An Overview of Fruit by-products Valorization: A step towards Sustainable Utilization

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ABSTRACT

Among the horticulture crops, fruits are the most utilized commodities. Processed, minimally processed, and raw forms are consumed because of their nutrients and bioactive compounds. Increased population has significantly increased the demand for the production and processing of fruits and their products. This over-production by processing industries leads to the production of a large amount of waste and by-products, which has created serious economic, environmental, and economic issues. To overcome these issues the utilization of waste and by-products is highly considered by researchers and scientists. The peels, unused flesh, seeds, pomace, and albedo are the major by-product, rich in many valuable compounds. These compounds are used by many industries as economical, low-cost, and natural sources of antioxidants, dietary fiber, enzymes, pectin, organic acids essential oils, food additives, etc. This paper aims to highlight the utilization of by-products from various fruits.

Keywords: Fruits by-product; Biomolecules; Extraction techniques; Valorization.

INTRODUCTION

In 2011, Food and Agriculture Organization (FAO) estimated that about one-third of all the food produced in the world is either wasted or lost, which amounts to 1.3 billion tons per year (Swaminathan & Swaminathan, & Swaminathan, 2015). For awareness regarding food waste and losses, 29 September 2020 was celebrated as the International Day of awareness of Food Loss and Waste. With the increase in urbanization and industrialization, demand for fruits and their processed products has raised. In a recent survey by FAO in developing countries, around 50% of fruits produced are lost in supply chain between their harvest and consumption. The processing industries, on the other hand, are the chief sources of by-products and waste generation in huge amounts (Blakeney, 2019). This has made fruit safety and management the major concern, globally. Since these materials are prone to microbial spoilage it may cause high level of environmental contamination.

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Hence, different management techniques are required to be explored to resolve this problem (Banerjee et al., 2017). According to FAO and the World Health Organization (WHO) recommendation, at least 400 grams of fruit and vegetables should be consumed by an adult, daily. Being the main reservoir of vitamins, minerals, dietary fiber, and other phytochemicals it aids human health by preventing several chronic diseases and the deficiency of micronutrients (Blakeney, 2019).

In this context, an event entitled “International year of fruits and Vegetables” was observed on the 15th of December 2020, discussing food safety and security in a way to decrease the food loss as waste and the importance of fruits and vegetables in human health.

A promising alternative to overcome these issue is the valorization of fruit by-products into high-value-added compounds. Consequently, by-products of processed fruits such as peels, unused flesh, and seeds are used for the production of functional food products of high nutritional value with several health benefits. This makes it applicable in different industries like nutraceutical, cosmetic, agriculture, pharmaceutical, etc (Dimou et al., 2019). Keeping in view these aspects, this article is written with the pretext to discuss different by-products of fruits, the valuable products extracted from them and their potential applications.

2. FRUIT BY-PRODUCTS

Fruits are the most utilized commodities among the horticulture crops. Fruit by-products can be defined as unused or unconsumed parts of fruit which is an outcome of improper handling or discarding of it. The quantity and the type of fruit by-products vary from its commodities and morphological components which include seeds, pomace, pulp, skin, leaves, tuber, etc (Panouille et al., 2007). It is observed that peel, seeds, and other non-consumable components of fruits have ample amount of essential nutrients and phytochemicals (Rudra et al., 2015). A schematic representation of the fruit waste and by-products utilization in different sectors is shown in Fig 1.

![Fig 1: Schematic representation of fruit waste and by-products Utilization.](image-url)
Several fruit by-products are found to be a rich source of phenolic compounds which are considered as one of the largest group of bioactive and value-added compounds (Ignat et al., 2011). For example, seeds of jackfruits, mangoes, avocados, and skins of grapes, oranges, lemons, encompass 15% higher concentrations of phenols than that of fruit pulp (Soong & Barlow, 2004). Annually, about 6 MMT of solid waste is generated from canning and frozen fruit industries. 5 to 9 MMT of solid waste is generated from grape wine processing yearly, which accounts to 20 to 30% of processed materials (Schieber, 2019). In Apple, 10.91% of pulp and seed are generated as by-products and 89.09% of the final product. The utilization of major fruit by-products like banana, pineapple, sugarcane, orange, and mango in terms of their high bioactive compounds in processing industries are discussed below.

2.1 Pineapple (Ananas comosus)

Pineapple (Ananas comosus) is one of the most utilized fruits of the family Bromeliaceae. Pineapple juice is the third most preferred juice after orange and apple (Cabrera et al., 2000). The by-products of pineapple mainly comprise peels, pulp, leaves, and stems, which ranges between 45-65% of total fruit used for processing. This indicates that if disposal management is not done properly, it will result in serious environmental pollution (Deliza et al., 2005). Pineapple peel is the chief by-product rich in sugars and acts as a nutrient in the fermentation process. It acts as a potential substrate for the production of ethanol, hydrogen, and methane generation (Choonut et al., 2014). Second major by-product of pineapple is the core that can be used for the production of non-alcoholic, alcoholic, vinegar, or beverages (Kodagoda & Marapana, 2017). A commercially available enzyme Bromelain is extracted from pineapple stem which has a proteolytic activity that makes it applicable in many industrial applications like, bread dough improver, meat tenderizer, tooth whitening agent, anti-browning agent, cosmetic substance, and animal feed (Arshad et al., 2014). Fibers from pineapple by-products have high quality of insoluble and soluble fibers that makes them a potential source for the development of less caloric food and dietary fiber-enriched food products (Huang et al., 2011).

2.2 Banana (Musa acuminata)

Banana (Musa acuminata) is one of the most popular fruit worldwide. Peel represents 30% of the total fruit and is considered as the main by-product (González-Montelongo et al., 2010). The Peel is a reservoir of various phytochemicals such as carotenoids, anthocyanin, phenolic compounds, triterpenes, sterols, and catecholamines which are known for their antioxidant property (Someya et al., 2002). A study resulted in a low-calorie food product having a high dietary fiber content when banana peel (10% concentration) was added to it and showed no significant change in the overall aroma, taste, and color (Kodagoda & Marapana, 2017). Banana peels are also a rich source of polymers such as hemicellulose, lignin, and pectin that makes them suitable for synthesizing silver nanoparticles which are known for the antimicrobial activity towards many tested bacterial and fungal cultures (Bankar et al., 2010). Banana peel also possess a pigment, anthocyanin, which is proved to be a good food colorant (Schieber, 2019). Other by-products of banana like pseudostem, peels, leaves, inflorescence, and stalks have been used in various food and non-food products as flavor, thickening and coloring agent, fibers, bioactive compounds and nutraceuticals (Padam et al., 2014).

2.3 Pomegranate (Punica granatum)

Pomegranate (Punica granatum) belongs to the family Lythraceae, is the oldest consumed fruit with high biological activities. The major pomegranate by-products are rind and peels which are found to have a good concentration of anthocyanins, tannins, and flavonoids. A study shows an inhibitory effect for lipid oxidation in cooked chicken patties by powdered extracts of pomegranate rind more than that of vitamin C (Aziz & Karboune, 2018). In food industry, it is used in the preparation of different products like juices,
2.4 Mango (Mangifera indica)
Mango (Mangifera indica) belongs to the Anacardiaceae family and is grown in many parts of India. In processed form, mangoes are consumed in various products such as juices, pickles, puree, canned slices, and concentrates along with their economical importance. The processing produces high amounts of by-products that are not fully approached (Ajila, Bhat, et al., 2007). It has been found that mango peel is a good source of phytochemicals, such as carotenoids, vitamins, polyphenols and exhibited good antioxidant properties which play an important role in the prevention of diseases (Ajila, Naidu, et al., 2007). Polyphenol content in mango peel is reported to be more than its flesh (Kim et al., 2010). Mango seed and peel could be used as a cost effective and natural alternative to synthetic food additives.

2.5 Oranges (Citrus sinensis)
Orange is a citrus species fruit that belongs to the Rutaceae family. In the global citrus fruit production, over 61% share is of the orange. Pigmented or blood oranges, common oranges, and navel oranges are some of the varieties (Stinco et al., 2016). In oranges, the peel, and seed is the major contributor of the waste part which account for about 50-60% of the total harvest (Negro et al., 2017). Orange peels have a great significance due to the presence of highly valuable products, such as polyphenols (including naringin and hesperidin), polymers such as cellulose, hemicellulose, pectin, and essential oils, mostly d-limonene (Satari & Karimi, 2018). Some advanced extraction techniques (microwave and ultrasound), that are free from solvent have been applied to obtain bio-products derived from waste (Boukroufa et al., 2015). Apart from the above discussion some other fruit by-products and Biomolecule extracted from them are discussed in Table 1.

Table 1: Fruits By-Product Valorisation By Utilizing Different Extractable Biomolecules

| Extracts      | Fruit by-product | Extraction method                                      | References                                      |
|---------------|------------------|-------------------------------------------------------|------------------------------------------------|
| Pectin        | Lemon peel       | Ethanol extraction, Acid-assisted extraction, centrifugation, freeze-drying. | (Masmoudi et al., 2008)                        |
| Apple Pomace  | Solid-liquid extraction |                                                       | (Wang & Lu, 2014)                              |
| Orange peel   | Microwave-assisted extraction | Ultrasound-assisted extraction.                        | (Yousuf et al., 2019)                          |
| Flavanones    | Orange peels     | Solid-liquid extraction                               | (Lachos-Perez et al., 2018)                    |
| Dietary fibers| Apple Pomace     | Solid-liquid extraction                               | (Schieber et al., 2003)                        |
| Phenolic Compounds | Mango peel | Methanol elution, Acid assisted extraction, ethanol precipitation, Freeze-drying, resin adsorption, evaporation. | (Heranzini et al., 2005)                       |
| Apple pomace  | Solid-liquid extraction |                                                       | (Schieber et al., 2003)                        |
| Grape pomace  | High voltage electrical discharge, Water extraction. |                                                       | (Boussetta et al., 2009)                       |
| Carotenoids,  | Mango peel       | Supercritical CO2 extraction.                         | (Garcia-Mendoza et al., 2015)                  |
| Tomato pomace | Ultrasound-assisted extraction. (Hexane/ethanol as solvent) | (Luengo et al., 2014)                           |
| Lycopene      | Tomato pomace    | Supercritical CO2 extraction.                         | (Baydas et al., 2000)                         |
| Anthocyanin   | Grape skin       | Pulsed electric field, Ultrasonics, High hydrostatic pressure | (Corrales et al., 2008)                       |
| Essential oils| Orange peel      | Microwave and ultrasound extraction, solid-liquid extraction. | (Boukroufa et al., 2015)                       |

3. VALORIZATION AND APPLICATION OF EXTRACTS
Valorization of fruits by-products is done by utilization of extracts via different techniques. Application of these extracts is observed in different sectors like nutraceuticals, packaging material, preservation, etc. By-products are mainly obtained and then discarded due to lack
of management by food processing industries. The by-product that is produced unintentionally governs the major part of processing cost of the product. Hence, the idea for the utilization of by-products within the same industry will ensure an eco-sustainability of the food processing industry (Tremocoldi et al., 2018). To overcome these challenges, components extracted from fruit by-products are utilized by many sectors for different applications. The increased market demand of consumers for natural fragrance and flavors has triggered the utilization of vanillin (4-hydroxy-3-methoxy benzaldehyde) for the vanilla flavor in the cosmetic, detergent, food, and pharmaceutical industries (Ashwini et al., 2008). Ferulic acid, a precursor of vanillic acid is found in pineapple peels which are used in the synthesis of vanillin (Ong et al., 2014). Pomegranate peel is a rich source of phenolic compounds that includes a high concentration of anthocyanin. In a study, fish gelatin active film was incorporated with pomegranate peel powder of 5% and shows an inhibitory effect for Escherichia coli, Staphylococcus aureus, and Listeria monocytogenes (Hanani et al., 2019). Pectin is another product that plays an important role in the preparation of food products such as jam, jellies, sweets because of its high gelling property. It is found in by-products of fruits such as apple, orange, carrot, peach, etc. (Nawirska & Kwaśniewska, 2005). It has been found that polyphenols extracted from orange peel and flesh are known to have a therapeutic aspect. It protects human HepG2 cells against peroxyl radical-induced oxidation and leukocytes from oxidative DNA damage (Park et al., 2014). An overview of components obtained from different fruit by-products having different applications are shown in Table 2.

### Table 2: List of fruit by-product and their application in different sectors

| Fruits | Type of By-products | Component                          | Application                          | References                 |
|--------|--------------------|------------------------------------|--------------------------------------|----------------------------|
| Grape  | Skin, marc, seeds  | Polyphenols                        | Food industry                        | (Andrade et al., 2019)    |
|        | Pomace             | Phenolic Compounds                 | Beverage industry                    | (Fierascu et al., 2020)   |
| Mango  | Peels              | Phenolics, Carotenoids, flavonoids | Food and pharmaceutical industry     | (Ruiz-Montañez et al., 2014) |
| Orange | Peels              | Essential oil, polyphenols, and pectin | Fructo-oligosaccharides production | (de la Rosa et al., 2019) |
| Apple  | Pomace             | Phenolic compounds                 | Production of microbial oils, biofuel, Bioethanol production cosmetic industry | (Liu et al., 2019) |
| Pineapple | Peels       | Ferulic acid                       | Synthesis of Vaznillin               | (Ong et al., 2014)        |

### CONCLUSION

An enormous amount of waste is generated during the industrial processing of fruits. This waste has become a serious challenge as it affects the environment and needs to be either managed or valorized. Being a source of functional ingredients, extensive research is required for the utilization of the fruits by-products from processing industries. Besides this, increased environmental concern has also made the valorization of these by-products a promising field and a global requirement for sustainable development. Fruit by-products, which are treated as waste are known to have an enormous potential for the extraction of valuable compounds like pectin, bioactive compounds, and other useful phytochemical compounds. There is thus a need to search for alternative scientific technologies in place of the conventional extraction techniques to extract out these compounds from the fruit waste. These extracted valuable compounds can then be utilized in pharmaceutical, food, chemical, and cosmetic industries, and can furthermore be used in the development of functional food products which in turn will be an effective and sustainable solution for the fruit by-products valorization.
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