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Exploring Potato Peel Valorization in the Food Industry: A Review

Kumar Sandeep[1], Shweta Sachan[2], Anit Kumar[1], Kanchan kumari[1] and Kumar Satya Prakash*[3]

[1]Department of Food Science and Postharvest Technology, Bihar Agricultural College Bihar Agricultural University, Sabour-813210, Bhagalpur, Bihar, India.
[2]Department of Food Technology, School of Chemical Technology, Harcourt Butler Technical University, Kanpur-208002, Uttar Pradesh, India.
[3]Department of Agricultural Engineering, Bihar Agricultural College, Bihar Agricultural University, Sabour-813210, Bhagalpur, Bihar, India.

ABSTRACT

Potato (Solanum tuberosum) is one of the most widely consumed crops globally, with its production increasing annually to meet rising demand. The main challenges include managing the large volume of potato peel waste and efficiently extracting bioactive compounds & value addition which can be complex and costly. A significant by-product of potato processing is potato peel, which accounts for 15–40% of the original raw product's mass. This waste is generated in substantial quantities by food processing industries, contributing to environmental concerns and inefficiencies in resource utilization. However, the valorization of potato peel offers a promising, cost-effective approach to converting this waste into valuable resources for both food and non-food applications. This review explores the composition of potato peel, including its basic components and bioactive compounds. Key bioactive properties of potato peel include its antioxidant potential, its function as a dietary fiber, and its nutritional benefits. Additionally, potato peel has been shown to possess antimicrobial, antibacterial, antiviral, anti-obesity, and anti-diabetic properties, making it an attractive ingredient for health-related food applications. Furthermore, this review highlights the various ways potato peel has been integrated into processed food products. These include the enhancement of bread, cakes, vegetable oils, fish–rapeseed oil mixtures, oil-in-water emulsions, cooked salmon, minced horse mackerel, lamb meat, and beef patties. By the application of potato peel in various ways, its use has shown great potential to improve food quality, minimize waste, and promote more sustainable food processing methods. Therefore, the effective utilization of potato peel presents numerous benefits for both the food processing industry and the environment, aligning with broader goals of sustainability and resource optimization. This review and study demonstrates how potato peel can be reused to enhance food products with valuable nutrients, supporting waste reduction and sustainability in food processing and thus it encourages innovation and sustainable practices in the use of agricultural by-products.

Keywords: *Potato peel, Nutrient, Fiber, Value-added, Health effects, Food Products, Processing and Application*

1. Introduction

Potato is the fourth major crop to be consumed worldwide after wheat, rice, and maize. It is consumed worldwide and is an important part of the human diet for 1.3 billion people [38], with a worldwide generation rate of above 375 million tonnes in 2022 [13]. The agricultural residues derived range from up to 840 million tonnes in 2010 [6]. Uttar Pradesh, India is the highest producer of potatoes with a production rate of 15,892000 tonnes in the year 2021-22 [3].

According to Food and Agriculture Organization (FAO), the annual potato production crossed over 375 million tonnes in 2022. India ranks second in potato production in the world after China [32]. Potato peel waste around 15-40% is derived from potatoes during processing and in the form of production losses, which mainly dependent on the type of peeling method used. Peeling of potato is achieved by different methods depending on the purpose it is to be used for, like abrasive peeling method is used for chips, while for frozen and dehydrated products steam peeling is used, lastly, lye peeling is usually preferred as a neutralization step [4].

The current valorization of potato peel waste focuses on using the product in the food processing industry, pharmaceutical as well as in biosynthesis industries where the value of potato peel recycling increases. Earlier potato peel was utilized as a source of animal feed because of its low value [28], as a fertilizer and also utilized as the raw material to be used for biogas generation but during these processes takes place the abundant loss of nutritive materials that have antioxidant, antibacterial, apoptotic, chemopreventive and anti-inflammatory properties [40]. This by-product from the potato processing industry is an inexpensive, valuable, and pocket-friendly raw material for substances for its value addition, and extraction comprising of dietary fibers, biopolymers, natural antioxidants, and organic food additives. Potato peel is arising as a modernized food product or as an origin of natural antioxidants that are used to stabilize lipids present in food; recognition of the factors that influence its properties is the major problem to be solved. Major disposal of waste is done by dumping it back inland. Potato peel consists of various nutrients and other bioactive compounds like antioxidants, dietary fibers, pigments, vitamins, and minerals [2]. Because of the existence of natural antioxidants in potato peel, it can be used as an attractive substitute for synthetic agents in the food industries [34, 30]. Reduction in moisture content of potato peel reduces industrial cost [20].

*Corresponding Author: ***Kumar Satya Prakash****

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Thus, the valorization of potato peel is to be done to deal with the global challenge of food wastage and use the opportunity for waste utilization as a variance of extending the shelf life of food.

2. Basic composition of potato peel

Depending upon the geographical area where the potato is cultivated, there is a variation in the composition, variety, breed, color, etc and thus in the order, its peel composition may also vary [31]. Peels of potato consist of lipids, polyphenols, fatty acids, and phenolic acids that act as antioxidant and antibacterial activities [21]. The potato peel consists of the moisture content (85.06% db basis), total carbohydrate (68.70%), TSS (1.00%), reducing sugar (0.61%), nitrogen (1.30%), and fat (2.60%) [4].

2.1 Bioactive composition of potato peel

2.1.1 Dietary fibers

The dietary fiber from the potato peel has a hypocholesterolemic effect that is found after the study of the feeding of rats for four weeks on potato peel. This shows that there is 40% depletion in the plasma cholesterol content and reduction of the hepatic fat cholesterol levels was decreased by 30% when compared with the animals that are fed only with the diet supplemented by cellulose [26]. Dried potato peel may be converted into potato peel powder, which has several applications in different food processing industries. Potato peel powder is also used as the replacement for dietary fiber in wheat flour for bakery products. Since, potato peel has almost 50% of fibers of the dietary fiber thus its physical and chemical characteristics show that it is better when compared to wheat bran in the content of dietary fiber, as well as it has better water holding capacity and the components of starch are also present in low quantities. The sensory score and the stack weight of 5-10% potato peel- containing biscuits were light weight and hard texture compared to the control biscuits. The chemical composition of potato peel is affected by the method of peeling. When extruded abrasion peeling was done the decrease in the amount of lignin takes place but the total dietary fiber content remains unaffected [39].

2.1.2 Phenolic compounds of potato peel

Phenolic compounds are recognized as the primary class of natural antioxidants [5]. The study of [37] analyzed phenolic compounds in both freeze-dried and aqueous extracts of potato peels and identified major phenolic acids such as chlorogenic (50.31%), gallic (41.67%), protocatechuic (7.815%), and caffeic (0.21%) acids. The flavonoids present in potato skins include quercetin, naringenin, catechin, and epicatechin. The phenolic content in potato peels is approximately ten times higher than that in the whole potato flesh [1, 41].In the Study of[35] compared the phenolic composition of aqueous and acidified ethanolic extracts of potato peels using a 72-hour maceration process with continuous stirring. They found that the acidified ethanolic extract had significantly higher total phenolic content (14.0 mg GAE per gram dw) and total flavonoids (3.3 mg quercetin equivalent/g dw) compared to the water extract (4.2 mg GAE per gram dw and 1.0 mg quercetin equivalent per gram dw).

3. Valorisation of potato peel

Depending on the properties of the potato peel, it has various applications and uses. Valorization of potato peel makes it into the value addition and value-added products that can be used for feeding animals, as a fertilizer, as a substrate in fermentation as well as various other applications in food industries.

3.1 Used as antioxidants

The primary cause of quality deterioration in the food industry is the oxidation of lipids through free radical chain reactions. To mitigate the generation of toxic oxidation molecules and reduce rancidity, food industries commonly use synthetic antioxidants to extend the shelf life of processed foods [33]. However, potato peels, which are rich in antioxidants like phenolic compounds, offer a valuable alternative. By recovering these value-added compounds from potato peels, the economics of the potato processing industry improve while providing a cost-effective and highly efficient substitute for synthetic antioxidants [2, 36].

Phenolic compounds in potato peel may be available either inbound structure or in free structure. The amount of ferulic acid in potato peel in free and bound form is 3.66 mg and 1.26mg of equivalent per gram of dry matter [27]. Study of[19] reported that potato contains several phenolic acids, including gallic acid, protocatechuic acid, p-hydroxybenzoic acid, chlorogenic acid, ferulic acid, vanillic acid, syringic acid, caffeic acid, salicylic acid, p-coumaric acid. Modern techniques for extracting polyphenols from potato peel include pressurized liquid extraction, subcritical water extraction, and microwave-assisted extraction [2, 36]. Total phenolic content (2.9 to 4.2 mg/g) is extracted from different varieties of potato peel powder.

Thus potato peel extract might be utilized safely as a natural antioxidant in oils, fats, and other food products so as it can control lipid oxidation [42]. Polysaccharide derived from potato peel is also a source of natural antioxidants and it is utilized in pharmaceutical, food, and cosmetic preparation as an additive. Thus, potato peel can be used as the replacement of synthetic antioxidants for retarding lipid oxidation as a source of natural antioxidants.

3.2 Used as dietary fibers and nutrition

The amount and the composition of dietary fibers present in cereals, vegetables, fruits, and nuts vary accordingly. Since, potato peel consists of 76.40% of dietary fiber, thus it is a rich source[11]. When the dietary fibers were extracted by an enzymatic-chemical method from potato peel, the following functional properties were shown, oil-holding limit (3.76g oil/ g fiber), water-holding limit (5.32 g water/g fibre), expansion (8.28 ml/g), and water dissolvability index (10.22%). Then dietary fibre that is extracted from the potato peel is mixed with the dough along with wheat flour for the preparation of biscuits. The quality of the biscuit was acceptable when 5% of the wheat flour was replaced by the potato peel fiber[11]. Dietary fiber enhances the absorption of other sugars by modifying gastric emptying time and stimulating insulin response, making it a promising anti-diabetic agent when extracted from potato peel, with lower production costs and efficient utilization. The dietary fiber in potato peel is also believed to offer protective effects against carcinogenesis and mutagenesis by binding to mutagenic and carcinogenic substances, increasing fecal bulk and water absorption, reducing intestinal transit time, and lowering fecal pH through fermentation by intestinal microflora.

3.3 Antimicrobial activity

The presence of glucosidase inhibitors in the potato peel gives it antimicrobial activity. Potato peel has various amounts of antimicrobial compounds present in it that are beneficial against bacterial and fungal organisms.

The anti-microbial nature of the potato peel is due to the presence of organic compounds such as flavonoids and terpenes [29].

3.4 Antibacterial and antiviral activity

In an in-vitro investigation done by [17], peel powder was prepared with different varieties of potato including russet, red, purple, and fingerling potato against pathogenic trichomonad strains (one vaginalis strain and the other two fetus related tritrichomonad strain), feline and bovine. Potato peel powder was not show any inhibitory movement against the normal native vaginal microbe species. In another investigation performed by [35], an antiviral effect was shown against the human enteric viruses by the acidified ethanolic potato peel extracts.

3.5 Anti-obesity and anti-diabetic properties

In the Study of [12], in an investigation, supplemented mice adipogenic high-fat diets (25% fat by weight) with 10 to 20% of potato peel for 21 days and compared it to the controlled sample. The results showed that the peel-containing diet reduced the weight gain of mice by 73%. This anti-obesity activity of the potato peel is linked to the presence of a high amount of glycoalkaloids. The presence of α-glucosidase inhibitors in potato peel retards the glucose liberation from the dietary carbohydrate, thus it reduces the postprandial glucose level in the human body and helps in controlling type 2 diabetes.

4. Applications in food products

The application of potato peel in various food products like bread, flatbread, and cake, as an antioxidant in cooked salmon, etc. is mentioned in Table 1.

4.1 Cereal-based products

4.1.1 Bread, flatbreads and cakes

The ability of potato peel fiber to reduce the bread stalling, the addition of 0.4 gram of fiber per 100 gram of flour is done that resulted in increased frozen water content and also the formation of soft bread crumb for a storage period of 7 days. The hardness of the bread crumb was found to be lower than the controlled sample where potato peel fiber was not added to the bread [10]. When the Russet potato peel powder is added to quinoa flour at a concentration of 5%, it resulted in a decrease in the amount of acrylamide content in baked flatbreads (367μg/kg) as compared to the controlled sample (487μg/kg). These results show that potato peel-formulated quinoa flatbreads can be used as nutrition-rich, gluten-free, and low acrylamide functional food.

When cakes were made by replacing wheat flour with 2%, 5%, and 10% Spunta variety potato peel powder, the resulting cakes had a good texture due to the peel powder's water-holding and oil absorption capacities [17]. Similarly, incorporating potato peel powder as a substitute for wheat flour in biscuits increased water absorption, dough development time, and stability, while also enhancing antioxidant activity and fiber content [19].

4.1.2 Pasta

Potato peel, a valuable by-product of the potato processing industry, offers numerous benefits when incorporated into pasta. Its use not only helps utilize a waste product that would otherwise be discarded but also significantly enhances the nutritional value and functional properties of the pasta. Potato peel is particularly rich in dietary fibers, essential minerals, and potent antioxidants, which contribute to improved health benefits and the overall nutritional profile of the pasta. This makes it an ideal ingredient for developing gluten-free pasta, which is especially beneficial for individuals with celiac disease or gluten sensitivities. By integrating potato peel into gluten-free pasta formulations, manufacturers can create products that not only provide added nutritional advantages but also address specific dietary needs. The study of [15] developed gluten-free pasta using potato peel extract and found that potato peel extract improved the properties of gluten-free pasta in term of color, total phenolic content, and antioxidant stability.

4.2 Edible films and packaging

Potato peel, a by-product of the potato processing industry, offers significant potential for use in the development of edible films and coatings due to its rich content of dietary fibers, phenolic compounds, and antioxidants. Recent research has demonstrated that potato peel can be effectively utilized to create biodegradable and edible films with enhanced functional properties presented in Table 1. The high fiber content in potato peels contributes to improved mechanical strength and flexibility of the films, while its antioxidant properties offer added benefits by prolonging the shelf life of food products through active preservation. In the Study of [24] prepared starch-based film by using potato peel phenolic extracts showed water tolerance, elastic and stretchable properties along with antioxidant stability. Sensory analysis of smoked seabream fillet covered with film using potato peel phenolic extracts experienced satisfying golden color, smell, and flavor.

Edible coatings made from potato peel extracts can provide a protective barrier, reducing moisture loss and oxidation in food items. Techniques such as solvent casting or extrusion are commonly employed to integrate potato peel powder or extracts into film matrices. Studies have shown that these films not only offer environmental benefits by reducing plastic waste but also enhance the nutritional profile of coated foods. The incorporation of potato peel into edible films and coatings thus represents a sustainable and innovative approach to both food preservation and waste management, while potentially adding functional benefits to food products.In the Study of [7] used cured cheese is packaged with edible film based on the formulation of starch, potato peel, and Quince peel in the ratio of 32.8, 41.0 and 13.1 respectively. The edible film increased hardness of cheese as compared with control and natamycin coated cheeses. Film- coated cheese did not affect the sensory attributes of the cheese.

4.3 Vegetable oils& Oil Emulsions

The food industry is currently dealing with the main problem that is lipid oxidation that results in the decreased shelf life of the food products. For reducing rancidity, different types of synthetic antioxidants are added to the food products but there is a safety concern related to the addition of synthetic food additives, thus they need to be replaced by natural antioxidants [9]. To avoid the problem of lipid oxidation in soybean oil potato peel is added as an antioxidant. The addition of the potato peel ethanolic extract in the soybean oil resulted in decreased lipid oxidation which can be indicated by the production of peroxides, conjugated dienes, conjugated trienes, and p-anisidine values [16]. For this study, the ethanolic extracts of the potato peel of Agria variety were used based on their chlorogenic acid levels (14.01 ppm, 20.37 ppm, and 31.94 ppm), and accelerated oxidation condition for 15 days at 60°C was given, which resulted in higher peroxide values of the controlled oil than the oil enriched with potato peel. [2]

found the same effect in the potato peel of the ethanolic extracts of the Agria variety. Study of[42] used different peel extracts to protect the refined soybean oil from being oxidized.

4.4 Meat Mackerel

The inhibition of oxidation is done by incorporating aqueous methanolic acetonic extracts which are derived from the potato peels of various varieties likely Russet, Innovator, Purple, and Yellow in the fish meat model system [1]. These extracts were used for decreasing the generation of oxidative rancidity in cod Salmon fish for the storage of over 7 days and the results of thiobarbituric acid reactive substances (TBARS) were analyzed. These results have shown that the TBAR formation was inhibited by 83.4% by the russet variety, 39.7% by the purple variety, 31.4% by the innovator, and lastly 9.48% by the yellow potato peel extract towards the finish of the storage period of 72 hours. At the end of the storage period, the peroxide values of sunflower oil containing 200 ppm of potato peel powder, sugar beet pulp, tert-butyl hydroquinone (TBHQ), BHT, and BHA were 11.9 ± 0.19, 13.8 ± 0.26, 11.0 ± 0.26, 13.4 ± 0.26, and 13.9 ± 0.24 meq/kg, respectively, while the control oil had a significantly higher peroxide value of 25.8 ± 0.24 meq/kg.

Because of the higher values of p-anisidine in the potato peel, it can be used as a natural antioxidant for delaying lipid and protein oxidation in another fish model called minced horse mackerel [14].

4.4 Meat Patties

The analysis of the effectiveness of potato peel in controlling lipid oxidation in irradiated meat was reported by [23]. Ethanolic potato peel extract was added to lamb meat before irradiation (5 kGy, 4 mL of 1% extract per 100 g of meat). After 7 days of cold storage (3°C), the TBA value was 54% lower in meat-containing potato peel extract compared to the control, demonstrating the extract's potential. Similarly, carbonyl content in the meat at the end of storage was 30% lower in samples with potato peel extract, indicating its effectiveness in managing lipid oxidation in meat products. In another study by [25] the ability of potato peel extracts (90% ethanol) to reduce lipid oxidation in ground beef patties during cold storage at 5°C for 12 days was investigated. The antioxidant activity of potato peel extracts, measured by TBARS, showed a 5% reduction compared to the control. This antioxidant effect was strongest at a pH range of 5.0-6.0. Additionally, sensory analysis revealed that the extracts not only inhibited lipid oxidation but also prevented color changes in beef patties during cold storage, compared to control samples.

4.5 Cooked rice

The ability of various fruit and vegetable peel powders, including potato peel powder, to inhibit the growth of *Bacillus cereus* in cooked rice was reported by [22]. The peel powders were mixed with rice at a 10% concentration (w/w) along with four strains of *Bacillus cereus*. In the control samples (no peel powder added), 5g rice aliquots cooled from 54.5°C to 7.2°C over 12, 15, 18, or 21 hours showed a rise in *Bacillus cereus* levels of 1.93, 2.82, 3.83, and 3.58 log cfu/g, respectively. In rice samples with organic gold potato peel powder, the increase in B. cereus levels was significantly lower, with rises of 0.27, 0.53, 1.38, and 2.00 log cfu/g under the same conditions. These findings demonstrate the potential of potato peel powder to inhibit Bacillus cereus growth in food products.

5. Challenges for utilization

There are several methods for extracting value-added compounds from the potato peel are developed in the laboratory but industrial-scale production is also challenging jobs. The physicochemical property varies depending on its origin, varieties, seasonal variations, and also geographical locations. These properties affect the process of handling and also material design. Starch composition varies depending on the storage properties, amount of starch in the potato peel is reduced during open storage due to fermentation. Since potato peel is rich in moisture content therefore several problems affect its collection, handling, storage, and transportation processes. Drying potato peel may help for further utilization. Economic and continuous fulfillment is a challenge for the utilization the utilization of potato peel for industrial purpose.

Changing the methods of the extraction of value-added items from the potato peel is successful at a laboratory level does there is a need for these methods to be scaled up to be used at the industrial level.

6. Conclusions

Due to the increasing demand and rising environmental impact of the agriculture industry, there is a need to use by-products and waste products in food supply chain management and industries related to food management. In India, potato processing industries generate a bulk amount of potato peel, which is discarded or sometimes used as a source of animal feeding; this increases the environmental impact of potato peel and results in a decrease in potato peel added value. The major by-product generated from the potato processing industry is potato peel. Thus, gaining huge interest in the research community and food and drug enterprises industries because of its chemical composition and nutritional health value. Various studies have shown that major bioactive and antioxidant compounds can be potentially recovered from peel that can be used as antimicrobial agent or functional ingredients in food products and supplements. Due to the presence of a high amount of antioxidants in the potato peel extract it can be used as an alternative for preventing lipid oxidation in various oils and meat. Potato peel can also be used as a fermentation agent because of the presence of a high amount of starch but because of the presence of a low amount of fermentable reducing sugar content, the process needs the initial hydrolysis of carbohydrates and then it can be used as a dietary fiber source in producing healthy and the functional foods. Lastly, potato peel can also be used in the preparation of different processed food products.

Future scope of study

Future research could explore more efficient and cost-effective methods for extracting bioactive compounds from potato peel and enhancing their stability in food products. Additionally, studies could focus on broader consumer acceptance, regulatory adaptations, and innovative applications in both food and non-food industries to further maximize the environmental and economic benefits of potato peel valorization.

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Table 1. Utilization of potato peel in Processed Products

Application	Parameter	Conclusions	References
Bread	Hardness over storage study	Potato fiber was added to prepare bread at a concentration of 0.4% with flour, resulting in reduced bread hardness over 7 days of the shelf-life study compared with the control sample.	[10]
Flatbread	Acrylamide content	Added 5% potato peel powder to the flour for the development of quinoa-based flatbread which resulted in a reduction of acrylamide concentration from 487 to 367 μg/kg.	[8]
Cake	Texture and sensory analysis	Incorporated potato peel powder in the formulation of cakes and improved nutritional value and texture, reducing the hardness of cakes by 30.24%. Sensory data revealed no significant difference between formulated cakes and control.	[21]
Gluten-free pasta		Gluten-free pasta was developed by using potato peel extract and found that potato peel extract improved the properties of gluten-free pasta in terms of color, total phenolic content, and antioxidant stability.	[15]
Sunflower and soybean oil	Stability against oxidation	Extract of potato peel (100-200 ppm) exhibited superior antioxidant activity compared to BHT and BHA at their legal limits.	[26]
Fish-rapeseed oil mixture and oil--in-water emulsion	Stability against oxidation and sensory analysis	Potato peel extract (2400mg/kg) was significantly more effective than BHT in lowering peroxide values and p-anisidine values-5.7 times and 9 times more effective, respectively. Furthermore, sensory analysis revealed that these extracts resulted in lower rancidity scores compared to the control.	[18]
Cooked salmon	Antioxidant efficacy	Phenolic-rich extracts slow down the oxidative rancidity in fish. These extracts proved effective in prohibiting the oxidation process in cooked salmon as compared to the control sample for a 7-day shelf-life study.	[1]
Minced horse mackerel	Stability against oxidation	Ethanolic extract of potato peel was used in minced horse mackerel and found that it inhibited the oxidation of lipids and protein, and also reduced the concentration of peroxide values, volatiles, and carbonyl compounds as compared with control and water extract samples.	[14]
Edible film for smoked fish fillets		Starch-based film by using potato peel phenolic extracts showed water tolerance, elastic and stretchable properties along antioxidant stability. Sensory analysis of smoked seabream fillet covered with film using potato peel phenolic extractsexperiencedsatisfying golden color, smell, and flavor.	[24]
Edible film for cured cheese		Cured cheese is packaged with an edible film based on the formulation of starch, potato peel, and Quince peel in the ratio of 32.8, 41.0, and 13.1 respectively. The edible film increased the hardness of cheese as compared with control and natamycin-coated cheeses. Film-coated cheese did not affect the sensory attributes of the cheese.	[7]

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