Review paper
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POTATO WASTE MANAGEMENT IN PAKISTAN'S PERSPECTIVE

Shinawar Waseem Ali[1*], Asad Nawaz[1], Sana Irshad[2], Aftab Ahmed Khan[1]

[1]Institute of Agricultural Sciences, University of the Punjab, Quid-i-Azam Campus, 54590 Lahore, Pakistan
[2]College of Earth and Environmental Sciences, University of the Punjab, Quid-i-Azam Campus, 54590 Lahore, Pakistan

[*]e-mail: shinawar.iags@pu.edu.pk

Abstract

Potato (L. *Solanum tuberosum*) belongs to *Solanaceae* family and is the fourth most cultivated crops after wheat, rice and maize the world. It is the good source of: carbohydrates, protein, vitamins, minerals and trace elements. In a Pakistan, there are good climatic environment for the growth of this crops, and Pakistan is self-sufficient in potato production.

Potato is being used in different industries as a whole or a part of processing having different products like french fries, potato chips, potato starch, potato powder and potato proteins etc. During the processing operations a reasonable amount of potato solids go into the waste especially the peels of potato, which may be a good source of many bioactive compounds. Potato peel contains fibber, dietary fiber and other carbohydrates that can be further hydrolyzed to produce inulin, oligofructose, lactulose and resistant starch etc. Potato peel has been proved medicinally important as it contains phenolic, polyphenolic compound, anthocyanins, non-anthocyanin flavonoids and glycoalkaloids which are health beneficial having antioxidental and anti-bacterial properties. Many products of industrial importance like amylases, citric acid and prebiotics etc., are being produced by using potato waste as microbial substrate. Moreover, Pakistan is facing energy crises these days and potato waste can be good substrate for biofuel / biogass production. Innovation in technologies for the efficient potato waste management and extraction/production of value added products from this waste in Pakistan's perspective are discussed in this study.

The discussion concludes that effective utilization of potato waste can play a vital role in developing indigenous industry for the production of a lot of value added products, as well as to meet the energy crises in Pakistan.

Key words: *Potato, Prebiotics, Waste management, Pakistan.*

1. Introduction

Potato (*L. Solanum tuberosum*) is the most important dicotyledonous tuber crop and has great importance worldwide [1]. It is the third crop in order of importance being consumed by humans in a quantity of over 300 million tons (Mt) every year, after wheat (630 Mt) and rice (608 Mt). The total soil area for the potato production worldwide is approximately 20 million hectares and fertilizer usage has made a tremendous increase in potato production during recent years. Total production of potato throughout the world is about 320 Mt annually having a great share in the sense of finance and food security [2, 3, and 4].

As a part of human diet, potato is of great nutritional importance. It is an important source of starch, vitamin C and potassium for people in both developed and developing countries. It is the good source of: carbohydrates, protein, vitamins, minerals and trace element present in a very less amount that are required for the body metabolism and growth [5]. Taking in account its nutritional features, potato can be considered as a partial replacement for cereal crops [6].

Pakistan is self-sufficient in potato production, and there are good climatic conditions for the growth of this crop [7]. Potato production depends upon the: climatic factors, fertility, sowing seasons, irrigation system and type of soil. Annual production of potato in Pakistan is 2.02 million metric tons and 280000 metric tons is used as seed, while 1.7 million metric tons are consumed by local population, accounting for 11 kg per capita per annum consumption [8, 9, and 10]. Most of the potato in Pakistan is being used locally at household level, cooking in different dishes. Food industries are processing potatoes in different products like: French fries, potato chips, potato starch, potato powder, potato protein etc., and/or potato is also being processed as an integral ingredient in different recipes [11, 12, and 13]. Major potato processing industries in

Pakistan are PepsiCo Inco, Ismail Industries, Tripple EM, Standard Foods, Consolidate, Bunny's, United snacks, JB Foods, Trading enterprises and Kohinoor Smith etc.

Different unit operations involved in potatoes processing are: washing, peeling, trimming, slicing, blanching, drying, frying, de-oiling and packing etc. [14]. During these operations about half of potato solids go into the waste, especially the peel of potato that accounts for 15 to 40% of total potato waste, and it is considered of zero importance for any type processing [15]. Though, peels are the major waste of potato processing, depending on the procedure applied, it contain a large amount of potato solids and essential nutrients like: potato starch, proteins, sugars and other carbohydrates etc. During peeling process, most of the nutrients get lost, that can be efficiently utilized in processing of different products [16, 17].

Potato waste management by above mentioned industries in Pakistan is a great challenge and mostly the waste being produced by these industries becomes the part of municipal waste or sewerage. The potato waste can be utilized as animal feed, but its transportation cost becomes so high that there are very less or zero chances of revenue generation. Moreover, there is one more problem associated while focusing on potato waste as animal feed, and the main reason is that every animal cannot take every food/residue. Nevertheless, potato waste can be converted/processed into much beneficial value added products with minimum cost of production. Moreover, newly developed food and feed products from potato waste can be a great achievement to overcome the problems related to: waste, environment, toxicity and biodiversity etc. Goal of waste management towards the welfare of mankind may be long term and short term, depending upon the final products with value addition by following different approaches. A lot of valuable products can be produced from potato waste by different chemical and physical processes like:

- Hydrolysis to produce compounds such as oligofructose, lactulose and resistant starch.
- Production of activated carbon, bandages and bioadsorbents.
- Production of medically important compounds such as flavonoids and glycoalkaloids.
- Production of industrially important materials such as: amylases, cellulase, citric acid, compost, dietary fibres and prebiotics etc.
- Production of Biofuel and Biogas.

The food industries are based on three interactive components: quality of products, efficiency of the processing and environmental management. So, this concept requires the continuous research and recipe development. Most important need of the time in Pakistan is cheap raw material and focus on the cost effective processing with the optimum use of available resources to improve the quality of products. Potato waste management can be very beneficial with reference to economic as well as social and environmental aspects contributing towards a healthy population. This review highlights the utilization of potato waste for the production of many value added products keeping in view the prevailing situations in under developed countries like Pakistan.

2. Utilization of potato waste

Keeping all the above discussion in consideration, in order to give a practical solution for Pakistan, it is better to combine potato waste management with economic aspects rather than prevention, so that waste reduction may be achieved with rise in production of value added products. Some of the promising value added products from potato waste are briefly discussed below.

2.1 Citric acid and vitamins

The recovery of valuable compounds from waste or residue is an empirical approach. Many compounds of economic importance can be recovered from potato waste. Potato peels can be used as medium of growth for *Aspergillus niger* species for citric acid production. It reduced the cost of growth medium, and five to four folds increase in citric acid production was observed in a study [18]. Citric acid is the leading organic acid, naturally present in citrus fruits, and commercially produced through fermentation process [19]. Currently Pakistan is spending billions of US dollars on import of food grade citric acid. As it is a commercial commodity, its production by using cheap raw materials, such as potato peels, will be a great contribution to national economy.

Potato peels are also a good source of vitamin C and vitamin B6. Moreover, potato peel is rich with many other nutrients i.e.: iron, calcium, magnesium, fiber and some proteins, etc. Many studies have reported the procurement of many micro and macronutrients from potato peels [20]. Optimization of production technologies of such value added products from potato waste will open new horizons for the food and feed industry in Pakistan.

2.2 Prebiotics

Prebiotics are materials that pass to large intestine without digestion [21] and help in the growth of healthy microbes in gut [22]. These may be helpful for colonic microflora as well as in the fermentation. Moreover, prebiotics can be potential source for: promoting digestion, weight loss, low risk of cardiovascular disease and reducing the risk of cancer [23]. Recent advances have revealed aspects related to the production of prebiotics from the potato waste such as inulin that is a polysaccharide which plants store as a nutrient [24, 25]. It is a small molecule of fructo-oligosaccharides having 3 - 60 fructose moieties. Inulin is generally found in: plants, bacteria, and some fungi. It is known in more than 3,600 fruits and vegetables [26]. These compounds are used in the food industry to improve sensory and physical properties of some products. For example, they help preserve freshness and moisture in cakes, and the physical stability in beverages [27]. Galacto-oligosaccharides (GOS) are also a product that can be synthesized by using potato peels as raw material [27, 28]. Many other compounds may result from the hydrolysis of GOS e.g. lactate, which may improve the growth of *Bifidobacteria* and *Lactobacilli* [29]. These microorganisms can help: synthesize vitamins, stimulate immunity, and prevent stomach upset in the human [30]. Thus, the utilization of potato waste for the production of prebiotics is a novel idea for Pakistani industries.

2.3 Enzyme production

The cellulase hydrolysis process takes place via an enzymatic complex of cellulases. Such enzymes are bio-catalyzers that work in interaction to produce sugars and are commercially important [31]. Acid hydrolysis of hemi-cellulosic biomass that is available in the form of potato peel was carried out to produce five and six carbon sugar by enzymatic activity [32, 33]. Of these sugars, glucose attracts most of the interest from industry, due to the possibility of converting it into ethanol [32].

Amylases are one of the first enzymes to be produced commercially by microorganisms [34]. Amylases are amylolytic enzymes and represents a group of catalytic proteins of great importance in carbohydrate metabolism. Amylase production has increased dramatically due to its wide spread use in: food, textile, baking and detergent industries. Besides its use in the saccharification or liquification of starch [35, 36], the enzyme is also used for the: warp sizing of textile fibers, clarification of beer and fruits juices, and for the pretreatment of animal fodder to improve the digestion capability [37]. Many studies reveal the production of high activity enzyme by using potato peels such as: alpha-amylase, alkaline protease enzymes and several extracellular hydrolytic enzymes [38, 39]. Pakistan is spending a huge amount of foreign exchange reserves on the import of above mentioned enzymes, which can be saved through the promotion of such industries that can utilize potato waste as cheaper substrate for the production of these enzymes.

2.4 Steroidal glycoalkaloids

Steroid glycoalkaloids, compounds of medicinal importance, exist naturally in potatoes especially in potato peels [40]. They therefore must have important functions both in the plant and in the diet. Glycoalkaloids are relatively stable in potatoes and its levels are not affected by: boiling, freeze-drying, or dehydration [41]. These compounds are important in preventing skin cancer. They also find importance in manufacturing of steroid hormone. A study has been conducted to investigate the amount of steroids in potato peels by using ultrasound assisted extraction (UAE) and solid liquid extraction (SLE). It was identified that 1,102 µg steroidal alkaloids were recovered per gram dried potato peel using UAE, while 710.51 glycoalkaloid µg/g of dried potato peel using SLE [42, 43]. So Pakistan has great potential to produce steroidal glycoalkaloids through potato waste treatment/extraction.

2.5 Activated carbon, bio-adsorbent

Activated carbon is used in: gas purification, decaffeination, gold purification, metal extraction, water purification, removal of endocrinal disrupters, sewage treatment [44, 45], air filters in gas masks and respirators, filters in compressed air, and in many other applications [46]. Potato peels are used for activated carbon production [47].

Clean water is a vital resource for life, but addition of industrial effluents makes it polluted. The most common pollutant in the water are heavy metals [48]. There is variety of techniques for purification of water, however bio-techniques have attracted a lot of consideration due to their cost effectiveness and easy availability. Adsorption of toxicants from water is one of the very effective treatments to clean the water. Agro-wastes, being cheap and easy to use, can be the potent raw material for the manufacture of bio-adsorbents that can be used to treat heavy metal pollution in water [49]. It is a real way to use a bulk of potato waste with pre-treatment. Many studies report the effective use of bioadsorbents, developed from potato peels, for heavy metal removal. Potato peels (waste from restaurants) treated with KOH after heat treatment were found to be efficient adsorbent for removal of drugs from pharmaceutical waste [50]. Potato waste was used for the removal of hexavalent chromium (Cr (VI)), which is carcinogenic and teratogenic, from aqueous effluents such as tannery waste etc. Approximately 4 g/L of adsorbent was found to be effective in complete removal of the Cr(VI) at pH 2.5 in two hours [51]. Potato peels charcoal (PPC) was found effective as an adsorbent for the removal of Cu(II) from aqueous solutions [49]. Like other under developing countries, clean drinking water is unavailable to a large number of population in Pakistan. Utilization of potato waste for the development of cheap and easy to use bioadsorbents for the treatment of drinking water will be very cost effective and beneficial for a large segment of Pakistani population.

2.6 Dressing of wounds

Sterile potato peels can be used as a dressing for burn wounds. Carefully placing the peels edge to edge on an extensive wound was both time consuming and back-breaking for the nursing staff. Patel *et al*., simplified the method of application of the potato peels by preparing roller bandages with potato peels attached to one surface [52]. Potato peels are found to have antibacterial and antifungal activities that are species independent and have potential to treat superficial infections and burns [53]. The healing power of boiled potato waste applied to affected areas of skin on acute burn patients has been reported. This is attributed to the anti-bacterial properties contained by potato peels. A research conducted in India found that potato waste dressing is easy to prepare, apply as well as confiscate. It is a comfy dressing and is also cost effective for treating wounds of: pemphigus, bullous pemphigoid and leg ulcers [54].

2.7 Mannanases production

Mannanases have been tested in several industrial processes, such as: extraction of vegetable oils from leguminous seeds, viscosity reduction of extracts during the manufacture of instant coffee and manufacture of oligosaccharide [55], as well as applications in the textile industry [56]. In paper industry, mannanases have synergistic action in the bio-bleaching of the wood pulp, significantly reducing the amount of chemicals used [55]. The growing interest in production for industrial applications is due to its importance in the bioconversion of agro-industrial residues. Potato peels are reported as very productive substrate for the production of mannanases by *Bacillus amyloliquefaciens* [57].

2.8 Antioxidants and nutraceuticals

Antioxidants come up frequently in discussions about good health and preventing diseases [58]. These powerful substances, which mostly come from the fresh fruits, and vegetables we eat, prohibit (and in some cases even prevent) the oxidation of other molecules in the body [25]. The benefits of antioxidants are very important to good health, because if free radicals are left unchallenged, they can cause a wide range of illnesses and chronic diseases [20, 23]. A number of byproducts from vegetable processing industry have been previously studied as potential sources of antioxidants [25]. Some important antioxidants in this group are flavnoids and tocopherols [11]. Potato peels also comprise a range of phytonutrients that are a natural mean of obtaining antioxidants which are helpful in inhibiting cellular deterioration of the body. These phytonutrients include: polyphenols, carotenoids, flavonoids, and caffeic acid [20]. Potato peels are also used for preservation of soya beans, as it contain anti-oxidants. Isolation and extraction can be made through extraction process by using different organic solvents [58]. So, potato peel provides an excellent source for the recovery of phenolic compounds, since almost 50% of phenolic compounds are located in the peel and adjoining tissues and decrease toward the center of the tuber. A study quantified the phenolic compounds in potato peel extract and it was measured that they contain: gallic (41.67%), chlorogenic (50.31%), protocatechuic (7.815%), and caffeic (0.21%) substances [25]. Some studies also divulge the antioxidant effects of potato waste in biological system. The extract of potato waste showed a strong concentration-dependent reticence of deoxyribose (DNA) oxidation. Potato peel was also found significantly influencing both glycemic index and antioxidant activity in streptozotocin (STZ)-induced diabetic male wistar rats. Where it reduced significantly the hypertrophy of both liver and kidney and normalized the activities of serum alanineaminotransferase (ALT) and aspartateaminotransferase (AST) [59]. Potato waste extract was also found significant protector of human erythrocyte membrane proteins from oxidative injury by acting as a strong antioxidant [60]. Production of nutraceuticals in Pakistan is a new market for pharmaceutical industries. These industries can get benefit of the availability of huge amount of potato waste in Pakistan to extract these bioactive compounds.

2.9 Dietary fibers

Dietary fiber increases the weight and size of stool and softens it making its movement easy through elementary canal. Diet with high fiber lowers the chances of hemorrhoids and diverticular disease. They also lower cholesterol level and help to maintain sugar level of body thus aid in attaining healthy body weight. Some works had been reported previously on potato peel as a source of dietary fiber. Diverse sources of dietary fibers can be used to replace wheat flour in the preparation of bakery goods. Potato peel can be promising source of dietary fiber as approximately 50% of potato peels (w/w) is dietary fiber. Potato peels are proved superior in terms of total dietary fiber content, water holding capacity (WHC) and low quantities of starchy components. They are insoluble in water and bind bile acids in vitro. It is thought that binding of bile acids is key mechanisms by which dietary fibers lower the cholesterol [61, 62, and 63]. In a previous study, 40% decrease in plasma cholesterol and 30% reduction in hepatic fat cholesterol levels was observed in rats fed on potato peels in comparison to normal diet [64].

2.10 Composting

Compost is organic matter that has been decomposed and recycled as fertilizer for soil amendment. It is a key ingredient in organic farming. Compost helps in binding the clusters of soil particles, called aggregates, which provide good soil structure. Such soil is full of tiny air channels and pores that hold air, moisture and compost brings and feeds diverse life in the soil (bacteria, fungi, insects, worms etc.) and more support healthy plant growth. Healthy soil is an important factor in protecting our waters. Compost increases soil's ability to retain water and decreases runoff. Runoff pollutes water by carrying soil, fertilizers and pesticide residues to nearby streams [65, 66]. Compost is commercially sold in Pakistan replacing fertilizers. Potato peels, lignocellulose waste, is a key raw material for composting. Many studies divulged the use of potato peels for the preparation of compost [67].

2.11 Bio-fuel production

Renewable biofuels are produced through the use or conversion of biomass i.e. recently living organisms, most often referring to plants or plant-derived materials. This biomass conversion by microbes can result in fuel in solid, liquid, or gas form. This new biomass can be used directly as biofuels and/or is a potential renewable energy resource. Potato waste has large quantities of starch, cellulose, hemicellulose and fermentable sugars to warrant use as an ethanol feedstock. In a previous study, potato waste was hydrolyzed with various enzymes and/or acid and fermented by *Saccharomyces cerevisae* var. *bayanusto* for ethanol production. Enzymatic hydrolysis with a blend of three enzymes produced 18.5 g/L reducing sugars, and also produced 7.6 g/L of ethanol after fermentation. The results demonstrate that potato waste has a high potential for ethanol production [68, 69].

Hydrogen from renewable energy is considered a promising alternative to traditional petroleum-based transportation fuels. Potato steam peels can be used as feedstock to produce hydrogen through fermentation processes. Recent researches show that using potato steam peels to produce hydrogen along with feeding animals with its by-products offer more environmental benefits than using the potato steam peels directly for animal fodder. The strong advantages of steam potato peels over other feedstock types are that they do not compete with the food and feed industries for biomass and land. Steam potato peels are traditionally used as fodder and also they are perspective feedstock for producing bio-hydrogen [70]. There was shown the possibility of electricity generation through the butanol production from potato peel fermentation by *Clostridium acetobutylicum* [68, 71, and 72]. The biofuel production by using potato waste can itself help potato processing industries to become energy sufficient in present energy crises of Pakistan.

3. Conclusions

- Despite of all the progress in research and promising potential of potato waste utilization, there are no investigations on development of these methods on industrial scale, especially in Pakistan.

- It is necessary to discover the advanced strategies for the management of potato waste and develop useful products from the waste that can lead to healthy as well as commercial benefits. It will be environment friendly and key step towards zero waste generation to use waste as resource with aim of clean production.

- It is also worth mentioning that with the low investment in raw material different useful products from potato waste can be obtained while minimizing the waste. Production of prebiotics and other nutraceuticals from potato waste can be a leading factor to overcome the malnutrition in Pakistan.

- So potato peels should be considered as a rich source of many commercially valuable products and this waste of zero importance can be utilized as key resource at industrial scale in under developing countries like Pakistan.

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