How to Cite:
Ahmad, T., Rauf, M. A., Awais , M., Ali, R., Sajjad, M., Raees, M., Riaz, T., & Qadeer, B. (2022). Fruits and vegetables peel's incorporation in different food products: A review. *International Journal of Health Sciences*, *6*(S7), 6578-6602. Retrieved from https://sciencescholar.us/journal/index.php/ijhs/article/view/13755

Fruits and vegetables peel's incorporation in different food products: A review

Tanveer Ahmad
Institute of Food Science & Technology, Khawaja Fareed University of Engineering and Information Technology, Rahim Yar Khan, Pakistan
*Correspondence email: tanveerahmad7304@gmail.com

Muhammad Arham Rauf
National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan

Muhammad Awais
National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan

Rafaqat Ali
National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan

Muhammad Sajjad
National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan

Muhammad Raees
National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan

Talha Riaz
School of Food Science and Engineering, South China University of Technology, Guangzhou, China

Bisma Qadeer
Institute of Food Science & Technology, Khawaja Fareed University of Engineering and Information Technology, Rahim Yar Khan, Pakistan

***Abstract*---**Agriculture has a significant role in ensuring food security and expanding access to food. Although it is predicted that global food demand will increase in the next years, whether or not agriculture can increase food production to fulfil this demand is uncertain. Pakistan is nearly food self-sufficient, despite only using 30% of its potential

agricultural output. Even so, the country's population continues to consume significantly less food than is advised by the national food security line. Thirty percent of the food gap in the country is made up of food that is available but is not being eaten due of various barriers caused by the economic, physical, and sometimes natural situations.The largest amount of loss is attributable to fruits and vegetables, which account for 0.5 billion tones. Losses of fruits and vegetables are substantial in developing countries at the agricultural stage, but they are primarily characterized by the processing stage, which accounts for 25% of total losses. Food losses are high specially in developing countries. To alleviate this challenging issue different wastes from agricultural products like fruit and vegetable peels are incorporated into different food lines like bakery products, beverages, probiotics and confectionary products etc., where such peels used as a substitute of different food products and additionally provide nutritive final food product which along with helping the food security issue, help in providing rich food products.

***Keywords*---**Agriculture, primarily characterized, additionally,

Introduction

The need for food worldwide is rising every year resulting from the continuous growth in human population. A growing problem is the lack of resources and the vast amount of waste produced by the agriculture industry. For instance, not all of the fruit and vegetable portions are consumed by customers, and this phenomenon can cause enormous volumes of food to be wasted worldwide. Furthermore, the environmental impact of unused agricultural by-products such as pomace, peels, seed coat, hull, husk, and seeds can be substantial. In order to promote sustainable consumption and production patterns we may be able to boost food sustainability by making better use of food scraps like peels and cores. In doing so, we'd be in line with the United Nations' Sustainable Development Goals (Backes *et al.*, 2020).

Functional foods are food products that can only be deemed functional if, in addition to providing basic nutritional effects they must have positive impacts on one or more functions of the human. Thereby, enhancing general physical conditions or/and lowering the risk of disease progression. Beverages are the most popular of various forms of functional foods currently available in the market. They readily suit the customer’s criteria regarding shape, storage, size, and ability to include necessary bioactive substances and nutrients(Kasapoğlu *et al.*, 2019).

Customer demands in the food production sector have altered substantially during the last few decades. Food is increasingly believed to have a direct impact on people's health. Foods are now developed to combat nutrition-related disorders and promote physical and mental health in addition to satisfying human appetite and providing important nutrients. Developing a novel functional food is a costly endeavor. Product formation necessitates in-depth knowledge of products and

consumers, which is why qualitative and quantitative market research must be conducted before each product launch(Betoret *et al.*, 2011).

Nutritionally, fruits and vegetables are energy-compact foods high in vitamins, minerals, fiber, and other bioactive compounds. A healthy diet is centered on fruits, vegetables, legumes, nuts, and whole grains. Due to their low energy level and high vitamin and mineral content, they are referred to as the food groups with the highest nutrient density. Additionally, they are excellent sources of nutritional fibre and phytonutrients (McMullin *et al.*, 2019). Changes in eating habits combined with a growing worldwide population have led to a dramatic increase in the demand for fresh produce. The consumption of fruits and vegetables is essential for human health and wellbeing(Vilariño *et al.*, 2017). The largest amount of loss is attributable to fruits and vegetables, which account for 0.5 billion tones. Losses of fruits and vegetables are substantial in developing countries at the agricultural stage, but they are primarily characterized by the processing stage, which accounts for 25% of total losses(Ferreira *et al.*, 2015).

Organic wastes like fruit and vegetable peels are common and can be found in landfills from both the food processing sector and households. However, fruit and vegetable peels are inexpensive lignocellulosic materials with some potential for reuse. The characterization of peel is crucial for its particular reutilization (Pathak *et al.*, 2016).Besides direct food waste, the indirect waste of water, energy, land, labor, chemicals, and fertilizers that results from fruit and vegetable losses is significant. Significant environmental problems are caused by the massive volumes of food that are lost or thrown away each year. In landfills, their decomposition produces detrimental greenhouse gases (Vilariño *et al.*, 2017). In the past few decades, rapid global expansion in the food processing sectors has been accompanied by substantial increases in losses and waste produced by the processing itself. It is estimated that the United Kingdom generates approximately 14 MMT of food and beverage waste, of which 20% is a result of food manufacture, distribution, and retail (Sagar *et al.*, 2018).

Researchers have looked into the possibility of extracting dietary fiber, phenolic compounds, and other useful chemicals from the high concentration of phytochemical constituents in wasted fruit and vegetables (Galanakis, 2012). According to studies, there are large amounts of important nutrients and phytochemicals in the seeds, peels, and other parts of widely consumed fruits and vegetables (Rudra *et al.*, 2015). For example, compared to fruit pulp, 15% more phenolic compounds can be found in the peel of avocados, lemons, grapes, and mangoes. Bioactive chemicals used in the food, textile, pharmaceutical, and cosmetic sectors can be extracted from fruit and vegetable wastes.

This review is about the utilization of fruits and vegetable peels to form energy rich food products including bakery products, beverages, as a coated material etc.

1. Food security and food wastage

Agriculture has a significant role in ensuring food security and expanding access to food. Although it is predicted that global food demand will increase in the next years, whether or not agriculture can increase food production to fulfil this

demand is uncertain (Cook *et al.*, 2011). According to the latest data from the Food and Agriculture Organization (FAO) of the United Nations, approximately 13% of people in developing nations are malnourished (Pawlak and Kołodziejczak, 2020). By 2050, about 2.4 billion more people are expected to live in developing countries. Most of these people will live in sub-Saharan Africa and South Asia. Although agriculture plays a vital role in these regions' economy and is a significant source of employment, more than 20% of the population in these areas is currently regarded as having food insecurity (Wheeler and Von Braun, 2013).

From primary production to consumption, approximately one-third of the world's food supply is lost or squandered. This number demonstrates a considerable loss of key resources along the food chain, which undermines food security and causes resource depletion and environmental degradation (Kummu *et al.*, 2012). SDG 12.3, which calls for the eradication of food waste at the consumption and retail levels by 2030, is one of the Sustainable Development Goals (SDGs) outlined in the 2030 Agenda for Sustainable Development, which was released is 2015 (Nations, 2015).By the year 2050, food waste is projected to have more than doubled. In addition, it is projected that there would be an annual increase in global food consumption, which will increase agricultural production (Hiç *et al.*, 2016). Only until 70% of the planet's land area is dedicated to agricultural production will this need for food be met, forcing farmers to extend their agricultural land area or turn to genetic engineering to boost productivity per acre. But these actions will not only harm the biological environment but also lead to the extinction of ecologically diverse regions (Dion, 2015).

At each and every point of the supply and handling chain, losses and waste are inevitable, including transportation, harvesting, sorting and grading, processing, storage, marketing, and before or after cooking. Supply chain losses takes place at every stage from production to consumption, even during and after harvest (Parfitt *et al.*, 2010).Pakistan is nearly food self-sufficient, despite only using 30% of its potential agricultural output. Even so, the country's population continues to consume significantly less food than is advised by the national food security line. Thirty percent of the food gap in the country is made up of food that is available but is not being eaten due of various barriers caused by the economic, physical, and sometimes natural situations. Most of Pakistan's food is produced in two of the country's seven administrative divisions, Punjab and Sindh, whereas the Federally Administered Tribal Areas (FATA) suffer from the greatest rates of food insecurity. There is a food gap in all administrative units despite high levels of domestic food production due to inefficient food procurement and distribution mechanisms, the black market movement of food commodities, a lack of regulatory monitoring of the marketing sector, reduced purchasing capacity, and natural calamities (Hussain and Routray, 2012).

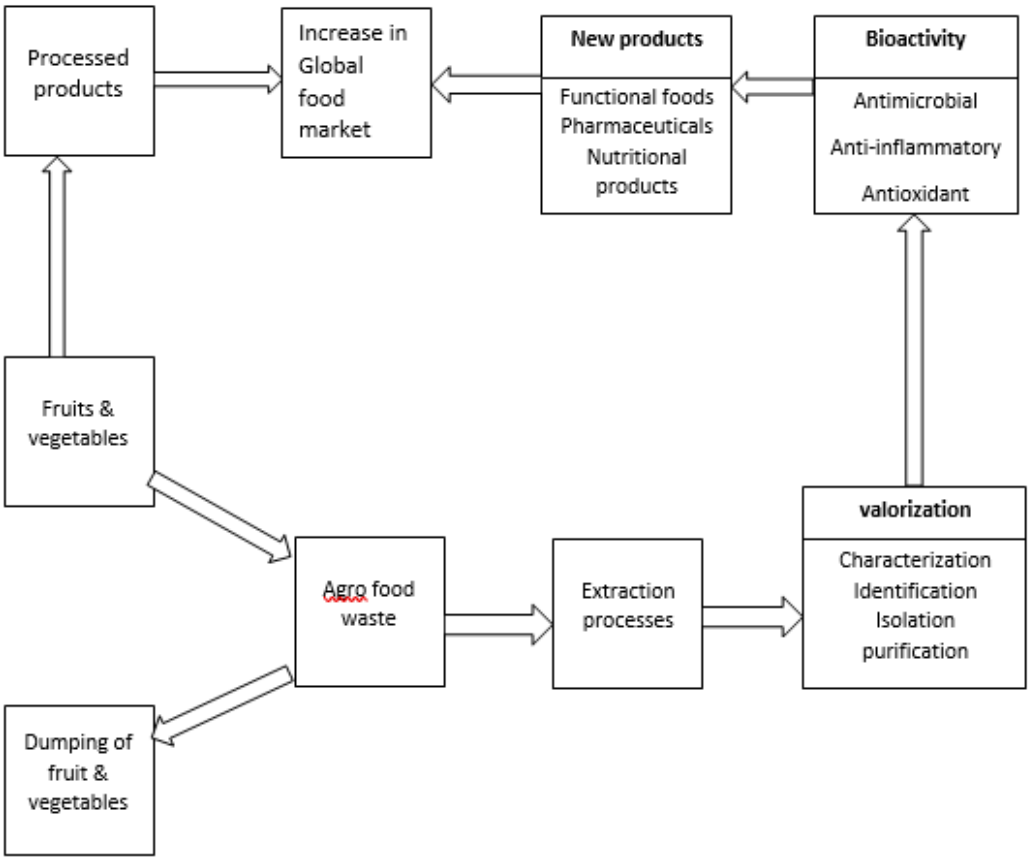

Figure 2.1General Mechanism of Fruit & vegetable peel into Functional Food Products

Food Products

Different fruits and vegetables peels are incorporated in different food products enlisted below

3.1 Fruit and vegetable peel based Probiotics

For almost two centuries, people have been using fruits as medicine to cure a variety of ailments like severe thirst, dry cough, and sore throat. In the last few years, there has been a growing need for novel functional meals, and probiotics have quickly emerged as a popular example of this type of food (Abdel-Hamid *et al.*, 2020). Additionally, the peels and pulp of fruits are affluent in bioactive chemicals. The peels of citrus, pomegranate, mango & barbary fig are rich in antioxidants, fiber contents, & oligosaccharides (as prebiotics) that are all helpful to health(de Moraes Crizel *et al.*, 2013). It has been demonstrated that both consuming probiotics and a diet high in fiber can help reduce the risk of developing colon cancer and alleviate constipation(Drago, 2019). It has been suggested that probiotic dairy meals include a component of fruit dietary fibers

because of their demonstrated effect on the survival of these bacteria(do Espírito Santo *et al.*, 2012). Pineapple peel powder added to probiotic yoghurt increased its antibacterial, anticancer and antioxidant effects against E. coli, but had no reaction on Staphylococcus aureus(Sah *et al.*, 2016). Probiotic yoghurt's rheological qualities were improved by powdered apple, banana, and passion fruit peels, and Lactobacillus casei, Lactobacillus acidophilus, Lactobacillus paracasei, and Bifidobacterium animalis subsp. lactis all grew faster(do Espírito Santo *et al.*, 2012). A probiotic yoghurt without the addition of any fats or sweets was manufactured by using a composite powder of fruit peels made up of orange peel, passion fruit peel, and pineapple fruit peel. Concentrations of 1 %, 0.5% & 0.7% (w/v) of the powder were used(Dias *et al.*, 2020).

3.2 Fruit and vegetable peel based dairy products

Milk is the primary ingredient in the development of a variety of products from dairy sector, the kinds of which are consumed on a massive scale all over the world. In 2019, the total amount of milk produced worldwide was 513 million metric tons, with the European Union being the largest producer of dairy products (Lau *et al.*, 2021). As the use of dairy products & functional dairy products continues to rise on a global scale, the creation of even more varieties of functional dairy products is becoming an increasingly pressing concern. Both semi-hard and hard cheeses were made using two different recipes, with different concentrations of grape purée (0.8 and 1.6% respectively). Except for the cheeses' pH values, which dropped when GP was added, the cheeses' physicochemical properties did not undergo any notable changes after the addition of GP. Increases in both the GP content and the ripening period resulted in greater total phenolic contents (TPC) & radical scavenging activity (RSA) in the cheeses. The research indicated that the semi-hard cheese that had been distilled after being fortified with 1.6% of Grape Pomace had the greatest TPC and RSA values. After GP fortification, there was not a discernible change either in the microbiological counts or the proteolysis (Marchiani *et al.*, 2016).

Tomato peels are rich in carotenoids which are extracted from peel and employed as natural colorants & antioxidants in the creation of functional ice cream were lyco-red carotenoids. According to the study, lycopene constituted 86.13 percent of the total lyco-red extract. The subsequent constituents included phytoene, b-carotene, and phytofluorene. In addition, the rate of lyco-red degradation was found to be accelerated by both an increase in temperature & a decline in pH value. The researchers found that the rate of lyco-red degradation did not significantly change under the conditions of pH 7 to 10 and temperatures ranging from 40 to 70 degrees Celsius. In addition, more than ninety percent of the lyco-red was kept at the conditions of one hundred degrees Celsius for thirty minutes and pH 2. The retention rate of lyco-red pigments at a temperature of 100 degrees Celsius for 180 minutes was 83.80%. The ice cream's RSA and FRAP (Ferric Reducing Antioxidant Power) rose in proportion to the amount of lyco-red present. In addition, after 30 days of storage, the ice cream that had been enriched with 5% lyco-red demonstrated a FRAP value that was greater by more than 400% when compared to the control. Storage periods of 0 and 30 days were employed in the sensory evaluation of ice cream. Scores for the ice cream containing between 1% and 4% fat were between 87 and 97, significantly better than the control's

score of 84 after zero days in storage. Furthermore, lyco-red integration in ice cream at a level between 2% and 3% showed the highest organoleptic acceptability (Rizk *et al.*, 2014).

Pomegranate peel powder at concentrations of 0.1% to 0.4% was used into the ice cream formulation. Pomegranate seed oil at a concentration of 2% to 4% was also used as a dairy fat replacement. PGP was found to significantly increase overall acidity, decrease pH, and alter the color of the ice cream. Both the antioxidant and anti-diabetic properties of ice creams were significantly improved upon by the addition of Pomegranate peel powder & pomegranate seed oil. Because of the addition of pomegranate seed oil, the amount of conjugated fatty acids in the frozen treat increased dramatically. Results from the sensory analysis showed that the sour, astringent, and color qualities were much more positively affected by an increase in PGP content. As the concentration of pomegranate seed oil increased, so did the proportion of oxidized flavor. Ice cream formulations containing 0.4% (w/w) of Pomegranate peel powder & 2.0% (w/w) of pomegranate seed oil were proven to be suitable for the formulation of functional foods (Çam *et al.*, 2013)

3.3 Fruit and vegetable peel based Bakery products

Bakery goods range in complexity from bread and cakes to biscuits (crackers and cookies) and all three rely on wheat flour as a primary component due to its ability to add both volume and structure (Lai and Lin, 2007).Daily consumption of bakery goods is significant, and they play a crucial part in human nutrition. Functional ingredients in baked goods are gaining popularity not just for their nutritional value, but also for their potential to lower the risk of chronic disease (Eswaran *et al.*, 2013). Wastes obtained from food industry are abundant sources of useful components like fiber, minerals, and phytochemicals. The incorporation of functional components originating from fruit and vegetable peels can boost the technical, nutritional, & health-promoting properties of baked foods. The major difficulty in incorporating fiber into baked goods is the negative effects on the final product's quality &, consequently, the low consumer acceptability. Reduced loaf volume, hard crumbs, harsh flavors, and dark colors are just a few characteristics of baked goods high in fiber. Research topics that remain in demand include the investigation of these consequences and potential mitigation strategies, the investigation of unexplored sources of fiber and the possible benefits these sources could have on one's health (Ktenioudaki and Gallagher, 2012).

Researchers have studied the impact of different fibers (Fibrex, Exafine, Fibruline, and Swelite) from different sources (pea, sugar beet, and chicory roots) on dough mixing capabilities when added individually or in combination(Rosell *et al.*, 2006). A range of the wheat flour (0-30%) in the cookie samples was replaced with wheat, apple, lemon, and wheat bran fibres. Studies were conducted to see how the nutritional profiles of cookie samples changed when fiber was added in varying amounts and from different sources(Bilgiçli *et al.*, 2007).The aim of this research was to compare the chemical, physical, & sensory properties of traditional Egyptian Balady flat bread made with wheat flour to dough that contained either 5% or 10% banana peel as a substitute for the wheat flour. Regarding the sensory characteristics, the bread that was made by incorporating 5% & 10% of Banana

peel was judged to be acceptable. The findings indicated that a bread that is acceptable in terms of nutrition and overall acceptability may be formulated by substituting no more than 10% of the flour (Eshak, 2016).

To investigate the effect of passion fruit peel as a substitute of wheat flour in bakery products was studied. In order to boost bakery products with components including dietary fibre, minerals, and bioactive substances, flour formed after drying the peel was examined and employed as an ingredient. According to the sensory study, a minimum acceptable rate of 70% was achieved with the formulations for the bread and cakes in terms of appearance, color, flavor, texture, & taste(Reis *et al.*, 2020). Inulin (Raftilin) (10.5%) was added to a typical wheat flour-based recipe together with one of the following raw ingredients in an effort to create nutritionally and functionally better biscuits: carob (24.5%), oat fiber (16.5%), apple fiber, amaranth, and soy flour, (Vitali *et al.*, 2009).An extract from pomegranate peel was proposed to be encapsulated and used as a "green" wall material in by-products of orange juice. The antiradical activity, phenolic content, and color of raw & encapsulated peel extract were tested for stability under accelerated storage conditions.Extracts with a phenolic content of 5000 ppm were used as bio functional components in cookie recipes. It was discovered that even when covered, phenolic components deteriorated significantly during baking. When comparing encapsulated and non-encapsulated phenolic compounds, the encapsulation effect is statistically ($p < 0.05$) significant for both retention and activity(Kaderides *et al.*, 2020).

3.4 Fruits and vegetable's peel based beverages

The development of novel products rich in bioactive components that target lifestyle disorders is the top goal in this area of study because the market for functional beverages is constantly expanding. Fruit juices have recently been suggested to be ideal probiotic media due to their high nutrient content (Granato *et al.*, 2010).Lactiplantabacillus plantarum was employed to produce a vegetable probiotic beverage from potato starch waste in raw form, enzyme-resistant dextrin, & concentrated red grape. In contrast to grape must, starch-containing beverages provide a more favorable environment for the growth, survival, and generation of lactic acid bacteria during storage (Saeedyzadeh *et al.*, 2017). When creating a probiotic beverage, pumpkin waste may serve as an ideal substrate for Lacticaseibacillus casei development. The probiotic strain Lactobacillus casei clung to the waste powder from pumpkin and survived processing into a soy or apple juice beverage, showing an 80% or higher resistance to gastrointestinal disorders, both of which are very desirable from a consumer perspective due to their functional properties (Genevois *et al.*, 2016).

Total phenolic contents of 25.94 & 11.38 mg of GAE/g extracts from orange peel & pulp, respectively, were employed to make functional carrot juice. The thermosonic method was then used to process the functional juices. Maximum total polyphenol content (30.25 mg GAE/100 mL) and DPPH scavenging activity (61.22%) in carrot juice with peel was achieved at a volume of 125 mL, a processing time of 6.50 minutes, and a temperature of 52.78 °C. Sample Carrot, peel and pulp included, had the highest levels of TPC (28.94 mg GAE/100 mL) and DPPH activity (54.87%) when subjected to the optimal ultrasonic process

settings of 125 mL juice volume, 5.04 min, and 59.99 °C, respectively(Adiamo *et al.*, 2018).After the addition of pomegranate peel extract, the safety and quality of carrot juice, a beverage with a poor antioxidant capacity and a high propensity for microbial formation, were evaluated. To extract the substance, high-pressure extraction was performed. Following processing, the phenolic and flavonoid concentrations of the fortified juices, as well as their ABTS and FRAP antioxidant capacities, increased by 3.6, 3.5, 8.2, and 9.4 times, respectively. PPE-enhanced juices had a 1.0 log10 CFU mL-1 reduction in microorganisms on the 28th day of storage (Kaderides *et al.*, 2020).

Both fermented and non-fermented probiotic beverages were developed by combining the pectin derived from passion fruit peels and pulp with sugar. These beverages enhanced the survival of the probiotic bacteria L. rhamnosus under simulated gastrointestinal circumstances when compared to non-fermented beverages. Furthermore, probiotic beverages containing pectin from passion fruit peels offered more consistent survival throughout the first and last stages of storage.(Santos *et al.*, 2017). Waste sucrose syrup created by osmotic dehydration of highbush blueberries is required to create a unique probiotic drink utilizing red beet juice. This is due to the fact that probiotic meals must meet particular nutritional needs. Lactic acid bacteria are created in various amounts depending on how much residual sucrose syrup is consumed during the fermentation of the juice by Lactobacillus strains. Researchers discovered that this fermented probiotic beverage had high amounts of lactic acid (2.6-6.1 g/L), betalain pigments (25.7%-63.3% retention), and polyphenols, which were twice as rich as in pure fermented red beet juice. (Chwastek *et al.*, 2016).

3.5 Fruit and vegetable peel in confectionary products

Because of rising demand for natural food colorants, the use of pigments derived from natural sources is quickly becoming a market norm (Gordillo *et al.*, 2018). The anthocyanin family of pigments is the most diverse and widespread family of water-soluble pigments in plants. These chemicals are what cause fruits, vegetables, cereals, and flowers to change color. As a result of their poor chemical stability, anthocyanin-based color mixtures have some constraints (Mojica *et al.*, 2017). The desired colors can be compromised by variables including exposure to heat, temperature, pH variation, light, metals, oxygen, and bleaching chemicals, among others, which can have an impact on their behavior and stability. Given these restrictions, the food industry faces a hurdle in incorporating these chemicals.Anthocyanins found in black beans have potential applications as food coloring and have positive health effects. The aim was to assess the physicochemical stability and potential anti-diabetic properties of anthocyanins and to maximize their extraction from black bean coatings. Anthocyanins were measured at a total of 32 mg per gram of dry extract. Bean anthocyanins had an approximated half-life of 277 days and were stable at pH 2.5 and low temperatures of 4 °C (89.6%) (Mojica *et al.*, 2017).

Both the icing on donuts and the traditional Brazilian delicacy known as "beijinho" use blackthorn fruit extract and fig peel as natural purple colorants. In addition to their ability to fight germs, the extracts were also tested for their antioxidant activity. Using natural colorants in the icing solution improved the

doughnuts' firmness and consistency while also giving "beijinhos" more desired qualities like softness and chewiness. Additionally, it was found that both natural extracts significantly increased their antibacterial and antioxidant capacities (Backes *et al.*, 2020). According to studies, rambutan seed contains a relatively high amount of fat, and these fats are similar to those found in cocoa fat, despite some differences in physical properties. Rambutan seed fat consumption has increased because previous research discovered that this fat can be used as a substitute for cocoa butter in chocolate products. As a result, the extracted fat from rambutan seed could not only be used to make candles, soaps, and fuels, but it could also be a source of natural edible fat with industrial applications (Issara *et al.*, 2014).

Experimentally, a debittered food grade orange fibre, isolated from an orange juice by-product, was developed and evaluated as a fat-replacer in bakery confectionary goods at various percentages (30, 50, and 70%). The DOF displayed a high level of total fibre, a low level of water activity, and a high level of water binding capability. Through storage at room temperature, the resultant bread items were evaluated for dietary, technological, and microbiological characteristics. Results showed that the inclusion of DOF causes finished goods to have improved textural properties and a higher moisture content, particularly after one day of storage. Additionally, the fat-replacing technique produced final products with, in addition to a steady content of carbohydrates, that showed decreasing fat content, increased content of dietary fibre, and protein at various degrees of DOF (Caggia *et al.*, 2020). Different particle size pineapple and papaya peels that were desiccated by hot air circulation and freeze drying were employed as powder components to enliven gummy candies. In comparison to powder-free controls, changes in soluble solids (°Brix), pH, water activity (aw), color, instrumental texture, and sensory perception of the products were evaluated. Candy with stable acidity, °Brix, water activity, and pH was produced by adding 5 g/100g of each fruit peel powder. The texture, color, and physicochemical properties of freeze-dried peels with smaller particle sizes were improved because the powders were more evenly dispersed, strengthening the gel's structure and resulting in better coloration (Romo-Zamarrón *et al.*, 2019).

Passion fruit with its seeds and orange peels were used as functional ingredients to make dark chocolate. Dark chocolate is well known for its high antioxidant activity and is particularly rich in flavonoids, which promote health. Both orange peels and the seeds of passion fruit are rich in dietary fibre. The amount of dietary fibre in dark chocolate may therefore be increased by the addition of these components. Dark chocolate's nutritional contents, antioxidant characteristics, and sensory qualities were examined in relation to the impacts of passion fruits with seeds and orange peels. The formulation of dark chocolate with citrus peel and passion fruit offers consumers an alternative approach of accessing dietary fibre and antioxidants that are good for their health. The product has a potential confectionary market and adequate sensory qualities (Yeo and Thed, 2022).

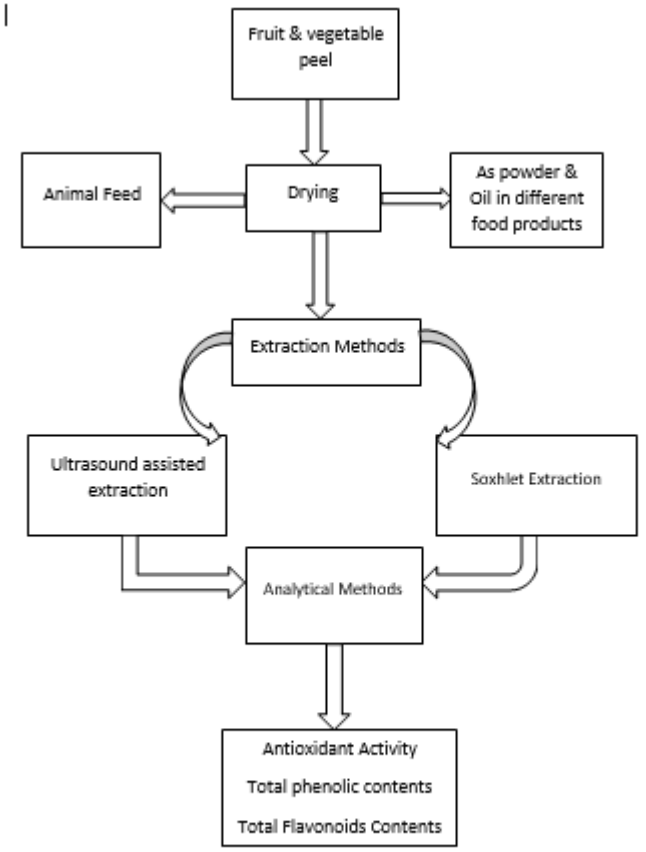

Figure 3.1 Flow Diagram for the extraction & Analysis of Bioactive Substances from Peel

3.6 Fruit and vegetable's peel based muscle foods

For many people, especially young people and children who eat processed meat products as a form of fast food, the predominant source of protein in their daily meals comes from the consumption of meat and meat products (Aymerich *et al.*, 2008). Meat products are particularly vulnerable to microbiological spoilage and lipid rancidity, which necessitates the use of synthetic preservatives like nitrates and nitrites, which pose a carcinogenic risk to humans (Mahmoud *et al.*, 2017). Protein degradation, lipid oxidation, and microbial contamination all contribute to rapid spoilage in muscle food products like fish and meat, despite their high nutrient content (Gullón *et al.*, 2020). These products' oxidative changes not only lead to the accumulation of dangerous compounds, but also to unfavorable alterations in taste, color, and texture, which in turn decreases product acceptance and shelf life (Das *et al.*, 2021). An extract of pomegranate rind powder was added to ground pork at a rate of 0.02 grams of extract per one hundred grams of meat in order to reduce lipid oxidation (Qin *et al.*, 2013). Chicken sausages produced with powdered banana peel had a greater nutritional value, more dietary fiber, a greater cooking yield, and the capacity to contain more water while having less fat. In addition, the high fiber content of sweet

potato peel flour altered the texture of the dough, making the hamburger meat more brittle (Marconato *et al.*, 2020).

Color is an important indicator of the freshness of meat and meat products. The color stability of beef products can be improved by using natural antioxidants, which have been shown to do so in two ways: by preventing lipid oxidation and by preventing the conversion of metmyoglobin to oxymyoglobin in meat (Mahmoud *et al.*, 2017). Banana peel extract, used as a marination ingredient in beef, has been demonstrated to exhibit antibacterial effect against Staphylococcus aureus, aerobic microbes, and Enterobacteriaceae. E. coli and Salmonella spp. were confirmed to be absent from beef samples. This makes it a great natural meat preservative. As a result, the extract from banana peels can be utilized as a safe and effective meat preservative (Hafez and Eissawy, 2018). When dried carrot pomace was added to sausages at a level of 9%, a significant improvement in gumminess and chewiness was seen (Yadav *et al.*, 2018).

3.7 Fruit and vegetable's peel based ready to eat and ready to cook products

Due to the vast numbers produced annually, by-products from fruit processing businesses have become one of the world's most challenging features. However, these plant wastes offer a rich source of beneficial components such as dietary fiber, phytonutrients, protein, carbohydrates, and essential oils etc. (Goda *et al.*, 2019). Peels from bananas have the potential to add value to diets and to act as a source of nutrients in their own right. The banana peel powder was incorporated into the formulation of the extruded product as well as the pasta at a level of five percent. The pasta and the extruded product were analyzed for their color and texture profiles using a specific objective method. This research showed that when banana peels were ground into powder, their nutritional value increased dramatically. When banana peel powder (at a concentration of 5 percent) was added to the extruded product and pasta during manufacture, it did not significantly alter the color or texture profile assessments (Puraikalan, 2018).

The peel of the mango fruit, which is a byproduct of the production of mango products such as mango pulp and amchur, is currently discarded, which adds to environmental pollution. By adding mango peel to macaroni at varying concentrations (2.5%, 5.0%, and 7.5%, respectively), we were able to examine its effect on the pasta's cooking characteristics, hardness, nutritional value, and overall sensory experience. Over the duration of the research, the overall quantity of dietary fiber in macaroni increased from 8.6 to 17.8 percent. The polyphenol content of the macaroni increased from 0.46 mg/g to 1.80 mg/g and the carotenoid content increased from 5 g/g to 84 g/g after the addition of mango peel powder at a rate of 7.5%. The antioxidant capabilities of the macaroni products were significantly boosted when mango peel was added to the mixture. As a result of these findings, it appears that it is possible to improve the nutritional value of macaroni by adding powdered mango peel without compromising its ability to cook or its textural or sensorial qualities (Ajila *et al.*, 2010).

Peels of fruit and vegetables, such as mangoes and pumpkins, are rich in a variety of bioactive substances, such as antioxidants and proteins. The mango

peels (MP) & pumpkin peels were added to the yellow corn grits in the amounts of 0.60%, 0.45%, and 0.30%. In a similar manner, research was conducted to investigate the impact that fortification had on the physicochemical and sensory qualities of extruded snack foods. In terms of bulk density and hardness, the results showed that the extruded snack items enhanced with 0.60 percent mango peel performed the best and the bulk density and hardness was 0.322 grams per cubic centimeter and 26.3 Newton's, respectively. The control sample yielded the highest expansion ratio (2.8%), which was found to be the case. The antioxidant power of the finished goods was significantly boosted by the addition of mango and pumpkin peels to the formulation. Comparing the fortification with 0.30% MP to the control sample, which had the lowest sensory ratings, the sensory evaluation revealed that the fortification with 0.30% MP had the best sensory qualities (Goda *et al.*, 2019).

The goal of this study was to improve the antioxidant properties of parboiled wheat noodles (salted and yellow alkaline noodles) and create a novel, marketable product by incorporating pomegranate peel extract (PPE) into the noodle formulations in three different concentrations. The white salted noodle with 1.50 percent PPE showed the highest levels of antioxidant activity when compared to other prepared noodles. Statistically significant ($p \leq 0.05$) differences were seen between the fortified noodle and the control noodle in terms of both color and texture. The fortified white salted noodles were noticeably softer than the white salted noodles and had a faint brown tint, while the fortified yellow alkaline noodles were noticeably darker in color and had a much more challenging texture. When compared to the yellow noodles, the optimal cooking time for the fortified white noodles was significantly less (Kazemi *et al.*, 2017).

Fruit and vegetable peel in edible coatings

The purpose of edible coatings is to extend food's shelf life while preserving its properties, characteristics, and functionality at the lowest possible cost. They are composed of thin layers that are applied to the food's surface (Zambrano-Zaragoza *et al.*, 2018).By increasing the shelf life, reducing microbial decomposition, and serving as an antimicrobial agent carrier matrix, this application can boost its functionality(Prakash *et al.*, 2020). Fruits and vegetables that are susceptible to microbial, insect, and pre- and post-harvest conditions during transport can be effectively preserved by coating(Raghav *et al.*, 2016).Coatings also contribute to the formation of a modified environment, which allows for the induction of various changes in minimally processed and fresh food products, such as antioxidant properties, sensory quality, microbial growth inhibition, color, ethylene production, firmness, and organic compounds during anaerobic processes (Ullah *et al.*, 2017). The presence of effective antibacterial activities in essential oils (EOs) has recently attracted a lot of attention to them, as well as to the primary components of essential oils. The primary EO component of lemongrass citral, 3,7-dimethyl-2,6-octadienal, has been reported for its antibacterial action against a variety of foodborne infections and is also being researched as an antimicrobial agent in edible coatings (Adukwu *et al.*, 2012).

In recent years, the applications of this emerging technology have expanded to include a variety of Nano systems, such as polymeric nanoparticles, Nano

emulsions, and Nano composites that release antioxidants and possess antibacterial properties on the surface of food. Fruit and vegetable peels are regarded appropriate materials for integration into films and coatings due to their high concentrations of phenolic chemicals, which have a strong antioxidant potential. Due to changes in amino acid sequence, fruit and vegetable peel-based films have a lower water permeability than gelatin-based films derived from mammals. Due to the peel's more heterogeneous microstructure, which resulted from insufficient breakdown in the film matrix, the addition of pomegranate peel powder to gelatin films considerably enhanced their water vapor permeability (WVP). The combination of hydrophobic and hydrophilic components in pomegranate peel balances the hygroscopic properties and maintains the films' consistent moisture content (Hanani *et al.*, 2019). Significant amounts of starch, fermentable carbohydrates, cellulose, and hemicellulose are present in the potato peels. Despite having a denser structure, films with low concentrations of potato peel in the biopolymer film had a higher WVP than those with high concentrations of potato peel in the film matrix (Borah *et al.*, 2017).For more cost-effective biodegradable food packaging, a film made from potato peel biopolymer proved useful. Adding various fruit peels to fish gelatin/polyethylene bilayer films typically resulted in a decrease in solubility (Hanani *et al.*, 2018).

Results

Table:4.1 Different fruits and vegetables peel based food products

Fruit/ Vegetable	**Food product**	**Processing condition**	**Key findings**	**Citations**
Apple	Apple peel-enriched Wheat cookies	Apple peel powder was used in place of equal amounts of flour in the enriched cookies at the ratios of 4%, 8%, 16%, 24%, and 32% respectively	Enriched cookies have higher amount of Total Polyphenol & antioxidant capacity then Controlled , 24% Apple peel powder gave cookies overall acceptability	(Nakov *et al.*, 2020)
Banana	Banana Peel Enriched Egyptian Balady flat bread	The use of banana peel as a partial replacement for wheat flour (between 5 and 10 percent)	The water holding capacity, protein content, fiber content, , oil holding capacity, zinc, Ca, Na & Potassium were high in Banana peel enriched bread as compared to the controlled bread	(Eshak, 2016)
Mango	Mango & Pumpkin powder Based Extruded snacks	The mango peels & pumpkin peels were added to the yellow corn grits in the amounts of 0.60 percent, 0.45 percent, & 0.30 percent	In addition to improved antioxidant activity and sensory evaluation, the results show that the highest bulk density and hardness were found in extruded snack foods that were supplemented with 0.60% Mango peel (0.322 g/cm3 and 26.3 N, respectively).	(Goda *et al.*, 2019)
Pomegranate	Dried pomegran-ate peel powder based Biscuits	In the making of the biscuits, up to ten percent of pomegranate peel was used.	The amount of PGP that was incorporated into the biscuits dough had a considerable impact on the dough's hardness. The addition of PGP had an effect on the functional qualities of biscuits, as evidenced by the improved breaking strength discovered after testing.	(Srivastava *et al.*, 2014)

Grapes	Grape Pomace - based bread	Different percentages of grape pomace (GP) have been added to the bread: 2, 5, and 10%.	The integration of Guava pomace led to a considerable rise in the antioxidant activity of the bread samples, which ranged from 11.06% (0% GP) to 55.64% (10% Guava pomace).	(Karnopp *et al.*, 2015)
Guava	Guava peel flour -based Cookies	Cookies were made with 30, 50, and 70% of their total flour content derived from guava peel flour (GPF).	The sensory analysis demonstrated that the cookies containing 30% GPF were accepted in a favorable manner. In conclusion, guava peel flour In the process of cookie-making, can be utilized to partially substitute for wheat flour	(Bertagnolli *et al.*, 2014)
Orange	Orange peel based Jam	Four jams with varied Orange peel level (0, 4, 8, and 12%) were developed and incorporated into jam	All samples were tested for sensory, physicochemical, and nutritional quality. Adding 12% orange peel to jam lowered ($p< 0.05$) overall approval and purchase intention	(Teixeira *et al.*, 2020)
watermelon	Watermelon Rind powder based noddle	Noodles were mixed with 50, 100, or 150 g/kg of watermelon rind powder (WRP)	Anincreased trend in ash, dietry fat, fiber, carbs, and TPC was observed in watermelon rind powder based noddle	(Ho and Che Dahri, 2016)
Strawberry	Soy flour and strawberry powder based biscuits	When producing biscuit samples, the amounts of rice flour, defatted soy flour, and strawberry powder used were 0, 5, 10, and 15%, respectively	Proximate analysis, physical attributes, and sensory evaluation were tested and have higher values as compared to the controlled in order to come to a conclusion regarding the biscuits' overall quality	(Omima *et al.*, 2022)
Apricot	Apricot kernel based Noddle	During the course of the research project, 5, 10, 15, and 20% of apricot kernel (AK) was introduced into the production of noodles	The incorporation of a greater quantity of AK resulted in an increase in the percentage of ash (0.69–1.00%), fat (0.4–10.6%), and protein (11.5–14.5%).	(Eyidemir and Hayta, 2009)

Garlic	Garlic peel powder based pan bread	2-8% of garlic peel powder was incorporated into pan bread	As the amount of garlic powder added was increased, the pH, moisture content, roasting loss, and specific volume were all found to decrease while TPC, DPPH, hardness & ABTS free radical scavenging ability increase	(Lee, 2022)
Carrot	Wheat Rolls enriched with Carrot Pomace powder	The effect of different levels of carrot pomace incorporation (replacing fine wheat flour with 1%, 3%, 5%, and 10% carrot pomace) was studied.	The nutrient composition of the product is increased by adding low concentrations of carrot pomace powder to wheat flour (between 1% and 3%) and this has a significant effect on the product's quality & acceptance.	(Kohajdová *et al.*, 2012)
Cauliflower	Cauliflower leaves based pancakes	Recipes for foods high in fiber were developed through the use of cauliflower leaves in the preparation of pancakes.	Iron and fiber content were both high in the dried cauliflower leaves. In addition, treatments containing two grams of cauliflower leaf powder was highly accepted by the panel	(Chauhan, 2015)
Tomato	Tomato pomace incorporated bread	Bread was made by using 6% and 10% of tomato pomace (TP).	Ascorbic acid, lycopene, beta-carotene, and total phenolics were all present in tomato pomace at concentrations of 111.89 mg/kg, 174.12 mg/kg, and 865.77 mg GAE/kg, respectively. The moisture content, titratable acidity, and bread crumb's flexibility of the bread have all significantly improved as a result of the use of Tomato pomace.	(Nour *et al.*, 2015)
Potato	Potato peel fiber based Biscuits	Biscuits were made with 0, 5, 10, and 15% potato peel fiber (PF).	The addition of PF resulted in a rise in the amount of carbohydrates, ash, and fat found in biscuits, but a decrease in the amount of protein found in them. formulation with 5% inclusion was optimal because anything higher than that resulted in a dark crumb color and a difficult texture.	(Dhingra *et al.*, 2012)

Legume seed coat	Low glycemic index noddle	In order to create noodles with a low glycemic index, the seed coat of legume, and broken rice were both added.	The amount of moisture, crude fiber, and ash in noodles went up a lot when legume seed coat was added. The glycemic index of noodles went down a lot when legume seed coat was added. It went from 66.43 to 56.13. In addition, the integration of legume seed coat raised the overall dietary fiber content of noodles from 5.86 to 9.10%, including 2.30 percent soluble fiber and 6.80 percent insoluble fiber.	(Beniwal and Jood, 2015)
Onion	Onion peel based Sausage	Onion peel powder (OPP) was added in sausages that were prepared using mechanically separated fish meat. The OPP was added to the sausages in the following proportions: 0% (control), 1%, 2%, and 3%. The sausages were separated into four groups. At a temperature of 5 °C sausages that had been cooked were kept for a period of twenty-eight days.	The acidic character of OPP was demonstrated by the fact that its addition resulted in large increases in antioxidant activity and total polyphenol content while simultaneously resulting in a fall in pH. The addition of 1–2% OPP resulted in improved sensory qualities. The results of an HPLC–MS/MS investigation showed that quercetin is the component that makes up the majority of OPP. In general, the findings suggest that the incorporation of OPP in concentrations ranging from 1% to 2% can lengthen the shelf life of a product without negatively impacting its sensory qualities.	(Bedrníček *et al.*, 2020)
Spinach	Crown pumpkin flour based extruded snacks	Using a twin-screw extruder, the flour that was obtained from the three different fractions of Crown pumpkin flour (the peel, the flesh, and the seed) was incorporated into a formulation for an extruded snack product at levels of 10%, 30%, and 50% (w/w with corn grit).	Peel and seed from the waste stream were added at a percentage of 10%, and the resulting extruded goods had expansion and density properties similar to those of the control sample. However, the product quality faced serious problems when waste stream material was added at a rate more than 10%. (hardness of the product).	(Norfezah *et al.*, 2011)

		This resulted in the production of ten expanded snack products		
Radish	Radish Fibre rich snack	Radish fiber ranging from five to twenty grams was added to the Maida, and the central composite design was utilized to construct models for the response.	In comparison to the control, the fiber-rich snack food had about 8% more total dietary fiber (12.24%) than control one. The product was stable and used for up to 4 months during the course of its six-month storage period at room temperature.	(Gupta and Premavalli, 2012)

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Conclusion

Agriculture has a significant role in ensuring food security and expanding access to food. Although it is predicted that global food demand will increase in the next years, whether or not agriculture can increase food production to fulfil this demand is uncertain. At each and every point of the supply and handling chain, losses and waste are inevitable, including transportation, harvesting, sorting and grading, processing, storage, marketing, and before or after cooking. Supply chain losses takes place at every stage from production to consumption, even during and after harvest. Pakistan is nearly food self-sufficient, despite only using 30% of its potential agricultural output. Even so, the country's population continues to consume significantly less food than is advised by the national food security line. Thirty percent of the food gap in the country is made up of food that is available but is not being eaten due of various barriers caused by the economic, physical, and sometimes natural situations. Most of Pakistan's food is produced in two of the country's seven administrative divisions, Punjab and Sindh, whereas the Federally Administered Tribal Areas (FATA) suffer from the greatest rates of food insecurity. There is a food gap in all administrative units despite high levels of domestic food production due to inefficient food procurement and distribution mechanisms, the black market movement of food commodities, a lack of regulatory monitoring of the marketing sector, reduced purchasing capacity, and natural calamities. Food losses are high specially in developing countries. To alleviate this challenging issue different wastes from agricultural products like fruit and vegetable peels are incorporated into different food lines where such peels used as a substitute of different food products and additionally provide nutritive final food product which along with helping the food security issue, help in providing nutrition rich food products.

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