of converting food waste into goods with added value, hence reducing food waste disposal in landfills and greenhouse gas emissions. It is a sensible waste management strategy.

The processing industries are the primary producers of enormous quantities of byproducts and trash [8]. Because of this, the disposal and management of fruit have become a global priority. Due to the vulnerability of these compounds to microbial degradation, it is likely that a high amount of environmental pollution will ensue. To find a solution to this issue, it is necessary to examine several management alternatives [11]. The transformation of fruit byproducts into compounds with a high value-added content is a promising potential solution to this issue. As a result, by-products of processed fruits, such as peels, leftover flesh, and seeds, are included into the production of functional food products with a high nutritional value and multiple health advantages. As a result, it can be utilized in numerous industries, including agriculture, nutraceuticals, cosmetics, and medicines.

Fruit Byproducts

Fruit waste is one of the main sources of municipal solid trash, which has long been a source of concern for the environment [29]. Any substance thrown from residential, commercial, or industrial activities is considered municipal solid waste [1]. Fruit peels or rinds are examples of byproducts that are frequently wasted during the consuming or production process. It is the outer covering of fruits that protects them from environmental conditions. Some fruits, such as pomegranate, have thick and rough skin, whilst others, such as mango, have a thin peel. Because of the rough texture and harsh aftertaste, most fruit skins are not consumed by consumers. Other fruit by-products, such as seeds, are commonly consumed with fruits like watermelon and kiwi. Larger seeds, on the other hand, are not eaten and are typically discarded after the flesh has been consumed. Fruit seeds are high in nutritional value and have been employed in the development of functional meals [22]. Fruit pomace is the solid matter that remains after fruit juice extraction and may include seeds, peel, pulps, and stems for certain fruits. For example, apple pomace accounts for 25% of apples, despite the fact that waste from the apple juice and cider industries can generate a large amount of pomace [28].

Applications of Fruit by products

Biofuels production from the residues of fruit and vegetable by-products

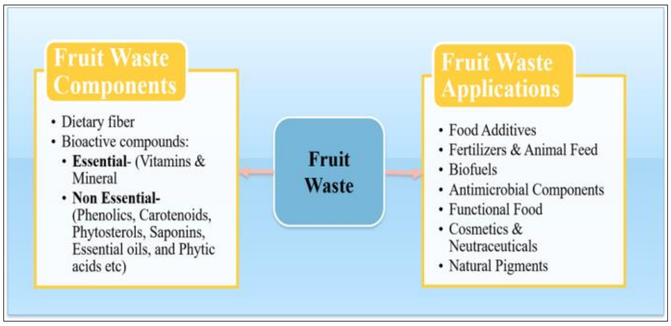

Fig 1: Components and Applications of fruit by products

When it comes to the production of biofuels, the high-carbohydrate byproducts of fruits and vegetables, such as starch, provide for good substrates [12]. Even the waste materials remaining after extraction can be utilized in the biofuels production process [7]. Other substrates, such as corn, lignocellulosic biomass, and molasses, are now used in the production of alcohol; nevertheless, these by-products can produce alcohol at a cheaper cost than the aforementioned substrates. Specifically, the carbohydrates and amino acids found in fruit and vegetable byproducts can be fermented to yield a mixture of fuel alcohols such as ethanol, propanol, butanol, etc. This can reduce fuel supply constraints and aid to the reduction of waste-related environmental challenges. Furthermore, the use of fruit and vegetable byproducts as raw materials for the production of alcohols can reduce the water and carbon footprints left by food processing industries, in addition to the greenhouse gas emissions produced by these industries, compared to the disposal of these materials in landfills [12]. Many researchers have investigated the manufacturing of ethanol from agricultural wastes, particularly citrus waste. Zhou et al. devised a new method for producing ethanol and enhanced recovery of Dlimonene from waste orange peels (CPW) [41]. The biodiesel was produced by catalyzing the transesterification of oil with methanol with sodium methoxide. In addition, the trans-esterification method was used to synthesize biodiesel from Citrus sinensis seeds, where a biodiesel yield of 76.93% was observed [10]. Apple pomace was employed by Parmar et al. [27] to make fermentable sugars, ethanol, and acetic acid. In East Java, Indonesia, the production of bio-briquettes from durian fruit waste biomass was researched and shown to be a viable alternative [25].

Application of fruits by-products directly to human foods

When compared to the amount of energy necessary for their valorization as value-added ingredients, the amount of energy needed to dispose of fruit and vegetable by-products is significantly lower. As a result, the vast majority of these by-products end up in the garbage or a landfill. It may be possible to add not only the fruit and vegetable extracts to different foods but also some fruit and vegetable by-products could be directly added to the food formulations at acceptable percentages, provided that their microbial and nutritional quality meets requirements for human consumption. This would reduce the amount of energy and time required to use value-added ingredients in various foods [19].

Extrusion is a procedure that can be used to boost the direct usage of fruit and vegetable by-products in meals such as morning cereals, pasta, bakery items, or snacks. This process can be used to fortify foods with fruit and vegetable by-products. In addition, during the mixing process of a variety of products, such as cookies, cakes, bread, cheese, etc., various fruit and vegetable byproducts may be added to enhance the nutritional value of the products [19]. For the manufacture of cookies, pineapple pomace powder (PPD) of diverse particle sizes (400–251 m, 250–150 m, and 149 m) was added into refined wheat flour (RWF) at different concentrations (5, 10, and 15%). The addition of PPD resulted in low-gluten cookies with favorable flour and dough characteristics and enhanced antioxidant activity [21]. Another nutrient-rich industrial byproduct, quince juice pomace, was previously repurposed as a sustainable supply of pectin [9] and antibacterial components for chewing candies [17]. Other studies demonstrated that fruit byproducts can also be utilized as a wheat flour reserve (example: berry pomace) [33], as a supplementation in cakes and cookies (example: sour cherry pomace) [31], and in the creation of fermented drinks (example: blueberry bagasse) [16]. Due to their high quantity of bioactive substances, particularly dietary fibre, fruit by-products are now regarded as dietary supplements with additional value. Indeed, their integration into meals results in a number of advantageous effects, including improved water and oil retention, enhanced oxidation stability and emulsification capabilities, and consideration as non-caloric bulking agents [2].

Fruit and Vegetable By-Products to Enhance Antioxidant Properties of Polymeric Films

The byproducts of fruit are extremely abundant in phenolic chemicals. Numerous studies have been conducted to investigate the addition of skin, peel, seeds, pomace, kernel, leaves, or their extracts to packaging in order to boost the antioxidant capabilities. Urbina et al. [35] reported that apple by-products might be utilized in fully renewable active packaging. To create an edible film, Torres-Leon et al. [34]

employed mango peel powder at a concentration of 1.09% by weight. They did this both with and without the inclusion of an antioxidant extract made from fruit kernels. The permeability of the film to water vapour was improved by the addition of mango kernel extract, and the presence of carotenoids and anthocyanins in mango peel made the film a good barrier to radiation across the light spectrum (600 nm). Recently, a combination of blood orange peel pectin and fish gelatin has been employed to create the edible film. A film composed of 50 percent orange peel pectin and 50 percent fish gelatin displayed strong tensile strength, antioxidant, and antibacterial properties. The blended edible film increased the physicochemical, textural, and microbiological stability of cheese (ricotta) coated with it [18].

Production of animal feed and fertilizer from extraction process waste

In general, fruit by-products have a high concentration of cellulose and hemicellulose but a low level of lignin in their structure. As a result, they are valuable resources for animal feed, particularly for ruminants [24]. In general, an economical method for utilizing fruit by-products involves first extracting some value-added compounds and then using the remaining residue as feed or fertilizer. After the extraction of value-added substances, the fermentation process can be employed to enhance the quality of feeds [16]. In fact, since fruit byproducts have a low protein content, fermentation can be utilized to increase their protein content for use in animal feed [24]. Occasionally, feed can be enhanced with functional components like as protein or phenolic extracts recovered from various fruit and vegetable byproducts in order to improve its nutritional value [16].

Biofertilizer derived from citrus waste is an abundant source of micronutrients such as carbon, nitrogen, and potassium. Due to its high pH and lignocellulose content, the citrus waste-based biofertilizer possesses good antibacterial capabilities and eliminates hazardous heavy metals from soil [39].

Additionally, wine pomace has been utilized as animal feed and bio fertilizer. Composting under aerobic settings serves two functions related to environmental protection and fertilizer production, hence minimizing environmental risks [40, 13]. Grape pomace has some utility as an organic fertiliser due to its low phosphoric acid and nitrogen concentration. In strawberry cultivation, a mixture of crushed grape skins (25% v/v) and pumice (75% v/v) resulted in an average fruit yield of 306 g per plant and a biomass output of 97 g per plant. These values were greater than those produced from compost made from olive tree leaves [20].

Synthesis of Active Principles from Fruit By-Products

Thousands of useful compounds extracted from fruit waste can be utilized in the culinary, cosmetic, and pharmaceutical industries [23]. To acquire products with added value, extraction procedures must be developed for every by-product of agro-food businesses (Bustamante et al., 2008). Polyphenols contained in skins, pulp, seeds, and pomace are the most popular target substances from fruit by-products [15]. The antimicrobial, antifungal, antiparasitic, and antioxidative effects of soap formulated with citrus seed oil were noteworthy [5]. Consequently, the use of these naturally occurring citrus seed oils in cosmetic products will reduce exposure to synthetic chemicals and improve the usage of seed waste. Using in-vitro antioxidant and anti-enzyme tests, the anti-aging activities of alcoholic extract of Citrus reticulata peels were investigated, and its usage in anti-wrinkle skin care formulations was recommended [4]. Because of its anti-aging effects, polyphenols derived from grape pomace could become an alternate, new source for the beauty industry that is more cost efficient. Gallic acid in grape pomace is particularly effective at inhibiting age-related collagenase and elastase enzymes [37].

Valorization of fruit wastes and by-products to produce natural pigments

The peel, seeds, and pomace make up most fruit processing industry waste and byproducts. These are good sources of protein, peptides, polysaccharides, dietary fibres, and bioactive-functional components such polyphenols, antioxidants, antibacterial agents, and natural colours [6]. Pigments are natural, nontoxic, have antioxidant properties, and can be used as food colouring [30]. Because of their health benefits, these natural pigments with colouring and pharmacological capabilities can be used in functional and nutraceutical food product development. It is believed that byproducts of processing industries, such as wine or juice, are richer sources of anthocyanin pigments, which can be used in a variety of food applications [14]. Due to the presence of a high anthocyanin concentration (4.31 mg Cy3GlE/g), blackberry residues are reportedly significant sources of natural colourants and nutraceuticals [3]. Apple peel is another excellent source of the anthocyanin pigment. It was observed that the anthocyanin concentration of Rome beauty apple peels was 169.7 mg of cyanindin 3-glucoside equivalent per 100g of dry peel powder [38]. In terms of naturally occurring pigments, betalains are second only to anthocyanins. These pigments impart a purplish-red colour to the fruits. The water extract of red dragon fruit (*Hylocereus polyrhizus*) peels contained 30.18 mg of betalain per 100 g of dried peel. (Rodriguez EB). According to Wang et al. [36], the peel of eight kinds of avocado (*Persea americana*) contains 25 to 66 g/g of green pigment (Chlorophyll). As a result, avocados, which are rich in the pigment chlorophyll, can be utilized to strengthen or colour a variety of food formulations.

Conclusion

Fruit by-products are agricultural, postharvest, processing, distribution, and consumption-related wastes. A portion of the by-products have been utilized as fuel, building materials, or animal feed, but the majority are discarded. Numerous fruit by-products from the processing industry have been demonstrated to have great nutritional value. By using these by-products as useful foods and ingredients, production costs can be reduced. Notably, it can improve food sustainability and is one of the ways for addressing the escalating food security issue. Literature research demonstrated that agriculture byproducts, such as fruit byproducts, can be used to boost and improve the nutritional content of functional foods. This review demonstrates the viability of fruit byproducts as value-added ingredients for food interventions. Utilizing these by-products in the functional food sector, with the necessary hygiene protocols and processing technology, will be a smart way to improve the variety of low-cost functional foods available to consumers. In addition, additional research might be conducted on underutilized fruit byproducts to uncover additional opportunities.

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