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Potato and potato peels: A comprehensive review on potato peels nutritional composition, bioactive compounds and its application in the food industry

Martha Kinoka

Abstract
Aim of the Study: The purpose of this study is to explore the potato peels effects on the value-added products on enhancing the nutritional value of food products.
Findings: This review study examines bioactive chemical components in potato peels and their value-added products, as well as their potential usage in various food businesses. Potato peel, in particular, is high in phenolic chemicals. Despite the presence of bioactive substances in both the meat and the peel, the peels are typically discarded during potato eating and processing. As a result, greater research into the exploitation of potato byproducts or trash, such as peels, is required. In addition to phenolic chemicals, they include bioactive components such as glycol alkaloids, polysaccharides, proteins, and vitamins. Potatoes and potato peels have a high potential for inclusion into various functional meals and nutraceuticals due to the increased nutritional content, notably dietary fiber and phenolic chemicals. Although control of bioactive food product improvement is necessary to ensure its safety for human consumption.
Novelty Impact: This review paper will provide a brief overview of nutritional composition, bio-active compounds and application of potato peels in the food industry.

Keywords: Potato peels, potato peels powder, bioactive compounds, value added products, nutraceuticals

Introduction
Valorization is the process of conserving or increasing the price or worth of anything. Valorization of potato peel waste is the use of potato peel (PP) waste, which is produced in large amounts, producing environmental pollution and health issues. As a result, trash can be used to create or produce value-added goods. The potato (*Solanum tuberosum* L.) is the most significant and adaptable vegetable crop, with a global production of roughly 368 million tons and over 5000 recognized variations. Potatoes are carbohydrate-rich foods that are cooked and served in a variety of ways across the world. Freshly picked potatoes are around 80% water and 20% dry substance. Starch accounts for about 60-80% of the dry mass. Furthermore, the potato is low in fat and high in various minerals, including vitamin C. It also contains vitamins B1, B3, and B6, as well as folate, pantothenic acid, riboflavin, and minerals including potassium, phosphorus, and magnesium. Potatoes also contain antioxidants, which may help to prevent ageing-related disorders (FAO, 2008). Tubers are the plant's edible portion, which may be consumed in a variety of ways, such as boiled, cooked, fried, crisped, and so on. Peeling raw tubers frequently results in a large amount of bulky trash, which is normally thrown or utilised as animal feed. (E. Capanoglu *et al*., 2016) [17].
Abrasion peeling is utilized specifically for potato chip manufacture, whereas steam peeling is used for dried and frozen potato goods (Schieber and Saldana, 2009) [31]. Steam peelers are small and yield less product losses, but they are expensive to purchase and operate. As a result, steam peeling is appropriate when large amounts of product (from 8 to 20 th^{-1}) must be peeled in a small amount of space and the emergence of a brown ring (also known as a heat ring or cooking ring) does not cause difficulties with the final product (Steam peeling). The brown ring appears as a result of tissue damage and an enzyme-catalyzed phenol oxidation process. It has been claimed that chemical peeling using NaOH might be used instead of steam peeling to avoid heat-ring.
Potato tuber production has been steadily increasing worldwide, driven by growing demand for human nutrition and bio processing, particularly in China, Asia, and Africa. As of 2013, potatoes are the fourth most produced edible crop, following rice, maize, and wheat, with an

estimated annual yield of 370 thousand tonnes. However, post-harvest processing often results in the discarding of 20-30% of the potato tubers by weight, generating significant amounts of potato peel waste (PPW). The disposal of PPW can have negative environmental impacts on land and water resources due to its rapid microbial degradation.

To solve this issue, several methods such as ultrasonic, high-pressure processing, subcritical water extraction, acidic and enzymatic hydrolysis have been used to recycle and valorize PPW. These techniques are designed to extract important components from PPW, such as biopolymers, polyphenols, glyco-alkaloids, and reducing sugars. The extracted sugars are typically utilized as a feedstock for microbial fermentation in the manufacture of bioethanol. Despite these efforts, the monosaccharide composition and uronic acid concentration of PPW extracts have received little attention. It is believed that PPW comprises a varied variety of monosaccharides and uronic acids, which have commercialization or additional processing potential.

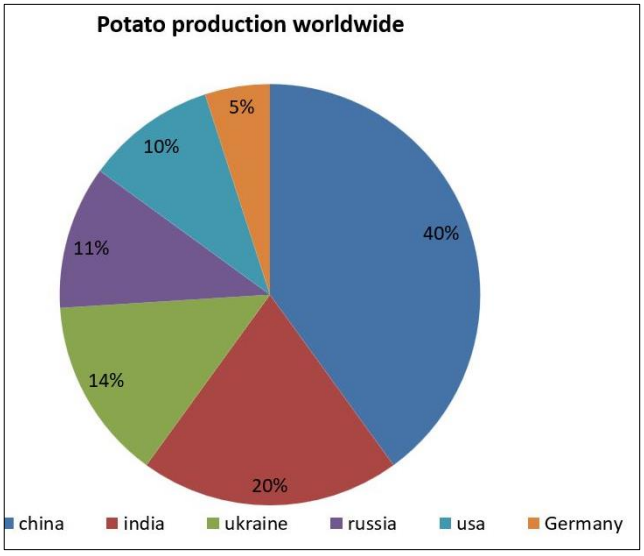

Fig 1: Potato production (FAOSTAT, 2020) – metric tonnes
World total: 359 million

India is ranked as the seventh largest country in the world, covering a total geographical area of 3.29 million square kilometers, with a land area of 2.97 million square kilometers, accounting for 90.4% of the total geographical area. Out of this, approximately 60.5% (1.79 million square kilometers) of the land is utilized for agricultural purposes. The agriculture sector in India generates a significant amount of biomass on an annual basis, with a major portion being in the form of residues. In 2010, it is estimated that agricultural activities in India produced around 840 million tons of agricultural residues. In 2014, India produced about 46395000 tons of potato with the global production of 1,028,368,789 tones from the area of 2024000 ha and 200674874 ha respectively (FAOSTAT 2014). While worldwide as we can see from figure 1 China ranks being the leading potato producing country by 40%, followed by India then Ukraine then USA and lastly Germany. Apart from its use in food products such as chips, French fries, hash browns, and frozen food, potato is also used as a raw material in canning, starch, and flour industries.

Potato processing generates a substantial quantity of trash due to its broad application in a variety of sectors. Potato waste, including peels, pulps, and starch, can, nevertheless, be used in animal feed compositions. This method might give more feed alternatives for cattle, making potato growing and processing more economically viable. Potato trash has the same calorie value as maize and barley but is lower in protein and calcium. Potato waste meal includes 7.6% crude protein, 7.0% ether extract, 4% crude fiber, and 4% ash and is made by drying and grinding whole potatoes, potato pulp, peelings, and discarded potato chips. 2002; Hulfan *et al*.

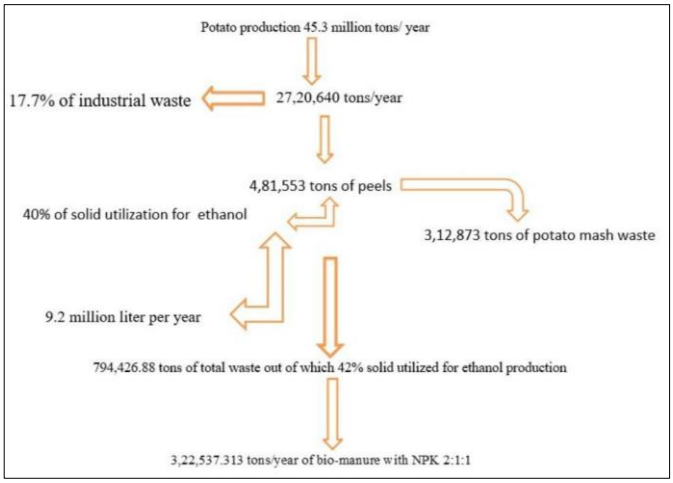

Fig 2: Utilization of potato peels waste

From fig 2, shows the chart from the production to the waste disposal and waste utilization, as you can see above start by industrial potato production then after the potatoes are peels for potato chips the peels which are waste are now taken for mash waste which is around 4, 81, 553 tons of peels per year then mashed while some are used for ethanol production, again to manure which ago the peels were mostly used for manure purposes and animal feed before some scientist started using them in the food industry.

Nutritional composition of potato and potato peels

Potatoes

The nutritional makeup of potatoes changes greatly from year to year, depending on the testing period (before and after storage), as well as the kind and type of cooking method utilized. Potatoes are cooked in a variety of ways, the most common and traditional of which are boiling, frying, and roasting. Frying, particularly deep-fat frying, has been the most popular cooking method in recent decades. Moisture, protein, reducing sugars, starch, fructose, glucose, sucrose, fiber, vitamin C concentration, and amino acid profile are all present in potatoes.

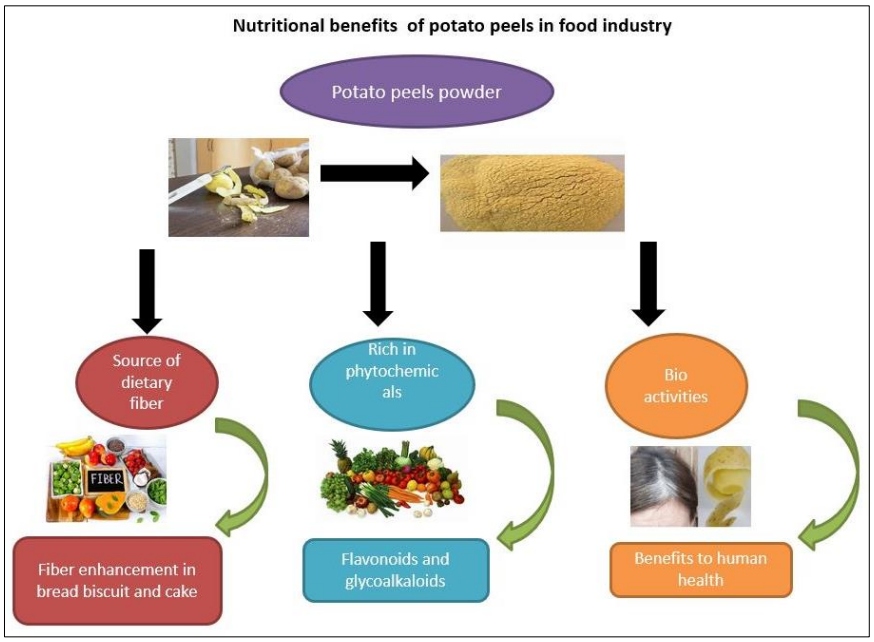

Fig 3: Nutritional benefits of potato peels in food industry

From the above figure 3, shows how potato peels contribute in the food industry as we can see is a good source of fiber also acts as phytochemicals and antioxidants in several bio activities in human health. Potato peels are often discarded, but they contain several important nutrients and can provide various nutritional benefits when included in the food industry. Here are some of the key benefits:

- **Fiber:** Potato peels are a good source of dietary fiber, which is essential for maintaining digestive health, promoting satiety, and regulating blood sugar levels.
- Vitamins and minerals: Potato peels contain significant amounts of vitamins and minerals, including potassium, vitamin C, vitamin B6, and iron. These nutrients are essential for maintaining optimal health and supporting various bodily functions.
- **Antioxidants:** Potato peels also contain antioxidants, which can help protect against oxidative stress and reduce the risk of chronic diseases such as cancer, heart disease, and diabetes.
- **Reduced waste:** Incorporating potato peels into food products can also help reduce food waste, which is a growing concern in the food industry.

Table 1: Description of potato varieties.

Variety	Shape of tubers	Color of skin and flesh	Cooking type	Characteristics after cooking
Zile	Oval	Yellow	B-BC	Darkening after boiling-none or very mild Enzymatic browning-none Starch content-medium to high Taste-satisfactory
Brasala	Round	Yellow	BC	Darkening after boiling- medium to minimal Enzymatic browning-low Starch content- steady and high Taste- excellent
Madara	Round oval	Skin; yellow Flesh; light yellow	B	After boiling darkening- weak Enzymatic browning- non Starch content- medium Taste- very good
Lenora	Round oval	Yellow	B	A little mealy, after boiling, the darkening is faint. The starch content is medium to high.
Imanta	Long oval	Skin; yellow with pink eyes Flesh white	BC-C	Mealym After boiling darkening- weak Taste – medium

B type – for frying, boiling (medium-mealy), C type – for most of meals (mealy), and BC type – for frying, boiling and other types of cooking.

Potato peels

The typical water content of potato peel residues is 77–85% w/w and the composition on a dry mass (DM) basis is as follows: 47–52% w/w starch, 8–16% w/w protein, ca. 7% w/w ash, up to 1% w/w soluble sugars, 0.5–2.6% w/w fat, while the rest is fibres. An overview on current practices and potential applications of potato residues is available in the literature. It is possible to use these materials as animal feed, however, the nutritive value is limited, and they undergo rapid microbial spoilage. Therefore, in many cases, the residues are treated as waste. Because of the high-water content, incineration is not appropriate, and therefore, biological treatment processes, such as composting and anaerobic digestion, are more suitable.

Dietary fiber is naturally available in cereals, vegetables, fruits and nuts. The amount and composition of fiber differs from food to food. It is suggested that healthy adults should eat between 20-35 g of dietary fiber each day. Several non-starch foods provide up to 20-35 g of fibre.100 g-1 dry weight and those containing starch provide about 10 g.100 g-1 of dry weight. The fiber content of fruits and vegetables is 1.5-2.5 g.100 g-1 of the edible portion.

Potato peels contain high quantities of polyphenols which have a role in the defense mechanism against python-pathogens and that's why it contains high dietary fibers. Therefore almost 50% of phenolics are located in the peel and

adjoining tissues and decrease toward the center of the tuber (Friedman, 2017) [10]. Potato peels polyphenols can reach almost three times more antioxidant activity than the other plant tissues and as we know dietary fibers are present in roughages and so potato peels have it and that's why we can use it to extract the dietary fiber. Total phenolic compound content in PPW differs between potato cultivars and it is a very heterogeneous class that can be classified in phenolic acids and flavonoids. Phenolic acids are the main phenolic compounds in potatoes**.**

Table 2: Chemical composition of raw potato peel.

Compound	Minimum and maximum values	Average content	Reference
Moisture	83.3-85.1	84.2	S.A. Arapoglou *et al*., 2019 [32]
Protein	1.2-2.3	1.8	Honma T, *et al*. 2016 [41]
Total lipids	0.1-0.4	0.3	Dhanya R, *et al*. 2019 [42]
Total carbohydrate	8.7-12.4	10.6	Arapoglou *et al*., 2015 [43]
Starch	7.8	7.8	Ashoka H *et al*., 2014 [44]
Total dietary fiber	2.5	2.5	Matias K *et al*., 2019
Ash	0.9-1.6	1.3	Yasmin A, *et al*. 2017 [45]

Another significant application of potato peel waste in the food industry is its potential as a natural antioxidant due to the presence of phenols. Studies have shown that extracts from potato peel waste can effectively inhibit lipid oxidation, making it a promising natural antioxidant for food preservation. Specifically, potato peel waste extract has been found to protect against oxidation of soybean oil and fish-rapeseed oil mixture.

Also Studies show that potato dietary fibre is able to bind bile acids in-vitro and can be part of the mechanism that lowers plasma cholesterol. In addition, high intake of dietary fibre has a positive effect on blood glucose profile. Therefore by adding dry potato peels waste powder to baked products we can produce some goods which can be the best for people who don't take in foods containing dietary fibre. As we dietary fibre is very importance in the body as it has the rough stuff can also help lower cholesterol, keep your blood sugar stable, make it easier to lose weight and even help keep you alive longer**.**

Main Bioactive Components of Potato Peel

Potato peel is considered an interesting source of several bioactive compounds, among which are phenolic compounds, glycol-alkaloids, polysaccharides, proteins, and vitamins. These compounds will be described in the following sections;

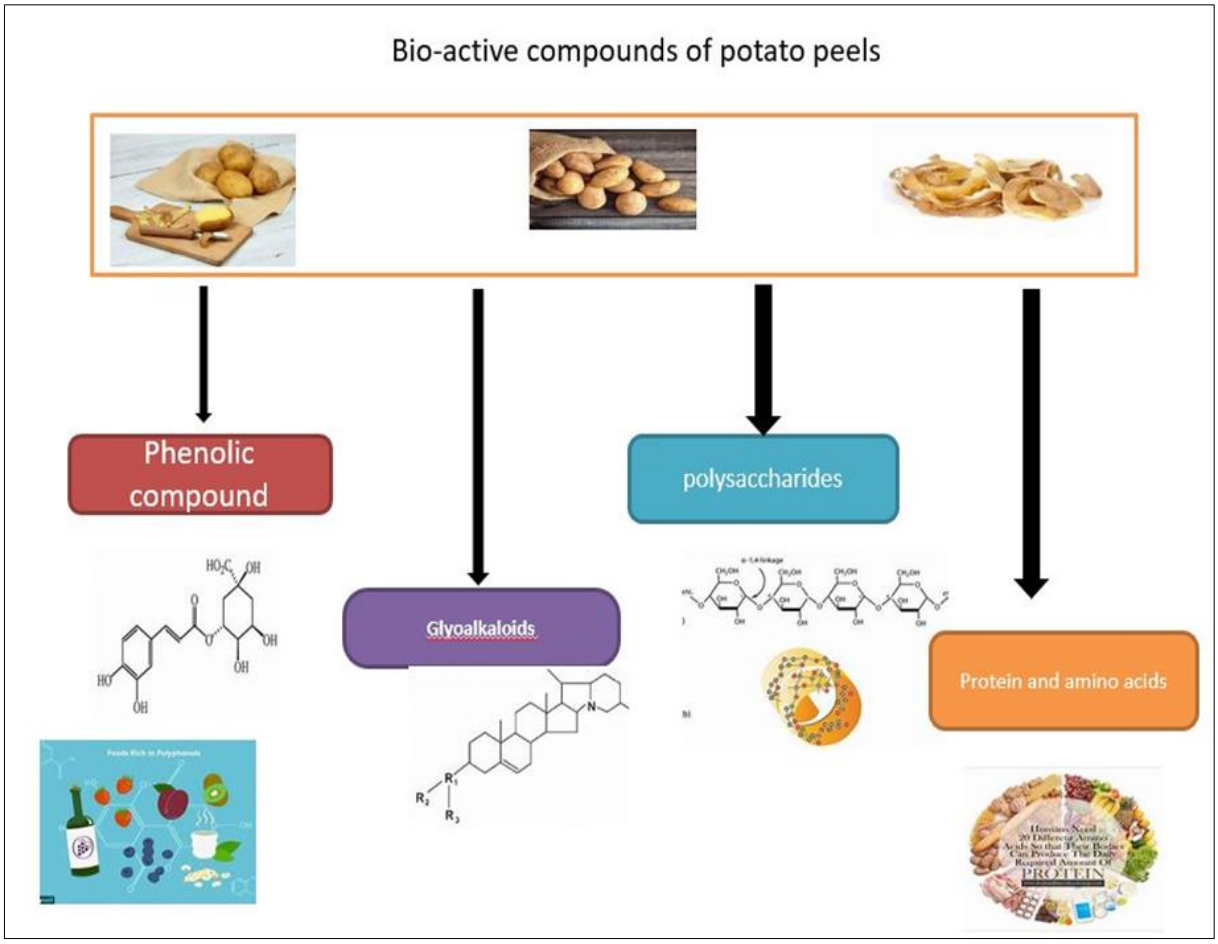

Fig 4: Bio active compounds of potato peels

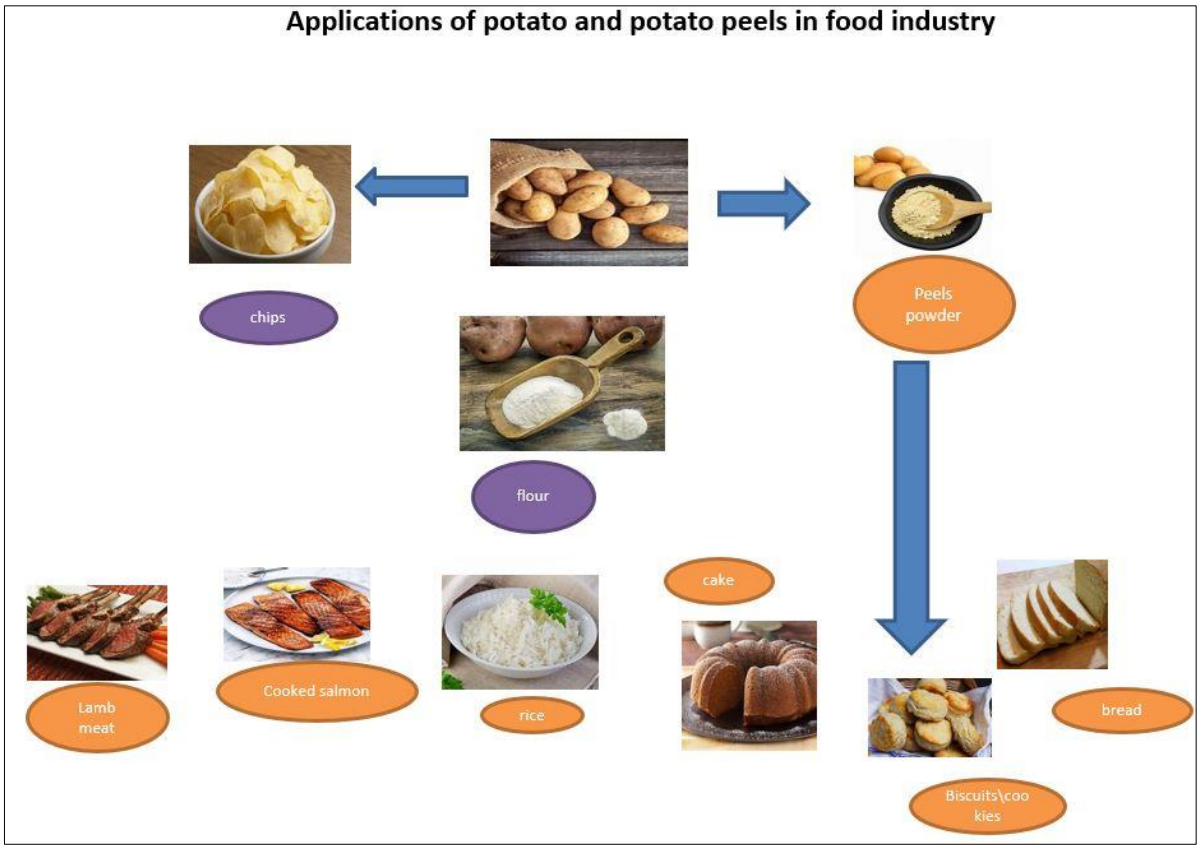

Fig 5: Application of potato peels in food industry.

Vegetable oils, fish-rapeseed oil mixture and oil-in-water emulsions

With the aim of reducing rancidity and the production of toxic oxidation molecules, the addition of synthetic antioxidants or fortification to food products is one of the most effective strategies applied by the food industry (Carocho & Ferreira, 2013) [34]. Potato peels powder have been applied as antioxidants in the protection of soybean oil against lipid oxidation. Some measurable parameters can indicate the oxidation incidence, such as the production of peroxides (the primary products of lipid peroxidation), conjugated dienes, conjugated trienes and p-anisidine values.

Cooked salmon and minced horse mackerel

Here potato peels powder is used as a source of natural antioxidants for retarding lipid and protein oxidation in another fish model, namely minced horse mackerel. The authors compared two different concentrations of PP extracts from the Sava variety, using both water and ethanol as solvents. The PP ethanol extracts were the most effective in retarding lipid and protein oxidation, resulting in lower levels of peroxide values, volatiles and carbonyl also showed a protective effect in fish meat against the loss of α-tocopherol, tryptophan and tyrosine residues. It was also found that the ethanol extracts presented higher content of phenolic compounds than water extracts.

Lamb meat and beef patties

Mansour and Khalil (2000) [35] assessed the work of PP extracts (90% ethanol) in reducing lipid oxidation in ground beef patties and lamb meat, during cold storage (5 ◦C) for 12 days. The antioxidant activity of the PP extracts was evaluated by TBARS, showing 59.5% of inhibition relative to control. This activity indicated the maximum at pH ranging from 5.0 to 6.0. Moreover, a sensory analysis showed the extracts were able to control lipid oxidation and color change of beef patties samples during cold storage.

Cooked rice

the addition of potato peels in rice shows or indicate the potential of it as it acts as anti-bacterial by retarding the growth of bacteria *B. cereus* as (Mukhopadhyay, 2018) [36] studied the growth inhibition of *Bacillus cereus* in cooked rice by nine fruit and vegetable peel powders, including PP. The results demonstrated the potential of PP in retarding B. cereus outgrowth in food products.

Other applications of potato peels

Based on its properties, Potato peels have a myriad of applications and uses. Valorization of potato peels into value-added products such as animal feed, fertilizer, and substrate for fermentation as well as for extraction of chemicals and fuels are elaborated in the following sections.

Animal Feed

Multiple investigations in recent years have illustrated that wastes from the processing of fruits and vegetables can be effectively utilized in the production of livestock feed to produce high-quality and nutrient-dense animal feeds. Due to its polyphenol content, PP is extremely nutritious and can be employed to make animal feeds again. PP was manipulated to feed cows and pigs by growers and cattle feedlot operators for a long time. Due to its high starch content, beef cattle diets frequently incorporate PP as an energy source. Milk production is improved when PP is fed; also, the yield and nature of meat are improved by and large. Some meat traders,

purveyors, and culinary specialists in Japan and North America accepted that PP-took care hamburger is milder, more watery, harder, sub-par in variety, and has less flavour than corn-took-care meat. Up to 50% of the concentrate feed blend (25 cent cotton seed meal;) can be successfully replaced with PP. 4% of rice bran, 25% of wheat bran; limestone, 1.5%; 30% yellow corn; 1% sodium chloride; molasses, 3%; and a 0.5% mixture of vitamins and minerals) in sheep feed. PP is also a good feed material for fish. When fish are fed with PP for 30 days, nutritional parameters such as fat and protein were improved in muscles and liver tissue (Maske and Satyanarayan 2012) [36]. As a consequence, feeding PP to fish and ruminants has no detrimental results on their health.

Antioxidants from Potato peels

Quantity losses in the food business are frequently caused by lipid oxidation, which is a chain process involving free radicals. Adding synthetic antioxidants during processing is an efficient technique to prevent rancidity and the generation of hazardous oxidation compounds, hence increasing the shelf life of food items. Butylated hydroxytoluene, butylated hydroxyanisole, tert-butyl hydroquinone, and propyl gallate, on the other hand, are recognized carcinogens. As a result, customers are becoming more interested in natural antioxidants that provide health advantages while having little adverse effects. Fruit and vegetable waste, such potato peels (PP), are high in antioxidants like phenolic compounds. Depending on the PP species, freeze-dried extracts of PP contain phenolic acids ranging from 15% to 32%. Recovering these beneficial molecules from PP might boost the profitability of potato processing companies and give a low-cost alternative to manufactured antioxidants.

Pharmaceutical application

Potato peel waste is an environmentally acceptable and cost-effective adsorbent for pharmaceutical effluents. Because of poor wastewater treatment, pharmaceutical preparations can affect drinking water sources, groundwater, and surface waterways. According to Lazaro and Werman (2016) [37], dietary fibers derived from potato peels have a hypocholesterolemic impact in rats. When compared to the control group, rats fed potato peel fiber had a 40% decrease in plasma cholesterol and a 30% decrease in hepatic fat cholesterol. Furthermore, dyslipidemia, which is characterised by high levels of low-density lipoprotein (LDL) and cholesterol, as well as raised triglyceride content, might contribute to blood platelet aggregation and increase the risk of hypertension and cardiovascular disease (CVD).

Application in the baking industry In baking industries

In the baking business, dietary fibers from various sources, including potato peel fiber (PPF), which contains roughly 50% dietary fiber (w/w), have been combined with wheat flour. PPF has been shown in research to be a cost-effective raw material with superior physical and chemical qualities when compared to wheat bran. PPF has been proven to have better water retention and a decreased starch content. Furthermore, the use of extruded potato peels can aid in the elimination of issues such as musty odour in PPF. Investigated the effect of using 5% and 10% (w/w) potato peel as a replacement for wheat flour in biscuit processing and discovered that it resulted in biscuits with lower stack weight but acceptable sensory scores. A further study found that muffins with 25% potato peel addition had satisfactory quality and compression resistance.

Biogas production

Potato peel trash may be used to produce biogas (CH4) by anaerobic fermentation, utilizing the starch found in the peels. This technique is favorable since it is low-cost and simple, and it can be carried out in the same location and under identical conditions (Arapoglou D, Vlyssides A, Varzakas T, *et al*. 2019) [32]. According to reports, each ton of starch waste may generate 250 m3 of biogas. Another study looked at the methane production capability of anaerobically digested potato peel and its waste from lactic acid fermentation. Methane production ranged from 60% to 70%, according to the findings. Under the same conditions, the digester utilizing potato peel fermentation residue as feedstock produced the most methane (273 Liter/kg), followed by 239 Liter/kg using potato peel trash. Wang yx *et al*. (2013) [38] also proposed a potato residue-based biogas fermentation method called combination fermentation, which yielded a biogas production ratio of 0.55 L/GVS, which was much higher than the multiple inoculum fermentation ratios of 0.32 L/GVS. Similarly, Aghel H, *et al*. (2014) [39] reported an energy generation rate of 2.8 kWh per kg/s and a COD removal rate of around 61% by the co-digestion of cow dung with potato pulp in a continuously stirred tank reactor (CSTR). In spite of that, increasing the solid loadings of potato peel fermentation residual feedstock from 6.4% to 9.1% resulted in lower methane output.

Bio fertilizer from potato peel

Potato peel has been successfully employed in the production of biofertilizers. PP includes a high concentration of proteins and carbohydrates, which are degraded by soil microbes to form nitrogen-rich fertilizers. The bacterial count in vermicompost produced from PP earthworms (Pheretima elongata) was greater than in the surrounding soil. The slurry produced by the PP biogas plant (anaerobic digester) is a valuable biofertilizer for land application, replenishing soil nutrients (Burkhardt M, *et al*. 2015) [40]. Similarly, for the synthesis of biofertilizers, potato peel, legume peel, cow dung, tulsi leaves, and neem leaves were fermented in water for 45 days. The use of this bio fertilizer resulted in an increase in vegetative growth and the physicochemical properties of a strawberry fruit. Mixing the residues (obtained from ethanol production via solid-state fermentation) with the microbes Azotobacter chroococcum, Fischerella muscicola, Anabaena variabilis, Nostoc muscorum, Cylindrospermum muscorum, Azospirillum lipoferum, and Aulosira fertilissima in equal ratio improved the nitrogen, phosphorus, and potassium content by 7.66, 21.

Bio-oil and biochar production from Potato peels waste

Biochar and bio-oil were produced from the fermentation of PP waste and its residue using a laboratory-scale auger paralyzer at 450 °C. Potato peel and its fermentation wastes were subjected to ultimate and proximate testing. In compared to bio-oils generated by hybrid poplar pyrolysis, bio-oils created from potato peels waste and fermentation residue had a greater degree of suberin-derived and lipid components and improved absorption efficiency (Han Y, Wei L, *et al*. 2015).

Generally, Potato peels powder has several industrial applications, including:

- Animal Feed: Potato peels powder can be used as a cost-effective source of feed for livestock, such as pigs, cattle, and chickens. The powder is rich in fiber, vitamins, and minerals, and can be added to animal feed to increase its nutritional value.
- Biodegradable Packaging Material: Potato peel powder may be used to make biodegradable packaging. The powder is combined with other natural ingredients to form a biodegradable film suitable for food packaging.
- Textile Industry: In the textile sector, potato peel powder may be used as a natural colour. Natural pigments in the powder can be used to colour fabrics and textiles.
- Cosmetics Industry: Potato peel powder may be used in a variety of cosmetic products, including face scrubs and body washes. The powder contains natural exfoliants that can help remove dead skin cells, leaving the skin soft and smooth.
- Biofuel: Potato peel powder may be used to make biofuels such as ethanol. The powder contains a lot of starch, which may be turned into ethanol by fermentation.

Overall, potato peel powder is a flexible and sustainable component with several industrial applications.

Future prospects

The future p-rospects of using potato peels powder are promising, as there is increasing interest in sustainable and eco-friendly products. Some potential future applications of potato peels powder include:

- **Food Industry**

Potato peel powder might be used as a natural food addition and thickening. Because of its high dietary fiber content, it can help lower cholesterol levels, improve digestion, and promote general health by lowering the risk of chronic illnesses. Furthermore, because of its neutral flavor, it may be added to a broad variety of culinary products without modifying their flavor. It may be used as a culinary component in a variety of foods such as baked products, soups, and snacks.

- **Agricultural Industry**

Potato peel powder has potential applications as a natural fertilizer and soil conditioner. It is a nutrient-rich source of essential elements like potassium and phosphorus that are crucial for optimal plant growth. Furthermore, it can enhance soil structure and improve water retention, resulting in healthier and more productive crops.

- **Animal feed**

Potato peels powder can be used as a nutritious feed ingredient for livestock, particularly pigs and poultry. It is rich in protein and other essential nutrients that can improve animal growth and health, also rich in nutrients, such as potassium and phosphorus, which are essential for plant growth. Additionally, it can help to improve soil structure and increase water retention, leading to healthier and more productive crops.

- **Biodegradable packaging**

Potato peels powder can be used to produce biodegradable packaging materials. This can reduce the amount of plastic waste generated by the packaging industry and provide a more sustainable alternative.

- **Bioremediation**

Potato peels powder can be used in bioremediation processes to clean up polluted soil or water. The high levels of starch and cellulose in potato peels can be broken down by microorganisms to release nutrients that can support the growth of beneficial bacteria and fungi.

- **Industrial applications**

Potato peels powder can be used as a raw material in various industrial applications, such as biofuels, papermaking, and textile production. The high cellulose content of potato peels makes them a promising source of renewable energy.

- **Cosmetics Industry**

Potato peel powder has been found to have antioxidant and anti-inflammatory properties, making it a potential ingredient in cosmetics and personal care products. It can be used in face masks, scrubs, and other skin care products to improve skin health.

- **Environmental Sustainability**

Potato peel powder can be used as a sustainable alternative to chemical fertilizers, as it contains nutrients that can enrich soil and promote plant growth. It can also be used as a biofuel source, reducing dependence on fossil fuels and contributing to a greener future.

- **Water Treatment**

Potato peels powder can be used as a natural coagulant in water treatment plants. It has been shown to effectively remove heavy metals and other contaminants from wastewater, making it a cost-effective and eco-friendly alternative

Hence, potato peel powder has a lot of potential for a variety of industries and applications, making it an exciting area for future research and development.

Conclusion

There is an urgent need to return byproducts and trash to the food supply chain and allied businesses in the context of the circular economy and the rising environmental effect of agro-industry. The potato processing business creates a large quantity of bulky trash, which is often wasted or utilized as animal feed, increasing the environmental effect and diminishing the crop's overall added value. Because of their intriguing chemical composition and nutritional worth, potato peels, the principal byproduct of this procedure, have recently piqued the interest of the academic community as well as the food and pharmaceutical businesses. Several research has shown that recovering bioactive chemicals and antioxidants from PP has a significant potential for usage as antibacterial agents or functional components in food items and supplements. Given the bulky nature of PP, additional study is required to improve commercial utilization of this potential resource using efficient green processes, while other uses should also be investigated to boost the overall added value of this essential crop.

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