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Potato Peel as a Source of Important Phytochemical Antioxidant Nutraceuticals and Their Role in Human Health – A Review

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1. Introduction

Food processing as one of the most important industries over the globe, however, by-products of such industrial activity that are mainly organic material must be handling in appropriate manner to avoid any environmental violence. Sanitation and disposal problem of food processing by-products is priority hence many approaches were suggested including recycling of such ingredients and utilize in several food and / or non-food applications (1). By-products of food processing is an inexpensive, affordable, and valuable starting material for the extraction of value added products such as dietary fiber, natural antioxidants, biopolymers, and natural food additives(2-4). However, the central dogma is still the stability, and economic feasibility of the processing development (5,6).

Potato (*Solanum tuberosum* L.) is one of the major world crops with world annual production of 180 million tones on 2009 according to the Food and Agriculture Organization (FAO) (7). Potato vegetation is dated back to South America around 500 B.C (8) and over centuries, it becomes a cornerstone in human nutrition in which nutritional quality was well established and documented and considers a source for many nutrients as shown in (table 1).

Of over 30 MT of annual production, tenth goes to industry to produce variable products including French fries and potato chips while the rest consumes freshly (7). By-products from potato processing, as like as any other food processing industry, are principally organic materials thus management and disposal are crucial toward a clean industry.

Potato peel (PP) has been studied as feed for pigs (9).However, potato peel is not suitable, without further treatments, as feed for non-ruminants because it is too fibrous to be digested (10). On the other hand, potato peel has been successfully used in feeding of multi-gastric animals. Milk fat from cows fed with PP was reported to be 3.3 g/kg higher than that of control (11).

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Water (g)	79.3	Calcium (mg)	12	Vitamin A, RAE (mcg)	0	Monounsaturated fatty acids, total (g)	0
Energy (kcal)	77	Copper (mg)	0.11	Vitamin C (mg)	19.7	16:1 (g)	0
Protein (g)	2.02	Iron (mg)	0.78	Vitamin B-6 (mg)	0.3	18:1 (g)	0
Fat, total (g)	0.09	Magnesium (mg)	23	Choline, total (mg)	12.1	20:1 (g)	0
Carbohydrate (g)	17.5	Phosphorus (mg)	57	Vitamin B-12 (mcg)	0	22:1 (g)	0
Sugars, total (g)	0.78	Potassium (mg)	421	Vitamin B-12, added (mcg)	0	Polyunsaturated fatty acids, total (g)	0.04
Fiber, total dietary (g)	2.2	Selenium (mcg)	0.3	Vitamin E, alpha tocopherol (mg)	0.01	18:2 (g)	0.03
Alcohol (g)	0	Sodium (mg)	6	Vitamin E, added (mg)	0	18:3 (g)	0.01
Cholesterol (mg)	0	Zinc (mg)	0.29	Vitamin D (D2 + D3) (mcg)	0	18:4 (g)	0
Saturated fatty acids, total (g)	0.03	Carotene, beta (mcg)	1	Folate, DFE (mcg)	16	20:4 (g)	0
4:0 (g)	0	Carotene, alpha (mcg)	0	Folate, food (mcg)	16	20:5 n-3 (g)	0
6:0 (g)	0	Cryptoxanthin, beta (mcg)	0	Folate, total (mcg)	16	22:5 n-3 (g)	0
8:0 (g)	0	Lutein + zeaxanthin (mcg)	8	Folic acid (mcg)	0	22:6 n-3 (g)	0
10:0 (g)	0	Lycopene (mcg)	0	Vitamin K (mcg)	1.9		
12:0 (g)	0	Caffeine (mg)	0	Niacin (mg)	1.05		
14:0 (g)	0	Theobromine (mg)	0	Retinol (mcg)	0		
16:0 (g)	0.02			Riboflavin (mg)	0.03		
18:0 (g)	0			Thiamin (mg)	0.08		

Values calculated per 100 gm fresh weight
Source: USDA Food and Nutrient Database for Dietary Studies (FNDDS)

Table 1. Chemical composition and nutritional value of potato.

The present review summarizes most attempts of potato peels utilization in food and non-food applications that include the extraction and verification of bioactive ingredients and nutritional quality of potato peels and their applications.

Although PP is being used for feeding livestock, by-products from potato processing industry still outpace such limited utilization. Another aspect was its utilization as a source for natural antimicrobial compounds (12).

2. Potato peels as a source of dietary fibers in food applications

Dietary fiber is well known as a bulking agent, increasing the intestinal mobility and hydration of the feces (13). Several authors have reviewed the importance of consumption of moderate amounts of dietary fibers for human health (14).

Scientifically speaking, dietary fiber is a broad term that includes several carbohydrates; cellulose, hemicelluloses, lignins, pectins, gums etc. (15). (16) reported that PP fibers are primarily insoluble, and can bind bile acids in-vitro. It is believed that binding of bile acids is one of the mechanisms whereby certain sources of dietary fibers lower plasma cholesterol. (17) studied the hypocholesterolemic effect of dietary fiber from PP and found that after four weeks of feeding on potato peels, rats showed 40 % reduction in plasma cholesterol content and 30% of hepatic fat cholesterol levels were reduced as compared with animals fed only with cellulose supplemented diet. Defects of dietary fiber on lipid-profile influence several health related issues. High concentrations of low-density lipoprotein (LDL) cholesterol, other dyslipidemia (high

concentration of triglycerides and low concentration of high-density lipoprotein [HDL] cholesterol), leads to blood platelets aggregation (18), risk factors for cardiovascular diseases (CVD) (19), and hypertension (20). Moreover, high intake of dietary fibers has a positive influence on blood glucose profile and it is related health complications, in healthy and diabetic individuals of both types. By altering the gastric emptying time, dietary fibers are able to affect the absorption of other simple sugars.

The effect of dietary fibers on blood glucose and insulin response has been demonstrated by many other authors as well (21,22).

Different sources of dietary fibers have been used to replace wheat flour in the preparation of bakery products. Potato peel was introduced as a promising source of dietary fiber. Since approximately 50% of potato peels (w/w) is dietary fibers (23). (24) studied the physical and chemical characteristics of PP and reported PP as being superior to wheat bran in its content of total dietary fiber, water holding capacity, and low quantities of starchy components. Wheat flour was also substituted with PP in the production of white bread, but it increased crumb darkening and reduced the loaf volume (24).

(25) found that PP caused a musty odor in breads, but the extrusion of potato peel before its utilization can diminish this aroma from the final product. (26) mentioned the effect of using PP in biscuit processing. The resulted biscuits produced using 5 and 10 % (w/w) of PP replaced wheat flour were smaller in terms of their stack weight and sensory score (color and appearance) in proportion to the levels used. In addition, supplementary biscuits were harder to bite than control biscuits.

(27) found that muffins with 25 % PP were darker, lower in height and more resistant to compression. Similarly, cookies with 10 and 15 % PP (w/w) were darker, harder, and smaller in diameter than control cookies. From a different prospect, (23) suggested the possible effect of potato peel as a good source of dietary fiber to be acting as anticarcinogenic material. Dietary fibers are known as protective materials against mutagenesis and carcinogenesis via several well established mechanisms that include binding of carcinogenic and mutagenic substances, reduce intestines-transit time, increase water absorption and fecal bulk, and lower fecal pH through the fermentation by intestinal

microflora (28). The probable role of extruded vs. unextruded potato peel, in comparison with wheat bran and cellulose as other sources of dietary fiber, in binding of the carcinogenic benzopyrene in designed in-vitro digestion model were investigated(16).

Un-extruded steam peels bound more benzopyrene than did peels extruded at temperature of 110 ^{o}C and feed moisture of 30%. Moreover, binding of benzopyrene by abrasion potato peels was lower than that by steam potato peels. In addition, abrasion peels contain approximately 25% dietary fiber and 50% starch, which may have maintained benzopyrene in suspension and / or higher amount of polyphenols remaining in abrasion peel, in contrast with steam peel, which may also have role in lowering of levels of benzopyrene by interaction and binding (16).

The method of peeling was found to be a key factor influencing the chemical composition of peels and its suitability for further utilization. (29) compared the influence of peeling method on composition of PP. Abrasion, method of peeling used by potato chip manufacturers, results in more starch and less dietary fiber than the steam peeling method used in the production of dehydrated potatoes. Potato peels with either abrasion or steam peeling methods were extruded; at barrel temperatures of either 110 ^{o}C or 150 ^{o}C and fed moistures of either 30 or 35%. Extrusion was associated with an increase in total dietary fiber and lignin contents and a decrease in starch content in steam peels. Lignin content was found to decrease but total dietary fiber content was unaffected in extruded abrasion peels. Soluble nonstarch polysaccharides increased in both types of peeling because of extrusion.

The higher quantity of glucose recovered from the insoluble fiber fraction of extruded steam peels was reported to be the possible reason in the formation of resistant starch. On the other hand, manual peeling of potato produced peels with approximately 63%, on a dry weight basis of alcohol-insoluble fibers, which was separated into pectic substances, hemicellulose, cellulose, and lignin. These fractions consisted of 3.4% pectin, 2.2% cellulose, 14.7% protein, 66.8% starch, and 7.7% ash. The sugars in the alcohol-soluble fraction consisted of 1.4% total soluble sugars and 0.9% reducing sugars (30).

3. Potato peels contribution in biotechnology

Several agro-industrial byproducts such as wheat bran, rice bran, molasses bran, barley bran, maize meal, soybean meal, potato peel and coconut oil cake have been screened as low-cost solid substrates for microbial production of enzymes to be use either in food applications or in other industrial sectors. Potato peel was reported to be an excellent substrate for the production of thermostable alpha-amylase, a starch hydrolyzing enzyme extensively used in different food industries, under solid-state controlled growth conditions (31) and was successfully used in some applications (32). Moreover, (33) and (34) used potato peel as a low-cost agro-industrial medium in production of both alpha-amylase and alkaline protease enzymes, respectively, to be used as detergents.

The antibacterial activity of the potato peel was found to be species dependent and the water extract of potato peel was effective only at high concentration against gram negative and one gram positive bacteria (35). (12) also investigated the extract of potato peel as antimicrobial agent against different types of bacteria and fungi. The results indicated the antibacterial and antifungal activities of potato peel to be species independent and when compared to one of antibiotics, streptocycline, potato peel had significant effect against *Pseudomonas aeruginosa* and *Clavibacter michigenensis*. In addition to its antimicrobial properties, potato peel can also function as a metal binder, probably due to its contents of polyphenolic compounds.

Potato peel also was able to support the economical growth and production of several extracellular hydrolytic enzymes, using *Bacillus subtilis* (30). (36) achieved the highest productivity, in terms of amount and activity, using Bacillus amylolequifaciens grown on solid media of potato peels, compare to peel samples of several fruits and vegetables, to produce β-mannanase (Figure 1). The growing interest in mannanase production for Industrial applications is due to its importance in the bioconversion of agro-industrial residues, which randomly hydrolyzes the axial chain of hetero-mannans, the major softwood hemicellulose (37).

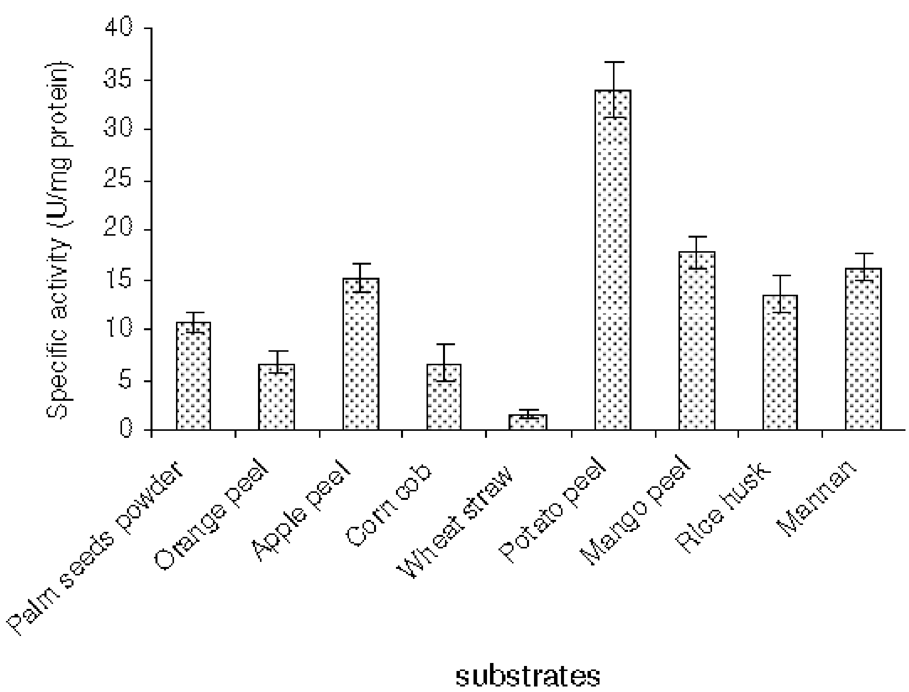

Fig. 1. Specific activity of mannanase produced by *B. amyloliquefaciens* gown on different lignocellulosic materials. Source {Mabrouk, 2008 #87932}

Mannanases have been tested in several industrial processes, such as extraction of vegetable oils from leguminous seeds, viscosity reduction of extracts during the manufacturing of instant coffee and oligosaccharides as well as it is importance in textile and paper industries. (38,39).

4. Potato peels in food applications

Potato peel also has acquired attention as a natural antioxidant in food system due to its high content of polyphenols, which was reported to be 10 times higher than their levels in the flesh (40) accounting for approximately 50 % of all polyphenols in potato tuber (41). Therefore, the effective utilization of potato peel as an antioxidant in food has been investigated extensively. Synthetic antioxidants, especially butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) are commonly used to prevent the oxidation process (42).

Concerns have been raised regarding the use of these synthetic antioxidants as being toxic and carcinogenic (43). Synthetic antioxidants may cause liver swelling and disturb the normal levels of liver enzymes (44). There is a strong need for alternative and effective antioxidants, from natural sources, to prevent deterioration of foods.

One of the first attempts to re-utilize PP was using it as a natural antioxidant in food systems. The oxidative deterioration of fats and oils is responsible for rancid odors and flavors, with a consequent decrease in nutritional quality and safety caused by the formation of secondary, potentially toxic, compounds. Thus, addition of antioxidants is an important step in processing to preserve flavor and color deterioration and to avoid nutrient loss. Due to the concerns of synthetic antioxidants in humans' foods, potato peel and extracts was proposed as a possible potential antioxidant in food systems (45). The same authors also measured the composition of fatty acids and polyphenolic content in peel of different potato varieties they also measured the antioxidant capacity of the petroleum-ether extracts in comparison with commercial antioxidants, tertiary butylhydroquinone (TBHQ), butylated hydroxyanisol, and butylated hydroxytoluene. Based on the results of their work, they suggested potato peel extract as a possible effective natural antioxidant retarding the oxidation process in vegetable oils; in particular colored skin-potato varieties which have been shown to contain the highest antioxidant activity reflecting high content of polyphenols (anthocyanins) that are responsible for their appearance (45).

(46) measured both amounts and type of phenolic compounds in freeze-dried, aqueous extract of potato peel. Chlorogenic (50.31%), gallic (41.67%), protocatechuic (7.815%), and caffeic (0.21%) acids were the major phenolic compounds detected in this study. They also measured the stability of sunflower oil heated at 63 ^{o}C when spiked with individual phenolic compounds that were detected in extract and with potato peel-water extract, respectively. When compared with control, sunflower oil in presence of aqueous potato peel extract was superior to BHT but not ascorbic acid derivative in preventing rancidity-related deteriorations in heated oil. On the other hand, (47) qualitatively and quantitatively, assessed polyphenols in either methanolic extract at 4 ^{o}C or water extract at 25 and 100 ^{o}C, respectively, of potato peel. Methanol extract of PP was shown to contain highest amounts of total polyphenolic compounds than water extract. (46). (47) reported that the main polyphenol detected in potato peel extract was chlorogenic acid. In terms of its safety as natural antioxidants in foods, potato peel freeze-dried extract was found not to be mutagenic when tested with *Salmonella typhimurium- Escherichia coli* microsome assay (35).

Moreover, the extract of potato peel had both bactericidal and bacteriostatic effects but only at a high concentration. Thus, potato peel was suggested as a possible safe, natural antioxidant to preserve foods.

More recently, potato peels, as well as some other agro-industrial by products, were examined for their content of total polyphenols and related antioxidant capacities (48). When extracted with mixture of 0.1 % of HCL in methanol: acetone: water (60:30:10, v/v/v), potato peel was found to contain approximately 177mg of total polyphenols /100 gm of fresh weight of peel.

In addition, (48) measured the total antioxidant capacity of potato peel extracts by measuring their antiradical scavenging activities and reducing power. A strong positive correlation was observed between total polyphenolic compounds in potato peel extracts and their antioxidant potency.

Lipid oxidation is a major cause of muscle food deterioration, affecting color, flavor, texture, and nutritional value ((49) and ((50). This oxidative deterioration of muscle involves the oxidation of the unsaturated fatty acids, catalyzed by hemoproteins as well as non-heme iron. (51) used freeze-dried extract of potato peel at two different levels of 500 and 1000 ppm as a natural antioxidant in ground beef patties to measure the efficacy of PP extract against the commercial antioxidant, control.

Freeze-dried extract of potato peel showed maximum antioxidant capacity at pH range of 5-6 while lost this activity at neutral and alkaline pH. In addition, antioxidant capacity, as measured with β-carotene linolate method, was significantly decreased when freeze-dried extract was boiled for more than 30 minutes and at temperature higher than 80 °C. (51) also studied the effect of heat, time, and pH on stability of potato peel extract. Further development in terms of amount being use and optimum storage conditions of food product was suggested.

(52) explored if the potato peel extract possess antioxidant potentiality in retarding lipid oxidation in lamb meat preserved with radiation. Radiation processing is one of the most effective technologies that can extend shelf life and eliminate pathogenic bacteria in raw meat and meat products. However, meat on irradiation may undergo pronounced oxidative changes that influence the sensory quality of meat (53). When added to lamb meat in ratio of 0.04%, before irradiation process, potato peel extract was able to retard lipid oxidation in a similar manner as butylated hydroxytoluene (BHT). More recently, potato peel extract were studied as a natural antioxidant to prevent deteriorations of food lipids (54). Using six different solvents and two other food processing by-products.

Compared to sesame cake and sugar beet pulp, potato peel was superior in its content of polyphenolic compounds also showed the strongest antioxidant capacity using three different confirming assays (54).

(55) and his colleagues also evaluated the effectiveness of potato peel extract, as natural antioxidant during 60 days storage of refined soy-bean oil at 25 and 45 °C. Free fatty acids, peroxide values, and iodine values were the criteria to assess the antioxidant activity of potato peels extract. Different organic solvents, including ethanol, methanol, acetone, hexane, petroleum-ether, and diethyl ether, were used to prepare extracts of potato peels.

The maximum efficiency of extraction was achieved by petroleum ether meanwhile diethyl ether, methanol, hexane, ethanol, and acetone, respectively, had had lower amounts of polyphenolic compounds in the extract. Potato peel extracted with petroleum ether exhibited strongest antioxidant activity in soybean oil during storage, equal almost to the antioxidant activity of synthetic antioxidants (BHA and BHT). However, the level of potato peel extract needed was 8–12 times higher than that of the synthetic antioxidants to control the development of rancidity during storage of cooking oils at high temperature. They suggested that potato peel extract in oils, fats and other food products can safely be used as natural antioxidant to suppress lipid oxidation (55).

Polyphenols in plants are present in either free form or bound to cell wall polysaccharides. Not all polyphenols are, therefore, readily extracted resulting in their underestimation by many researches.

(56) and (57) mention the incompleteness of data related to polyphenols in potato peel. They discussed the presence of other polyphenols in potato peel that were ignored by previous works. Principally they were interested to figure out the amount of ferulic acid-sugar esters in potato peels since many established works showed its ability to suppress the LDL-cholesterol oxidation in human plasma (58).

In their work (59) and his colleagues studied the thermal stability of ferulic acid which affects adhesion and texture of plant foods. (57) measured both free and bound forms of polyphenols in potato peel and their related free radical scavenging activities. Their results showed the superiority of bound- form of polyphenols, ferulic acid, in potato peels to quench free radicals, as measured by free radical scavenging activity technique, and strongly recommended it as a strong natural antioxidant.

5. Potentiality of potato peels antioxidants in biological systems

In light of above investigations, the potentiality of potato peel or potato peel extracts to act as antioxidant in biological systems have draw great scientific attention. The antioxidant potency of freeze-dried aqueous extract of potato peel was investigated, employing various established antioxidant measurement techniques in vitro; lipid peroxidation in rat liver homogenate,1,1-diphenyl-2-picrylhydrazyl (DPPH), as well as superoxide/hydroxyl radical scavenging, reducing power, and iron ion chelation (60).

The freeze-dried aqueous extract of potato peel powder showed strong inhibitory activity toward lipid peroxidation in rats' liver homogenate induced by the $FeCl_2$–H_2O_2 system. Furthermore, the water extract of PP exhibited a strong concentration-dependent inhibition of deoxyribose (DNA) oxidation.

The antioxidant activity measurements of potato peel extract did emphasis its strong reducing power activity, superoxide scavenging ability as well as its ion chelating potency. The in vitro results suggest the possibility that potato peel waste could be effectively employed as an ingredient in health or functional food, to alleviate oxidative stress (60).

In patients with diabetes mellitus, either type I or type II, it is well known that the production of ROS and lipid peroxides (LPO) increase (61). It has been suggested that oxidative stress (OS) is responsible for the pathophysiology of diabetes (62). The OS was reported to be related to hyperglycemia (63).

Hyperglycemia causes nonenzymatic glycation of protein through the Maillard reaction and alters energy metabolism, which results in an elevation of ROS levels and further development of diabetic complications (64). Potato peel was found to influence both glycemic index and antioxidant status in streptozotocin (STZ)-induced diabetic male Wistar rats (65). In that study, diabetic rats fed potato peel-powder-supplemented diet for 4 weeks showed significant decrease in blood glucose levels. In addition, Incorporation of PP powder into the diet reduced significantly the hypertrophy of both liver and kidney in STZ-diabetic rats and normalized the activities of serum alanine-aminotransferase (ALT) and aspartate-aminotransferase (AST).

Serum enzymes such as aspartate aminotransferase and alanine aminotransferase are employed in the evaluation of hepatic disorders and the increase in their levels reflects acute liver damage and inflammatory hepatocellular disorders (66). In addition, (65) measured both hepatic and renal-lipids oxidation, glutathione as well as activities of various antioxidant enzymes in liver and kidney of STZ-diabetic rats. It is suggested that PP powder in the diet may also be able to attenuate the eye lens damage associated with the diabetic conditions.

The strong antioxidant properties of potato peel extract (PP), which have been attributed to high content of polyphenolic compounds, was tested as a protective agent against erythrocytes-oxidative induced-damage in vitro (67) and by the measurement of morphological alterations and the structural alterations in the cell membrane. The total polyphenolic content in aqueous PP in this experiment was found to be 3.93 mg/g, dry weight based.

The major phenolic acids present were: gallic acid, caffeic acid, chlorogenic acid and protocatechuic acid. An experimental pro-oxidant system was used to induce lipid peroxidation in rat red blood cells (RBCs) and human RBC membranes. PP was found to inhibit lipid peroxidation with similar effectiveness in both the systems (about 80–85% inhibition by PP at 2.5 mg/ml).

While PP *per se* did not cause any morphological alteration in the erythrocytes, under the experimental conditions used, PP significantly inhibited the H_2O_2-induced morphological alterations in rat RBCs as revealed by scanning electron microscopy. (67) also suggested PP extract as a significant protector of human erythrocyte membrane proteins from oxidative damage probably by acting as a strong antioxidant. By virtue of its unique vascular and metabolic features, the liver is exposed to absorbed drugs and xenobiotics in concentrated form.

Detoxification reactions (phase I and phase II) metabolize xenobiotics aiming to increase substrate hydrophilicity for excretion. Drug-metabolizing enzymes detoxify many xenobiotics but bioactivate or increase the toxicity of others (68). In case of bioactivation, the liver is the first organ exposed to the damaging effects of the newly formed toxic substance.

Therefore, protective mechanisms relevant to the liver are of particular interest. Because free radicals and reactive oxygen species play a central role in liver diseases pathology and progression, dietary antioxidants have been proposed as therapeutic agents counteracting liver damage (69). (70) predicted a possible protective role of the potato peel extrcat against induced liver injury in rats.

Prior to the treatment with tetrachlorocarbon (CCL_4), the animals received doses of 100 mg, freeze-dried aqueous potato peel extract, / kg of body weight for seven consecutive days. The animals receiving an acute dose of carbon tetrachloride (CCL_4) to induce liver injury followed this. Liver enzymes as well as biomarkers of oxidative stress either in liver or in blood serum were measured. The administration of PP to rats orally at 100 mg/kg body weight/day reduced the risk of hepatic damage induced as a result of CCl_4 administration, as observed by evaluating of serum lactate dehydrogenase (LDH), aspartate aminotransferase (AST), and alanine aminotransferase (ALT) levels in CCl_4-treated rats. Also, the deteriorations of malondialdehyde (MDA); which is one of the end products of lipid peroxidation in the liver tissue, and depletion of hepatic glutathione (GSH) level; which is an important indicator of oxidative stress (71), were significantly higher in CCl_4-treated rats in comparison with animals that were pretreated with potato peel extract.

Super oxidase dismutase (SOD), catalse (CAT), and glutathione peroxidase (GPX) constitute a mutually supportive team of antioxidant defense against reactive oxygen species. SOD is the first line of antioxidant defense and it hastens the dismutation of superoxide radical to H_2O_2, while CAT/GPX converts H_2O_2 to water (72).

According to this scenario, a significant increase in SOD activity as a defense against the presence of free radicals can, generate overwhelmingly large amounts of H_2O_2. This in turn would disable the organism to handle the excessive H_2O_2, which would again result in oxidative stress.

Thus, increase in SOD accompanied by a decrease in CAT/GPX activity indicates a state of oxidative stress due to free radical generation (73). (70) elucidated the significant positive correlation between dosing of potato peel extract and SOD levels in rats treated with CCl_4. Additionally, histopathological studies showed that CCl_4 induced a remarkable degeneration in hepatocytes and focal necrosis. However, in general, lesions were markedly diminished in rats that were pre-administered with potato peel extract prior CCl_4 administration.

Study	Results	Reference
Solubility of PP fibres and its ability to bind bile salts	Are primarily insoluble, and can bind bile acids in-vitro. It is believed that binding of bile acids is one of the mechanisms whereby certain sources of dietary fibers lower plasma cholesterol	{Camire, 1993 #88855}
The hypocholesterolemic effect of dietary fiber from PP	40 % reduction in plasma cholesterol content and 30% of hepatic fat cholesterol levels were reduced in rats fed on potato peels compared to normal diet	{Lazarov, 1996 #88875}
Physical and chemical characteristics of PP and substitution of PP wheat flour in the production of white bread	Being superior to wheat bran in its content of total dietary fiber, water holding capacity, and low quantities of starchy components. Potato peels increased crumb darkening and reduced the loaf volume	{Toma, 1979 #88853}
The probable role of extruded vs. unextruded potato peel, in comparison with wheat bran and cellulose as other sources of dietary fiber, in binding of the carcinogenic benzopyrene in designed in-vitro digestion model	1. Un-extruded steam peels bounds more benzopyrene than did peels extruded at temperature of 110 ^{o}C and feed moisture of 30%. 2. Binding of benzopyrene by abrasion potato peels was lower than that by steam potato peels. 3. Abrasion peels contain approximately 25% dietary fiber and 50% starch, which may have maintained benzopyrene in suspension and / or higher amount of polyphenols remaining in abrasion peel, in contrast with steam peel, which may also have role in lowering of levels of benzopyrene by interaction and binding	{Camire, 1993 #88855}.

Raw and extruded PP fibres in the production of bread	PP caused a musty odor in breads, but the extrusion of potato peel before its utilization can diminish this aroma from the final product.	{Orr, 1982 #88797}
The effect of using PP in biscuit processing.	The resulted biscuits produced using 5 and 10 % (w/w) of PP replaced wheat flour were smaller in terms of their stack weight and sensory score (color and appearance) in proportion to the levels used. In addition, supplementary biscuits were harder to bite than control biscuits.	{Abdel-Magied, 1991 #88876}
Potato peels in the production of muffins and cookies	Muffins with 25 % PP were darker, lower in height and more resistant to compression. Similarly, cookies with 10 and 15 % PP (w/w) were darker, harder, and smaller in diameter than control cookies.	{Arora, 1994 #86730}
The influence of peeling method on chemical composition of PP.	1. Abrasion method used by potato chip manufacturers, results in more starch and less dietary fiber than the steam peeling method used in the production of dehydrated potatoes. 2. Extrusion was associated with an increase in total dietary fiber and lignin contents and a decrease in starch content in steam peels. 3. Lignin content was found to decrease but total dietary fiber content was unaffected in extruded abrasion peels. 4.Soluble nonstarch polysaccharides increased in both types of peeling because of extrusion.	{Camire, 1997 #88802}
Manual peeling of potato peels	Approximately 63%, on a dry weight basis of alcohol-insoluble fibers was separated into pectic substances, hemicellulose, cellulose, and lignin. These fractions consisted of 3.4% pectin, 2.2% cellulose, 14.7% protein, 66.8% starch, and 7.7% ash. The sugars in the alcohol-soluble fraction consisted of 1.4% total soluble sugars and 0.9% reducing sugars	{Mahmood, 1998 #88884}.

Potato peel used as a low-cost agro-industrial medium in production of both alpha-amylase and alkaline protease enzymes and several extracellular hydrolytic enzymes	High yield and high activity of the produced enzymes	{Mukherjee, 2008 #88896}, {Mukherjee, 2009 #88895}, {Fadel, 1999 #88873} and {Fadel, 2002 #88874} {Mahmood, 1998 #88884}. {Mabrouk, 2008 #88880} {McCleary, 1988 #88881} {Gubitz, 1996 #88882; Ademark, 1998 #88883}.
The extract of potato peel as antimicrobial.	Antibacterial and antifungal activities of potato peel to be species independent	{Prasad, 2007 #88515
Potato peel extracts was proposed as a possible potential antioxidant in food systems	Extract was superior to BHT but not ascorbic acid derivative in preventing rancidity-related deteriorations in heated oil	{Onyeneho, 1993 #88898} {Rodriguez De Sotillo, 1994 #80192} ({Rhee, 1996 #88903} ({Yin, 1997 #88904}., {Makrisa, 2007 #88902} {Mansour, 2000 #80194} {Formanek, 2003 #88897}. {Kanatt, 2005 #89686} {Mohdaly, 2010 #88957}. {Mohdaly, 2010 #88957}. {Rehman, 2004 #86733} {Rehman, 2004 #86733}.
Amounts and type of phenolic compounds in freeze-dried, aqueous extract of potato peel.	1. Chlorogenic (50.31%), gallic (41.67%), protocatechuic (7.815%), and caffeic (0.21%) acids were the major phenolic compounds detected in this study. 2. Qualitatively and quantitatively, assessed polyphenols in either methanolic extract at 4 °C or water extract at 25 and 100 °C, respectively, of potato peel. Methanol extract of PP was shown to contain highest amounts of total polyphenolic compounds than water extract. reported that the main polyphenol detected in potato peel extract was chlorogenic acid.	{Rodriguez De Sotillo, 1994 #80192} {Ishii, 1997 #88910}. {Nara, 2006 #45746} {Rodriguez De Sotillo, 1994 #80191}

Safety of potato peels extract when used as natural antioxidants in foods,	Potato peel freeze-dried extract was found not to be mutagenic when tested with *Salmonella typhimurium- Escherichia coli* microsome assay	{Rodriguez De Sotillo, 1998 #80193}.
The potentiality of potato peel or potato peel extracts to act as antioxidant in biological systems	1. Inhibitory activity toward lipid peroxidation in rats' liver homogenate induced by the $FeCl_2$–H_2O_2 system. the water extract of PP exhibited a strong concentration-dependent inhibition of deoxyribose (DNA) oxidation. 2. Potato peel was found to influence both glycemic index and antioxidant status in streptozotocin (STZ)-induced diabetic male Wistar rats reduced significantly the hypertrophy of both liver and kidney and normalized the activities of serum alanine-aminotransferase (ALT) and aspartate-aminotransferase (AST). 3. PP extract as a significant protector of human erythrocyte membrane proteins from oxidative damage probably by acting as a strong antioxidant.	{Singh, 2004 #79 {Singh, 2005 #88890}. 926}. {Singh, 2005 #88890}
Protective role of the potato peel extract against induced liver injury using CCL_4 in rats.	1. The administration of PP to rats orally at 100 mg/kg body weight/day reduced the risk of hepatic damage induced as a result of CCl_4 administration, as observed by evaluating of serum lactate dehydrogenase (LDH), aspartate aminotransferase (AST), and alanine aminotransferase (ALT) levels in CCl_4-treated rats. 2. Significant positive correlation between dosing of potato peel extract and SOD levels in rats treated with CCl_4 3. histopathological studies showed that CCl_4 induced a remarkable degeneration in hepatocytes and focal necrosis. However, in general, lesions were markedly diminished in rats that were pre-administered with potato peel extract prior CCl_4 administration.	{Singh, 2008 #87208}

Table 2. Summary of potato peels (PP) attempts of reutilization.

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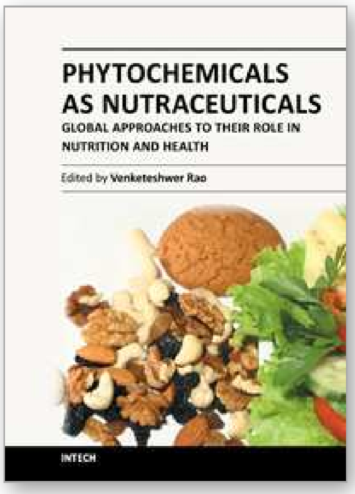

Phytochemicals as Nutraceuticals - Global Approaches to Their Role in Nutrition and Health

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Phytochemicals are biologically active compounds present in plants used for food and medicine. A great deal of interest has been generated recently in the isolation, characterization and biological activity of these phytochemicals. This book is in response to the need for more current and global scope of phytochemicals. It contains chapters written by internationally recognized authors. The topics covered in the book range from their occurrence, chemical and physical characteristics, analytical procedures, biological activity, safety and industrial applications. The book has been planned to meet the needs of the researchers, health professionals, government regulatory agencies and industries. This book will serve as a standard reference book in this important and fast growing area of phytochemicals, human nutrition and health.

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