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Comprehensive review on utilization of fruit wastes as nutraceuticals and healthy food

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Abstract
Seed coat, hull, husk, peels, seeds, and pomace are examples of non-utilized agriculture by-products that can pollute the environment. Furthermore, certain agricultural by-products are said to have a high nutritional value and might be employed in the food sector as a functional component and food. It is the outer covering of fruits that protects them from the surroundings. Some fruits, such as pomegranate, have a thick and rough skin, whereas others, such as mango, have a thin peel. Because of the hard texture and harsh flavor, most people avoid eating the fruit skins. Fruit peel wastes potentially contain helpful compounds similar to those found in fruit. These beneficial ingredients can be employed to create pharmacologic/medicinal, nutrient-dense, and energy-dense products. Fruit peel trash recycling has aided in the discovery of valuable substances as well as the reduction of solid waste management issues. These fruit peels can be used to extract phytochemicals of interest through efficient distillation, industrial extraction, scientific integration, and management. Fruits' outer skins are frequently peeled off and discarded because they are usually non-edible and useless. Phyto wastes are often viewed as non-edible hard seeds and peels and disposed as such. Fruit merchants on the streets and in markets, as well as the fruit processing industry as a whole, generate a lot of trash, which can be an environmental threat and a source of illness if not properly managed and handled. As a result, repurposing them as an antioxidant source could provide cost-effective new generational remedies and measurable economic rewards to the pharmaceutical and nutraceutical sectors, as well as contribute to pollution control. Bioactive-functional components like polyphenols, antioxidants, and antimicrobial compounds like natural pigments, as well as bioactive-functional components like protein, peptides, polysaccharides, dietary fibers, and others, may all be found. Different forms of fruit by-products were well-integrated in the production of functional foods, such as bread and dairy products, according to studies. This review article is crucial since it sheds light on the nutritional content, health advantages, and applications of fruit by-products from fruit wastes.

Keywords: Food waste, waste utilization, pomace, peel, pigments, application

1. Introduction

Fruit processing waste is well recognized as a significant environmental issue, considering that, for economic reasons, landfilling is the most common and broadly applied method of disposing of waste with high moisture content. Landfilling biomass, on the other hand, has serious environmental effects since it causes greenhouse gas accumulation (Roggeveen, 2010 and FAO, 2017) [39, 101]. Active chemicals derived from agricultural and food sector waste are becoming increasingly popular as functional food supplements and active pharmaceutical treatments. Biopolymers, especially pectin, are abundant in agro-food waste, with a global use of about 60 thousand metric tons in the food sector in 2018(Pectin-A Global Market Overview, 2019 and Albuquerque *et al.*, 2019) [92, 8].

In recent years, the food industry has seen a steady growth in demand for natural-source additives (e.g., antioxidants, preservatives) as an alternative to conventional additives that have been linked to health issues due to toxicity, as per concern functional meals demand had increased which may aid the immune system and illness resistance to the human body (Galanakis,2020) [46]. Viruses too have been a major concern for customers in recent decades especially during the coronavirus outbreak in 2019, so functional food became a trend to fight against pandemic (Galanakis, 2020) [46].

The use of bioactive peel and seed elements provides an effective, environmentally friendly, and low-cost therapy for a variety of human illnesses, as well as the development, improvement, and documentation of novel nutraceutical. Bioactive compounds having antioxidative, antidiabetic, hepatorenal protective, anti-thyroidal, anti-inflammatory, antibacterial, cardiovascular protecting, neuro-protective, anticancer, and wound healing properties have already been found in seed and peel extracts (Dike *et al.*, 2021) [26].

Fruits cultivated in certain geographical and sub-regions have long been consumed across the world owing to their various health advantages. Fruit consumption of 400 grams per day is recommended by the FAO and WHO to decrease heart disease, obesity, cancer, and other health problems (FAO 2018) [42]. Fruits' high popularity has resulted in a rise in yearly output on the worldwide market, which has led to advancements in processing technologies (Castellani *et al.*,2014) [126]. The fruits are processed into a variety of goods such as fruit juice, sweets, jelly, powders, and so on due to their perishable nature, and as a result of this processing a large amounts of fruit wastes such as peel, seed, and other inedible portions of fruits create a significant number of wastes, which are either discarded as fruit or feed to animals (Mirabella *et al.*, 2014) [127].

Fruits and vegetables, which account for 22% of world output, have a higher rate of food loss and waste than other commodities (FAO 2018) [42]. Approximately 75,000 Mt of mango fruit waste is produced internationally, which includes 10,384 Mt of fruit waste produced in Brazil, 39,000 t of banana waste produced in the US, and 1 Mt of apple pomace produced in India (Ermis and Ertan,2020) [128]. Several environmentalists have affirmed that dumping of fruit waste can have numerous environmental consequences, including the release of greenhouse gases (Carbon dioxide and methane), breeding of insects, mice, and bacteria in the vicinity of the fruit waste, which can prove to be deleterious to health (Cheok *et al.*, 2016) [25]. Fruit wastage emerges as a blue water hotspot in Asia, Latin America, and Europe because of food wastage volumes (FAO 2011) [41].

Not only this but some fruit wastes such as banana, mango, pomegranate, and others, contain the majority of their nutritional value in inedible parts, and if we simply discard it, it can result in the wastage of majority of nutritional value of the fruit, thus causing a greater loss (Nascimento *et al.*, 2016) [129]. Many health problems, including cancer, cardiovascular disease, chronic disease, diabetes, and hypertension, can be prevented by using fruit waste powder (Dabas *et al.*, 2013) [29].

Several methods have been developed to use of the fruit's waste for different purposes because Fruit waste containing numerous bioactive components may be used as a food product for human consumption, in addition to other applications such as biogas generation, cattle feed, and plant fertilizer, using various processing processes such as drying, extraction, and so on. (Bhandari *et al.*, 2013) [16]. By reducing the moisture content of the fruits waste, it may be turned into powders to prevent deterioration, enhance shelf life, and save transportation costs. The rise in human health consciousness has resulted in an increase in demand for nutritionally available foods, such as functional foods (Bhandari *et al.*, 2013) [16]. Dried powders are used in a variety of culinary items, including extruded goods, dairy, bread, and confectionery and are regarded as functional foods or nutritional supplements, and may also be employed as a replacement, due to their extensive physicochemical characteristics and these products improve the valorized product's physicochemical characteristics, such as phytochemical and antioxidant activity (Bhandari *et al.*, 2013) [16].

Apple and raspberry pomace powders can be used to boost fiber content and improve organoleptic aspects in baked foods. Apple pomace powder was used as a soya meal substitute and source of dietary fiber in baked goods such as cookies, toffees, and sauce, and it may also be employed as a flavoring in the juice industry. (Shalini and Gupta 2010 and Mirabella *et al.*, 2014) [108, 127]. Passion fruit peel, pineapple peel, and pomegranate powder can be added to dairy products such as skim yoghurt and probiotic yoghurt to assist speed up fermentation and enhance texture (Sah *et al.*, 2016) [106]. When avocado peel powder was added to the tea, it was discovered to have powerful antioxidant and sensory effects (Ajila *et al.*, 2010 and Mirabella *et al.*, 2014 and Rotta *et al.*, 2015) [4, 127, 102].

The powders are employed as an adsorbent in water treatment to remove colors and metals (copper, for example) that pollute the water. For waste water treatment, wood apple shells, grapefruit peels, orange peels, banana peel powder, and watermelon rind powders, among other things, have been utilized (Chen *et al.*, 2018) [24]. Fruit waste powders can be utilized to generate electricity, also apple fruit waste powder is utilized as a fuel for energy generation such as steam and biogas, lowering the cost of energy generation (fossil fuels) and disposal, as well as being used in bio-transformation (Shalini and Gupta 2010) [108]. As a drying fuel, peels, litchi seed, mango, and logon are used. Instead of deteriorating plastics that are hazardous to the environment, fruit waste powders are utilized in packaging as bio-plastic films such as PHA (polyhydroxy alkenoates) in green applications. The oxygen and moisture barrier characteristics of bio-plastic are superior. Fruit waste, such as citrus fruit waste, grape pomace, and apricot waste, is used to make bio-plastic films (Tsang *et al.*, 2019) [114]. Moro *et al.* (2017) [130] created a bio-plastic made from passion fruit peel powder, which contains 60% fiber. Pomegranate peel powder, red pitaya peel powder, and other natural colorants Fertilizer, animal feed, emulsifiers, essential oils, preservatives, and ethanol manufacture are just a few of the applications for fruit waste powder. (Choonut *et al.*, 2014 and Gunjal 2019 and Ajmal *et al.*, 2014) [27, 50, 7].

2. Fruit Waste Utilization

Solid trash (peel, skin, seeds, stones, etc.) and liquid waste (juice and washing water) are two forms of waste generated during the processing of fruits. Some fruits have a high rejected rate in horticulture. Portions such as mango (30-50%), pineapple (40-50%), and orange (30%) 50% of the time, and 20% of the time, it's bananas. (Sharma *et al.*, 2020) [112].

Table 1: fruit processing wastes available in India

Fruits	Nature of waste produced	Production (tones)	Approximate waste (%)	Potential quantities of waste (tones)
Mango	Peel, stones	6987.7	45	3144.4
Banana	Peel	2378,0	35	823.3
Citrus	Peel, rag and seed	1211.9	50	606.0
Pineapple	Skin, core	75.7	33	24.7
Grape	Stem, skin and seed	565	20	-
Apple	Peel, pomace and seeds	1376.0	-	412

Source: Joshi and Sharma,2011 [40]

The Indian government favors the establishment of fruit processing plants and the commercialization of value-added goods. The Indian market is brimming with raw fruit materials, however due to poor raw fruit management, every year, we lose roughly 30-35 percent of the fruits we produce, which is insufficient. (Bisht *et al.,* 2013) [18]. The major causes are a lack of infrastructure and inadequate postharvest management techniques. The post-harvest production losses in India from maturity to harvest are the cause of this loss. Processing costs have been estimated at Rs 75,00-1,00,000 crore per year (Bisht *et al.,* 2013) [18].

2.1 Avocado (*Persea Americana*) peel utilization

Avocado peels, like other fruit peels, are frequently thrown due to a lack of knowledge about their possible uses but there had used to extract oils from avocado peels and describe them in order to assess their appropriateness for eating and other in which the extraction was carried out using a Soxhlet apparatus using n-hexane as the solvent, which was chosen because to its low toxicity and high extraction rate (Tafere, 2021) [110]. The extracted oil's proximate analysis and physicochemical characteristics were examined. The oil recovered from the peel yielded 40.6 percent of the total output. The best working parameters for extracting oil from avocado peel oil were determined based on the particle size of 2.6 mm, solvent type N-hexane, and extraction duration of 3-5 hours. The influence of process factors on oil yield was investigated using a generic factorial design. At a 5-hour extraction period, a maximum oil yield of 40.6 percent was achieved. Avocado peel oil can be utilized in a variety of medicinal and energy-related applications (Tafere,2021) [110].

Avocado residues (seeds and peels) include readily removed starch and cellulose which helps making them ideal for bioplastic manufacture having characterization of starch revealed that it is a high-solubility, low-water-absorption, and low-swelling-power starch, which is reflected in the proportion of amylose and also effects the development of biodegradable films. With 3 g of starch, 2 g of glycerin, 6 g of PVA, and 5 mL of 30 percent NaOH, the greatest results in terms of film formation and durability were achieved (Sánchez, *et al.*,2021) [131].

Avocado (Persea americana) seeds constitute an un-conventional starch source, its seed starch functional and rheological properties suggest it could have many possible applications as an ingredient in food systems and other industrial applications as we use two different solvents (one containing Tris, NaCl and NaHSO3; the other only sodium bisulphite) in starch isolation had no influence on starch yield or properties (Barbosa *et al.*,2017) [82]. The isolated starches had functional properties similar to those of commercial maize starch in which avocado seed starch had a slightly lower gelatinization temperature (65.7 °C) than maize starch (66.32 °C) despite their differing amylose contents (Antonio, *et al.*,2017) They remained useful at higher temperatures (95 °C), with G' values between 850 and 1000 Pa in which Avocado seed starch has potential applications in products such as baby food, sauces, bread products, jellies, candies and sausages, also Other possible uses are as a vehicle in pharmaceutical products, and in biodegradable polymers for food packaging. (Guerrero, *et al.*,2017) [82].

2.2 Apple (*Malus domestica*) pomace utilization

Skin and flesh account for 95% of apple pomace, with seeds accounting for 2% to 4% and stems accounting for 1% and It's high in beneficial bioactive chemicals (Gramatina *et al.*, 2017 and Bhushan *et al.*, 2008) [77, 17]. In comparison to the rest of the apple, the investigations demonstrated that phenolic compounds are mostly prevalent in the peels (Kruczek *et al.*, 2017) [132]. According to Sluis *et al.*, (2002) [118], juices made from two apple species have roughly 3% to 10% of the antioxidant content of the whole fruit. Dietary fibers found in apple pomace are well-balanced in terms of soluble and insoluble fibers, and they are higher-quality elements than those found in popular cereals (Kruczek *et al.*, 2017) [132].

Table 2: Application of fruit peel waste in food and its results

Product	Application	Results	Reference
Chicken patty and beef	Wet apple pomace is used to replace 10% and 20% of the meat.	•Product having a high fibre content, pectin, and antioxidant activity. •Product with a softer texture	(Jung *et al.*, 2015) [133]
Chicken sausage	Apple pomace is substituted for 3%, 6%, and 9% of the chicken meat, respectively.	•Antioxidant activity and colour have been improved. Fibre enrichment is a great way to add some variety to your diet. •Hardness will increase	(Yadav *et al.*, 2016) [112]
Chicken nuggets	Apple pomace is substituted for 3%, 6%, and 9% of the chicken meat, respectively.	•Very good sensory characteristics for pomace additions up to 6%. •Improved emulsion stability and cooking yield.	(Yadav *et al.*, 2016) [112]
Buffalo meat patties	2 percent, 4 percent, 6 percent, and 8 percent of buffalo meat is replaced with apple pomace.	•Cooking yield and emulsion stability improved, textural characteristics improved, and sensoric assessment for up to 6% apple pomace was acceptable.	(Younis & Ahmad, 2018) [124]
Stirred yogurt and yoghurt drinks	Up to 3% dried apple pomace can be added to the fermented product.	•Viscosity, stiffness, stability, and antioxidant activity are all improved. •The product's colour has changed.	(Wang *et al.*, 2019) [121]
Acidophilic yoghurt	2.5 percent, 5%, 7.5 percent, and 10% extracted fibres from apple pomace were added to the mix.	•Physical and sensory qualities in the items have been improved by up to 5%.	(Issar *et al.*, 2017) [60]
Yoghurt	To get 3.3 percent, apple pomace extract was used. (wextract/wmilk)	•Increased antioxidant activity and phenolic content.	(Fernandes *et al.*, 2019) [107]

These facts sparked study into the use of apple pomace as a functional component in various food types for the purpose of fortification and increased nutritive content, with the primary goal of creating goods with increased value and acceptance by customers. The greatest result was reached by adding apple pomace extract to the pizza salami, which was enough to keep it from going rancid for 8 weeks when maintained at –18 °C. Sensory study found that the taste and fragrance of experimentally manufactured food did not alter (Kammerer *et al.,* 2014) [65].

Apple pomace's potential as a natural stabilizer and nutritional fiber source in stirred yoghurt and yoghurt drinks has also been investigated (Wang *et al.,* 2019) [121]. The whey separation also reduced during the course of the 28-day storage period, which was likely attributable to the additional apple pomace's water-holding capacity and emulsifying capabilities. In this study, the effect of yoghurt fortification was also seen as an increase in polyphenolic chemicals. Another study was conducted on the enrichment of dairy products by adding up to 10% fiber derived from apple pomace (Sharma, & Gupta, 2017) [84]. The use of apple pomace up to 6% as a substitute for buffalo meat in the patties yielded acceptable sensory results. The higher levels received a worse grading owing to a sweet flavor that was unsuitable for that type of product. The apple pomace has a high-water holding capacity, which elicited a favorable response from the panelists; nevertheless, the apple pomace's high oil holding capacity had a detrimental impact on the patties' taste qualities. (Younis and Ahmad, 2018) [124].

2.3 Banana peel (*Musa*) utilization

Banana peel has been used as an herbal medicine for the treatment of a variety of illnesses, including burns, coughs, ulcers, and diarrhea. Banana peel, for example, has been used to aid in the healing of burn wounds (Pereira & Maraschin, 2015) [93]. Banana peel extracts have also been linked to a variety of health benefits, including lowering blood sugar and cholesterol. Cardiovascular disease, diverticulosis, constipation, irritable bowel syndrome, colon cancer, and diabetes have all been linked to dietary fiber. (Rodriguez *et al.,* 2006) [100]. Individual phenolic compounds found in banana peel, such as dopamine, ferulic acid, and caffeic acid, have potent antioxidant capacity, antimicrobial activity, and could be used as food preservatives as for example like, dopamine's radical scavenging capacity was found to be greater than glutathione, BHT, luteolin, or quercetin, also has a higher radical scavenging capacity than catechin and is similar to Gallo catechin gallate and ascorbic acid in terms of action (Kanazawa & Sakakibara, 2000) [66]. Bioactive components found in peel and seed extracts show great potential in the treatment and management of diabetes, Antioxidant activities can help to mitigate the negative consequences of ROS (reactive oxygen species) This is a widely used technique, Antioxidant enzymes including paraoxonase (PON1), superoxide dismutase (SOD), and catalase may increase their activity in a direct or indirect way (CAT) (Ketnawa *et al.,* 2012) [66].

A large number of bananas (102 million tonnes of fresh fruit) are produced each year in which the peel, which accounts for around 35% of the total weight of the fruit, has been shown to be high in dietary fiber and phenolic compounds. (Anjum *et al.,* 2014 and Scarlett *et al.,* 2016) [10, 120]. The total phenolic content of banana peel ranges from 4.95 to 47 mg gallic acid equivalent/g dry matter, making it a rich source of phenolic compounds (Carranza *et al.,* 2016) [85]. This amount is 1.5–3 times higher than what was calculated in the flesh. The age of the fruit has been discovered to alter the phenolic content of the peel. (Sundaram *et al.,* 2011 and Sulaiman *et al.,* 2011) (10) [25]. As the fruit ripens, the amount of total phenolic content decreases. For example, overripe peel has 52 percent less phenol than ripe peel, while ripe peel contains 15–45 percent less phenol than green peel, total flavonoid levels and antioxidant capabilities were found to be comparable. (Fatemeh *et al.,*2012 and Sundaram *et al.,* 2011) [10, 44].

The effects of four distinct banana peel preparation techniques, including dry milling, wet milling, wet milling and tap water washing, and wet milling and hot water washing, on the chemical composition and characteristics of the banana peel dietary fiber concentrate were studied (BDFC) (Wachirasiri *et al.,* 2009) [95]. The BDFC had significantly more fat, protein, and starch content after dry milling than after wet milling, resulting in decreased water holding capacity (WHC) and oil holding capacity (OHC). Washing following wet milling might improve the removal of protein and fat, resulting in a higher concentration of total dietary fiber (Julakarangka *et al.,* 2009) [95]. When compared to washing with tap water following wet milling, washing with hot water resulted in a greater loss of soluble fiber fraction, resulting in a lower WHC and OHC of the produced BDFC. The BDFC had the greatest content of total and soluble dietary fiber, WHC and OHC, after wet milling and tap water washing (Luang *et al.,* 2008) [95].

2.4 Pineapple peel (*Ananas comosus*) utilization

The pulp, peels, stems, and leaves are the most common pineapple by-products. Processing residuals typically range from 45 to 65 percent. The main bio-waste from pineapple processing is the peel, which can be used to generate methane, ethanol, and hydrogen. (Upadhyay *et al.,* 2013 and Choonut *et al.,* 2014) [117, 27]. The core is the second primary bio-waste and can be utilized to make pineapple juice concentrates, alcoholic and non-alcoholic beverages, or vinegar. Bromelain, a commercially available enzyme produced from pineapple stems, is already on the market (Kodagoda and Marapana, 2017 and Arshad *et al.,* 2014 and Bresolin *et al.,* 2013) [76, 11, 19].

This enzyme has been used in a variety of industrial applications, including as a meat tenderizer, a bread dough improver, a fruit anti-browning agent, a beer clarifier, a tooth whitening agent, animal feed, and cosmetic substance, as well as in the textile industry, due to its strong proteolytic activity (Dorta and Sogi,2017) [31]. Bromalin can be recovered from various pineapple wastes, including as the stem, core, and peel, utilizing various extraction and purifying procedures. Pineapple by-products contain both soluble and insoluble dietary fiber, which can be exploited in the development of low-calorie and dietary fiber-rich foods. (Cassellis *et al.,* 2014 and Huang *et al.,* 2011) [23, 55].

Through submerged and solid-state fermentation, pineapple waste has been used to produce lactic and citric acids. Under anaerobic conditions, lactic acid was created from pineapple waste in a three-liter micro fermenter with a stirring speed of 50 rpm, a temperature of 40°C, and a pH of 6.0 (Rani *et al.,* 2004) [118]. Solid pineapple waste can also be used as the sole substrate for Yarrowia lipolytica solid state fermentation to produce citric acid. A two-stage fermentation procedure can also be used to make vinegar from pineapple waste (Sossou *et al.,* 2009) [134]. Pineapple peels, which are high in carbs and proteins, have been discovered to be a suitable feed for biogas production. The primary component of vanilla is vanillin (4 hydroxy 3 methoxy benzaldehyde), which is made from vanillic acid. Ferulic acid, a precursor to vanillic acid, is found in pineapple peel waste (Lun *et al.,* 2014) [83].

The pineapple industry's activity has resulted in massive waste generation. The peel accounted for 29-40 percent (w/w), the core for 9-10 percent (w/w), the stem for 2-5 percent (w/w), and the crown for 2-4 percent (w/w) of the total pineapple mass. (Ketnawa *et al.,* 2012) [72]. Pineapple peels were fermented with three distinct strains of acetic acid bacteria, which are Propionic bacteria. *Panteoagglomerans, Acidipropionici, and Pantea Dispersa* are only a few examples. (Teklu *et al.,* 2021) [135].

In a factorial experimental design, three fermentation periods (24hr, 48hr, and 72hr) and three acetic acid bacteria (Propionic Bacterium *Acidipropionici*, *Panteoagglomerans, and Pantea Dispersa*) were examined and organized where Fermentation was carried out at 28°C in 500 mL Erlenmeyer flasks containing 200 mL medium (Belay Dereje., *et al*, 2021) [14]. Constant factors were aeration rate, temperature, and carbon supply. The pH, total soluble solids, total residual reducing sugar, and titratable acidity were all determined. The pH, total soluble solids, total residual reducing sugar, and titratable acidity of the vinegar samples ranged from 3.5 to 4.31, 1.3 to 2.31 brix, 0.50 to 2.47 percent, and 3.13 to 6.15 mg/100g, respectively (Chalchisa *et al.,* 2021) [113]. The results collected showed significant differences (P0.05), As a result, the most critical parameters impacting vinegar output were bacterial strain and fermentation duration (Belay Dereje *et al*, 2021) [14]. The optimal yield of acetic acid generation by propionic bacterium *Acidipropionici* acetic acid bacterial strain was reported to be 6.15 g/L at a fermentation time of 72 hours based on experimental findings and interaction effects (Teklu *et al.,* 2021) [135].

Apart from bromelain extraction, Ketnawa *et al*. (2012) [72] suggest that the peel's fiber might be used in various industrial applications. Pineapple peel has been touted as having good culinary application potential due to its high concentration of dietary fibre, which accounts for 42.2 percent (w/w) of the content, and its ability to generate pectin (Huang *et al.,* 2011) [24].

2.5 Citrus peel (*Rutaceae*) utilization:

Citrus fruits are the second most eaten crop after grapes in terms of global agricultural output. Citrus fruits have vibrant colors and unique aromas, and they are the richest source of vitamin C (Taghizadeh *et al.,* 2017) [111]. Citrus raw materials are used in the food industry to make cordials and soft beverages, pasteurized juice concentrates, preservatives, and frozen canned juices, candied peels, flavoring oils, and marmalades (FAO 2017) [39].Citrus waste is generated at a 70 percent greater rate, with just 50 to 65 percent of it being treated where Citrus waste consists of seeds, peels, and membrane remnants, it is also vital to treat massive volumes of Citrus waste in order to avoid major contamination in the environment (Duhan *et al.,* 2014) [90].

Recent studies focus on newer techniques to use Citrus waste for applications in chemical industries in which Pulps, peels, seeds, and membrane residues (40–60% of the whole fruit) in Citrus waste exceeds to about 110–120 million tons per year in the world. Food processing, pharmaceutical, and chemical industries have developed biodegradable polymers and functional materials by organic acids obtained from Citrus wastes (Zhang *et al.*,2015) [34]. Many bioactive molecules, biogas, fuels, and ethanol were extracted from Citrus waste by physicochemical and microbial processes and applied in food and pharmaceutical industries (Mulhaupt *et al.,* 2013) [136].

Orange peel powder in bread goods is nutrient-dense orange peel. Orange peel powder is high in crude fiber, phenolic compounds, and -carotene, and may be used in baked goods like cookies (Belose *et al.,* 2020) [14].The modifications that happened during cookie storage were also investigated and Preliminary tests were carried out to determine the ideal level of orange peel powder for the production of high-quality cookies in which the high-quality cookies were made with 2% orange peel powder and 98% refined wheat flour. The moisture content of orange peel powder was 7.53 percent, carbs 80.27 percent, protein 5.34 percent, fat 2%, and crude fiber 14.87 percent, vitamin C 45 mg/100g, and iron 0.8 mg/100g, according to the chemical composition(Godase *et al.,* 2020) [14].

Orange peel powder has a light orange hue and a bulk density of 0.45 grammes per milliliter (Belose *et al.,* 2020) [14]. Fresh cookies included 4.2 percent moisture, 10.8% protein, 23.1 percent fat, 0.35 mg/100g crude fibre, 76.9% carbs, 35.8 mg/100g calcium, 2.7 mg/100g iron, and 650.3 g/100g -carotene (Godase *et al.,* 2020) [14]. According to a storage research, cookies produced with 2% orange peel powder and 98 percent refined wheat flour and packaged in polypropylene (PP) and low-density polyethylene (LDPE) may be kept in good condition for up to 3 months with little sensory, nutritional, and textural losses. (Belose *et al*., 2020) [14].

Citrus peels rich in flavonoids were shown to have anticancer properties. Citrus peels offer cancer-preventive properties, according to a study led by Lai *et al.,* Citrus peels had a considerable anti-inflammatory, antiproliferative, antiangiogenic, and apoptosis-inducing effect on prostate cancer tumors, as well as strong anti-inflammatory, antiproliferative, and antiangiogenic properties. Citrus peel's high polymethoxyflavone content may potentially help to prevent azoxymethane-induced colonic carcinogenesis (Shafie *et al*., 2021) [71].

2.6 Roselle (*Hibiscus sabdariffa*) and dragon (*Selenicereus undatus*) fruit peel utilization

The roselle (*Hibiscus sabdariffa*) will swiftly decay after two days after being picked off the tree. As a result, roselle should be utilized to its maximum potential as an antioxidant source (Suryaningsih *et al.,* 2021) [105]. Fruit waste has a lot of value as a source of pectin that may be used in a variety of ways. The primary goal was to find the best conventional and microwave-assisted heating settings for extracting pectin from red-flesh (Hylocereus polyrhizus) dragon fruit peels, white-flesh dragon fruit (Hylocereus undatus) peels (DFP) (Dao *et al.,* 2020) [137].

Dragon fruit peel, in addition to roselle, is a possible source of antioxidants. Flavonoids, antioxidants, anthocyanins, and vitamin C are found in Roselle's calyces (Hibiscus subdariffa L). These active chemicals have a lot of promise as a natural antioxidant source. Furthermore, total anthocyanins (622.91 mg/100g), ascorbic acid (140.13 mg/100g), and total phenolics (37.42 mg/g dry weight) were all present and roselle is a good source of phenolic compounds (Salem *et al.,* 2011) [3]. Because of the presence of these polyphenol components, roselle extract has a modest antioxidant effect. It also contains anthocyanins, which are plant pigments that give it its color. (Beltrán *et al.,* 2011) (20). The calyces of roselle are the most significant component, and they may be a rich source of phenolic compounds and anthocyanins and because of its antioxidant and color properties, Roselle's calyces are appropriate for use in meals as a natural extract, concentrate, or powder. (González *et al.,* 2012 and Prenest, 2007) [48, 96].

2.7 Grapes (*Vitis vinifera*) pomace utilization

The winemaking business uses around 80% of the grape crop, resulting in massive volumes of grape pomace that are still high in phenolic compounds which can be utilized, Because of its high phenolic, flavonoid, and vitamin C content and have more phenolic content and antioxidant activity than fruit meat, according to several studies. The main phenolic components were protocatechuic acid, caffeic acid, chlorogenic acid, and quinic acid and its rich in antioxidants (Zhang *et al*.,2021) (125).

preparation of an antibacterial agent the majority of the dietary fiber and phenolics in grapes collect in the fruit skins, seed, and pulp, which are discarded following juice production. The use of grape pomace as a functional element in baking goods has been investigated alternate fining agents for red wines, seafood to minimize rancidity on ice storage to boost dietary fiber and total phenolic acid in dairy products, eliminate red wine tannins in yoghurt and salad dressings, as well as preventing lipid oxidation. (Zhu *et al.*, 2015) [138].

Grape pomace extracts, in the form of liquid extracts, concentrates, or powders, can be used in foods, pharmaceuticals, cosmetics, and other items (Prodanov *et al.,* 2005) [97]. According to the investigations, grape pomace extracts might be utilized as a functional supplement in food preparation, to enhance beverages, or even as an element in an osmotic solution to make dried fruit with a greater phenolic content. Grape pomace extracts were also successfully integrated into chitosan edible films (hydrophobic and hydrophilic), offering antioxidant effects and perhaps extending shelf life (Ferreira *et al.,* 2014) [45].

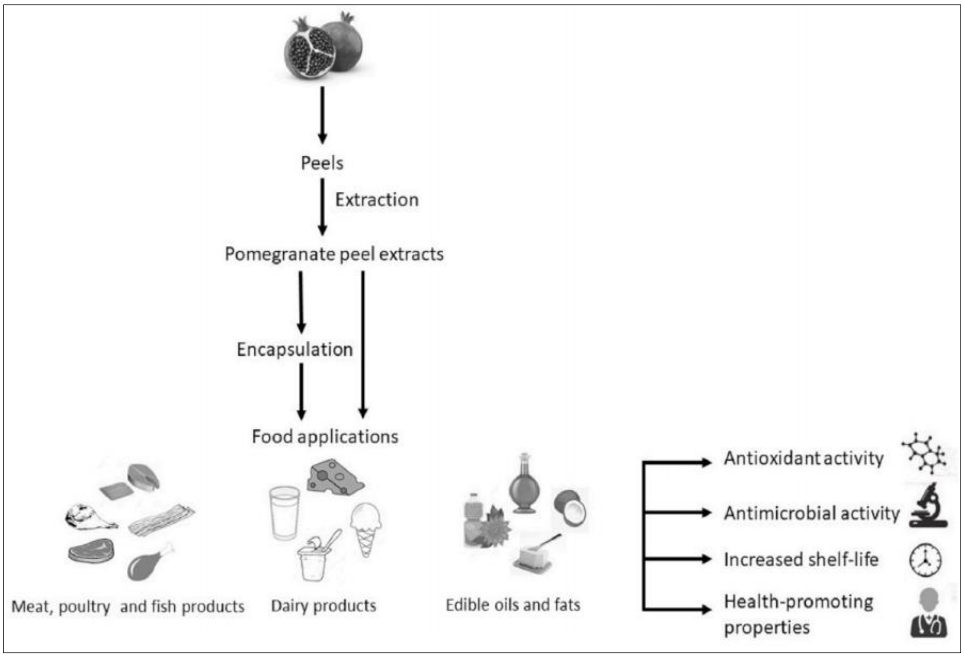
phenolic extracts from grape pomace can also be utilized to substitute synthetic antioxidants in the food sector in which the red grape extract was employed as a natural antioxidant in pork patties by Garrido *et al.,* (2011) [47]. The researchers looked at lipid oxidation, color stability, and overall product acceptance and came to the conclusion that grape pomace extracts might be employed as meat preservatives. Guerra-Rivas *et al*. (2016) [49] tested the shelf life of lamb meat using grape pomace seed extract with vitamin E as a control, after the 7th day of storage, both the grape seed extract and vitamin E were successful in lowering lipid oxidation (20%), according to the researchers (Beres *et al.*,2017) [15].

2.8 Mango (*Mangifera indica*) peel utilization

Mango trash accounts for roughly 75000 MT and is increasing due to increased mango fruit production and processing. Mango seed kernels are a substantial waste product, accounting for 20 to 60% of the total. Mango seed kernel oil is said to be high in polyunsaturated fatty acids like oleic and linoleic acids, both of which have health benefits (Dorta *et al.*,2012) [31]. Mango peel powder is also high in antioxidants and is used in a variety of value-added goods. When ripe mango peels were compared to raw fruit peels, the carotenoid content was found to be 4–8 times greater in ripe mango peels. Dry peel has a total dietary fiber level ranging from 45 to 78 percent. In both raw and ripe mango peels, soluble dietary fiber accounts for more than 35% of total dietary fiber (Ajila *et al.,* 2011) [4]. Soluble dietary fiber binds to cholesterol in the blood and reduces its intestinal absorption, whereas insoluble dietary fiber binds to cholesterol in the blood and reduces its intestinal absorption. The antimicrobial action of mango kernels, which are high in flavonoids and tannins, was discovered (Kittiphoom and Sutasinee, 2013) [139]. Mango kernels also contain a unique lipid component with technical and physiological benefits that might be used in the food business Furthermore, the antioxidant and antibacterial properties of mango kernel and peel can be used to substitute standard additives in food items to improve shelf life (Ethiraj and Suresh, 2012) [38]. On the other hand, the viability of bioactive chemicals found in mango by-products being considered for creative functional food creation should be underlined, also the possibility for making vinegar from mango peels and stones was examined (Simancas *et al.*,2021) [99].

Mango peel is high in dietary fiber, pectin, carotenoids, polyphenols, and enzymes, accounting about 10-20% of the fruit (Kim *et al.,* 2010) [114]. 51.2 percent total dietary fiber, 96 mg GAE/g polyphenols, and 3092 g/g carotenoids were found in mango peel. The water absorption of wheat flour infused with mango peel powder (MPP) increased from 60% to 68 percent, according to farinograph results (Ajila *et al.,* 2008) [6].

The antioxidant capabilities of the biscuits containing mango peel were boosted and may be used to obtain high-quality jelly pectin where Uronic acids, galactose, arabinose, and rhamnose are abundant in mango peel pectin, The pectin’s recovered are heavily methylated, resulting in gels containing substantial quantities of sugar (>50%) and acid. Vitamin C (188 to 392 g/g dry peel) and E (205 to 509 g/g dry peel) are also abundant in mango peel. Protease, peroxidase, polyphenol oxidase, xylanase, and amylase activity were found in both raw (green mangoes) and mature mango peels (Ajila *et al.,* 2007) [5].



Source: Kyriakos *et al.*, 2021 [79]

Fig 1: The prospect of using encapsulated or non-encapsulated pomegranate peel estracts as natural additives in various food products

2.9 Pomegranate (*Punica granatum*) peel utilization

Pomegranate (Punica granatum L.) is a significant source of phenolic chemicals in nature. Fresh or marketed in the form of juice is the most common way to consume it. Pomegranate output in the world is estimated to be worth $1 billion. In 2017, it is expected to reach about 3.8 million tonnes (Kahramanoglu, 2019) [64]. The processing of pomegranate juice creates a lot of trash consists mostly of peel (78%) and is a possible material for additional valuing (Kaderides *et al.*, 2020) [63]. However, the majority of these wastes are either employed as animal feed or thrown away into landfills (Erdogan *et al.*, 2014).

Secondary metabolites found in pomegranate peels include phenolic acids (e.g., gallic acid, ellagic acid, caffeic acid), flavonoids (e.g., catechin, Gallo catechin, epicatechin), anthocyanins), and hydrolysable tannins (e.g., ellagitannins (e.g., punicalagin), Gallo tannins) (Kaderides *et al.*, 2020) [63]. Many *in vitro* and *in vivo* investigations have linked the presence of these phenolic compounds to a variety of biological activities and health advantages, including antioxidant, anti-inflammatory, antimutagenic, anticarcinogenic, and antihypertensive properties (Kandylis *et al.*, 2020) [67]. Furthermore, their existence has been linked to the prevention and treatment of a number of chronic illnesses, including cardiovascular disease, diabetes, obesity, and Alzheimer's disease (pourrad *et al.*, 2021) [75].

Pomegranate peels account for almost a fourth of the fruit's total weight (Adamopoulos *et al*, 2015) [62]. Peels also have a significant amount of crude protein (1.30–8.72 g/100 g) (Hamza *et al.,* 2013) [103]. Salama, *et al.*, (2013) (103) reported that lysine, leucine, and aromatic amino acids (phenylalanine and proline) tyrosine), threonine, valine, and sulphur-containing amino acids and isoleucine (Emad *et al.*,2013) [103]. The principal minerals found in pomegranate peels include potassium, Calcium, Phosphorus, and sodium, with iron being present in large proportions. Zinc, Copper, and Selenium have also been discovered. Antioxidants abound in pomegranate peels. The levels of vitamin B1 (thiamine), B2 (riboflavin), and ascorbic acid are all high. Vitamins C (L-ascorbic acid), E (-tocopherol), and A (retinol) are all antioxidants (Rowayshed *et al.*, 2013) [103].

PPEs have been found to improve the physical, chemical, and microbiological stability of a variety of foods, including meat, fish, poultry, dairy products, as well as edible oils and fats, throughout processing and storage, as well as their shelf life (Kaderides *et al.*, 2021) [79]. Furthermore, their presence did not appear to have a negative influence on the completed items' sensory attributes or popular acceptability (Athanasia *et al.*, 2021) [140].

3. Applications of Fruit By-Products in Foods:

3.1 Pomegranate peel

In wheat bread Pomegranate peel (PGP) was used up to 10% of the time in wheat bread, the antioxidant levels of bread increased when PGP substitution increased, the concentration of free radicals dropped, antioxidant value increased (karnoop *et al.*,2015) [141].

In cookies the addition of up to 7.5 percent pomegranate peel (PGP) to cookies boosted the dietary fiber content from 0.32 to 1.96 g/100 g, which is more than 6 times greater than the control. boosted the mineral content of cookies, specifically calcium, sodium, potassium, iron, and zinc. The total phenolic compounds and antioxidant activity of cookies increased; Pomegranate peel (PGP) was used to make up to 10% of the biscuits. PGP was discovered to be high in dietary fibre, total polyphenol, -carotene, calcium, and iron. Increased PGP inclusion increased the hardness of the biscuit dough while decreasing the cohesion and springiness (Ismail *et al.*,2014) [58].

In wheat noodles the addition of PGP to wheat noodles changed the color and texture of the noodles, making them darker and tougher (Kazemi *et al.*, 2016) [70].

In manufacture of ice cream, pomegranate peel (PGP) was added. also 2 to 4% pomegranate seed oil was used as a milk fat replacement as a result ice cream increased total acidity, decreased pH, and changed the hue. Pomegranate seed oil raised the conjugated fatty acid content of ice cream, and combining PGP and pomegranate seed oil increased the antioxidant and anti-diabetic effects of ice creams. pomegranate seed oil is ideal for the creation of functional foods. (Aslan *et al.*,2013) [21].

3.2 Apple pomace (AP)

In order to make the cake, up to 30% apple pomace (AP) was used. Water absorption, mixing tolerance index, dietary fibre and dough development time all increased with higher AP incorporation, but dough stability decreased gelatinization temperature of the cake was found to rise (Sudha *et al.*, 2017) [109].

3.3 Mango seed kernel (MSK)

In antioxidant-rich idli and mathi, up to 40% of mango seed kernel (MSK) was included. Idli and mathi are traditional Indian snacks that are commonly eaten for breakfast in India. Due to the best approval for all features in sensory evaluation when compared to other formulations, the incorporation of 10% MSK in both idli and mathi formulations were used for further analysis. It was discovered that adding 10% MSK to both idli and mathi enhanced moisture content, crude fiber, crude fat, total ash, and energy considerably. Mineral content, such as calcium, iron, and magnesium, was dramatically boosted when 10% MSK was added also the addition of 10% MSK, the antioxidant activity of mathi increased (Kaur *et al.*, 2017) [69].

3.4 Grape pomace (GP)

In semi-hard and hard cheeses, 0.8 and 1.6 percent of GP were utilized in two different recipes. With increasing GP concentration and ripening time, cheeses' total phenolic content (TPC) and radical scavenging activity (RSA) increased. Semi-hard cheese fortified with 1.6 percent Chardonnay GP before distillation had the greatest TPC and RSA (Bertolino *et al.*, 2016) [96].

In this study, 1–3% GP, 0.5–1% GP, and 1–2% GP were used to make yoghurt, House Italian salad dressing, and Thousand Island salad dressing, respectively. The fortified items showed up to a 65 percent reduction in peroxide. Furthermore, the enriched samples' dietary fibre content ranged from 0.94 to 3.6 percent, with total phenolic content and DPPH radical scavenging activity (Tseng *et al.*, 2013) [115].

In the study, grape pomace (GP) was used in bread in amounts of 2, 5, and 10. The antioxidant activity of bread samples improved, addition of 10% GP, the total phenolic content of bread increased by more than 150 percent. The study also discovered that adding GP to bread changed the colour, texture, and colour of the crust and crumb. As the amount of GP reinforced increased, the hardness increased while the springiness and cohesiveness reduced. (Fuguero *et al.*, 2015) [142].

In the experiment, 20 to 30 percent of grape pomace (GP) was used in the cookie recipe. The colour and texture of the cookies were dramatically impacted by the fortification. With the addition of GP, the amount of dietary fibre, total phenolic content (TPC), and free-radical scavenging activity of cookies increased, the amount of dietary fibre (Sharma *et al.*, 2017) [84].

Five, ten, fifteen, and twenty percent of GP were used in cookies, Anthocyanin, total phenolic content (TPC), flavonoid, tannins, and antioxidant activity of cookies all rose significantly as GP concentration increased. Furthermore, the colour intensity rose as the GP amount increased, with the highest colour intensity reported in cookies fortified with 20% GP (Ghirardello *et al.*,2016) [143].

4. Pigments Extraction from Fruit Wastes

Compounds derived from fruit waste powder, such as anthocyanin, are utilized as a natural food colorant and bio-pigment (Gunjal 2019) [50].

Petrochemical-derived synthetic pigments have been widely utilized in a variety of food items. However, these colours have harmful impacts on human health, making it necessary for scientists to search for more safer, natural, and environmentally friendly pigments (Bhat., *et al*, 2021) [5]. In this regard, maximizing the potential of agri-food wastes, which may be achieved primarily via the use of green processing and extraction technologies. Because of their wide range of applications, the pigments industry has been significantly expanding in recent years.

As a result, sustainable pigment manufacturing from renewable bioresources is required, Valorisation of vegetal wastes (fruits and vegetables) and their by-products (e.g., peels, seeds, or pomace) can fulfil natural pigment production demands at industrial scales for possible food, pharmaceutical, and cosmeceutical uses. Natural colours such as anthocyanins, betalains, carotenoids, and chlorophylls are abundant in these wastes/by-products (Gupta., *et al.*, 2021) [85]. These natural pigments are thought to have a big role to play in the creation of functional foods and have a lot of biotherapeutic potential. We evaluated important research information and advancements on natural pigments from vegetal wastes, greener extraction and processing processes, encapsulating techniques, and possible bioactivities using a sustainability perspective. This evaluation is intended to help not just the concerned industries, but also health-conscious customers, as it was designed with an eco-friendly approach (Sharma *et al.*, 2021) [85].

5.Probiotics from Fruit Peels

Fruits have been used in medicine for dry cough, acute thirst, and painful throat for over two centuries. The need for innovative functional foods has risen in recent years, and probiotics are now widely consumed throughout the world and regarded one of the most important functional food items (Hamid *et al.*,2019) [1]. Furthermore, the fruits and peels are abundant in bioactive chemicals and have a high nutritional value (Viana *et al.*, 2019) [28]. The useful components found in abundance in pomegranate, citrus, mango, and Opuntia ficusindica (barbary fig) peel include antioxidants, fibre, and oligosaccharides (as prebiotics) (Coelho *et al.*,2019) (28). Both probiotics and dietary fibre have been shown to lower colon cancer risk and alleviate constipation, Furthermore, several dietary fibres derived from fruits have been proven to have a significant influence on the survival of these bacteria and are suggested as a component in probiotic dairy meals (Santo *et al.*, 2012) [107].

Anticancer, antioxidant, and antibacterial effects of probiotic yoghurt produced with pineapple peel powder were enhanced against Escherichia coli, but no significant impact was detected against Staphylococcus aureus (Kechnie *et al.*,2015) [106]. Apple, banana, and passion fruit peel powder improved the rheological qualities of probiotic yoghurt and increased the development *of Lactobacillus casei, Bifidobacterium* *animalis subsp. lactis, Lactobacillus acidophilus, and Lactobacillus paracasei* (Santo *et al.*, 2012) [107]. In fermented goods, the effect of mango peel supplementation on the kefir microorganism's growth rates and antioxidant qualities was also calculated (Vicenssuto *et al.*,2020) [119]. Efforts have also been made to produce a fat and sugar-free probiotic set yoghurt using composite fruit peel powder (orange, passion fruit, and pineapple) utilized in varied amounts, 1 percent, 0.5 percent, and 0.7 percent (w/v), respectively (musk *et al.*,2020) [94]. FPP (fruit peel powder) was developed from industrial waste and added to fat-free, sugar-free set yoghurts in three distinct. Over the course of a month, changes in tithable acidity, pH, and lactic acid bacteria viability were assessed. In fat and sugar-free yoghurt combined with 0.5 percent FPP combination, increased hardness, decreased syneresis, and high lactic acid bacteria counts were found (Sajiwanie.,2020) [94].

6. Conclusion

Fruit waste amounts to more than one billion tones worldwide, owing to the fact that the majority of waste is discarded in the inedible portion of the fruit, as well as the perishable nature and mechanical damage to fruits. The non-edible portion of certain fruits has more bioactive chemicals and health advantages than the edible portion, which is discarded in many businesses, producing environmental problems. These fruit wastes are turned into edible ingredients by processing them into powders and decreasing their moisture content to extend shelf life and inactivate deterioration-causing enzymes. Many processing, including as drying and extraction, have been developed to make the most of the fruit waste. To improve the functional characteristics of the created product, these powders have been integrated into numerous food items such as bread, confectionery, and dairy goods. The abundance of bioactive compounds found in fruit waste powders prompted the development of a number of extraction methods for bioactive component extraction and valorization of new products. Despite the advancement of numerous procedures, many companies continue to dispose of fruit waste or use it as cow fodder. Instead of discarding fruit waste, every fruit company should make an effort to safeguard the environment by repurposing it for medicinal human use. Despite the development of improved drying processes, issues such as stickiness, nutritional loss, and moisture rehydration still exist in some fruit powders. As a result, further research should be done by researchers in order to solve the difficulties. Other than encapsulation, co-crystallization, and other methods for integrating bioactive chemicals must be developed, as some compounds inactivate in particular environments due to their instability.

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