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Potato production usages and nutrition: A review

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Abstract
Potato (*Solanum tuberosum* L.) is an annual herbaceous, self-pollinated species. Potato belongs to family *solanaceae* and the genus S*olanum* with a basic set of 12 chromosomes (x = 12). It is used as vegetable and in industries for manufacturing starch, alcoholic beverages and other processed products like French fries, chips etc. Even though potato contains little amount of protein, nutritional quality of potato is better than cereals. Potatoes provide basic nutrients such as carbohydrates, dietary fiber (skin), several vitamins, and minerals (e.g., potassium, magnesium, iron). On occasion exposures to raw and cooked potatoes impart allergic reactions. Dietary intake of potatoes, especially coloured potatoes, play an important role in the production of antioxidant defence system by providing essential nutrient antioxidants, such as vitamins, b-carotene, polyphenols, and minerals. This may help lower the incidence of wide range of chronic and acute disease processes (like hypertension, heart diseases, cancer, neurodegenerative, and other diseases). However, retention of nutrients in potatoes is affected by various cooking and processing methods. Cooking at elevated temperatures also produces acrylamide a suspected carcinogen. Independent and/or collaborative studies have been conducted and reported on the various pathways leading to the formation of acrylamide in heat-processed foods. Potato has potential to produce more calories and protein per unit land area with little time and water than most of the major food crops.

Keywords: Potato, production, nutrition and health

1. Introduction
The potato is one of mankind's most valuable food crops. Potato is a crop which has always been a "poor man's food". Major potato-producing states are Uttar Pradesh, West Bengal, Madhya Pradesh, Punjab, Haryana, Bihar, Gujarat and Assam. The area and production and productivity of potato in India is around area 2.247 in million hectare, with production 53.114 in MT and productivity23.637 in MT per hectare but in case of Chhattisgarh planted Area: 32.250 ha, Production: 5, 98, 315 mt, Productivity: 18.552 kg ha-^{1}, during 2020-21 (FAOSTAT, 2020-21).

The tuber is known to supply carbohydrate, high-quality protein, and a substantial amount of essential vitamins, minerals, and trace elements (Horton & Sawyer, 1985) [87]. The relatively high carbohydrate and low-fat content of the potato makes it an excellent energy source for human consumption (Dean, 1994). Moreover, the potato crop provides more nutritious food per unit land area, in less time, and often under more adverse conditions than other food crops. It is said to be one of the most efficient crops in converting natural resources, labour and capital into a high-quality food with wide consumer acceptance (Horton, 1980) [88].

Potatoes (*Solanum tuberosum* L) belong to family Solanaceae originated in the Andean mountain region of South America. There are about 5000 potato varieties worldwide. Three thousand of them are found in the Andes alone, mainly in Peru, Bolivia, Ecuador, Chile, and Colombia (Hijmans and Spooner, 2001) [49]. There are two major subspecies of *Solanum tuberosum*: andigena or Andean; and tuberosum or Chilean.

Potatoes range in size, shape, color, starch content, and flavor. Some of the popular varieties of mature potatoes (large size) include the Russet Burbank, the White Rose, and the Katahdin, while the Red Le Soda and Red Pontiac are two types of new potatoes (harvested before maturity and are of a much smaller size). There are also other varieties available that feature purple-grey skin and a beautiful deep violet flesh. However, popularity of potato cultivars varies with geographical region (Anonymous, 2008) [4]. The International Potato Center (CIP), based in Lima, Peru, holds an ISO-accredited collection of potato germplasm (CIP, 2008) [1].

The potatoes' hardiness made them the ideal crop for the mountainous regions of Peru where fluctuating temperatures, poor soil conditions, and thin air made it nearly impossible to harvest wheat or corn. Today roots and tubers are the third largest carbohydrate food source in the

world, with potatoes representing nearly half of all root crops consumed (International Potato Center 2018). Potatoes contribute key nutrients to the diet including vitamin C, potassium, and dietary fiber (McGill *et al*. 2013) [60]. In fact, potatoes have a more favorable overall nutrient-to-price ratio than many other vegetables and are an important staple worldwide (Drewnowski 2013, IPC 2018) [28]. However, the impact of potato consumption on human health remains somewhat controversial. Conversely there is some limited evidence from observational studies linking potato consumption to an increased risk of weight gain and type 2 diabetes purportedly due to their high glycemic index (GI) (Halton *et al*. 2006; Mozaffarian *et al*. 2011) [89, 62]. This review will provide an overview of the nutritional value of potatoes as well as a critical evaluation of the role of potatoes and potato nutrients in health.

2. Potato production

Potato is now the fourth most important world food crop after wheat, rice, and maize (Corn) because of its great yield production and high nutritive value (Geohive, 2013) [36]. This diverse and adaptable tuber has spread from its origin in South American heartland in the high Andes to all elevation zones in temperate regions of all the continents, and its production has been increased most rapidly in the warm, humid, tropical Asian lowlands during the dry season. Further advances in breeding and production of pigmented varieties have made potato an increasingly important and diverse crop in terms of production and eventually consumption.

The United Nations declared 2008 as the International Year of the Potato (IYP) to increase awareness of the relationship that exists between poverty, food security, malnutrition, and the potential contribution of the potato to defeating hunger (United Nation General Assembly Resolution, 2005). World price of wheat, rice, nearly doubled between 2005 and 2008, and continues to rise. The factors that most influenced the high prices were the high cost of bio, and fossil fuels (Avendano, 2012) [6].

Fuel used in the production of potato is almost half that of wheat (Carlsson-Kanyama and Faist, 2010) [20]. Any increase in food price affects mostly the poor people and population in low-income countries. This may be one of the reasons that potato productions and consumption over the years have risen sharply in poor developing countries as dietary source of energy (Geohive, 2013) [36].

Given the global importance of potato as predominant staple having recognized nutritional significance, health beneficial effects of phytochemicals, mass production, and consumption patterns (fried, baked, mashed) are the clear reflection of ongoing positive and beneficial outcomes availed by the consumers. Fried potato products are widely consumed as popular snacks by all ages, children to old age, all across the world. Recently, a review has appeared in print that examined the nutrient and bioactive in potatoes and their impact on human health (Camire *et al*., 2009) [19].

The present review provides a single comprehensive source on potato production, consumption, and latest data on clinical trials showing the importance of potatoes in global nutritional village for human health, and managing hunger and poverty. The importance of potato as a staple food is unquestionable, but processing techniques and consumption rate of some of the heat-processed foods are of serious concerns and need to be monitored.

3. Potato Nutrition

Nutritional value of potato (100 g fresh) Energy 77 kcal, Water 79.25 g, Carbohydrate 17.49 g, Sugars 0.82 g, Starch 15.29 g, Dietary fibers 2.1 g, Fat 0.09 g, Ash 0.9%, Protein 2.05 g, Vitamin C 19.7 mg, Calcium 12.0 mg, Iron 0.8 mg, Magnesium 23 mg, Phosphorus 57 mg and Potassium 425 mg (USDA, 2019)

3.1 Macronutrients

Potatoes are classified as "starchy vegetables," highlighting their predominant macronutrient carbohydrate and predominant type of carbohydrate starch. Potato starch consists of amylopectin (branched chain glucose polymer) and amylase (straight chain glucose polymer) in a fairly constant ratio of 3:1 (Woolfe 1987) [83]. A small proportion of the starch found in potatoes is "resistant" to enzymatic degradation in the small intestine and, thus, reaches the large intestine essentially intact. This "resistant starch" (RS) is extensively fermented by the microflora in the large intestine producing short-chain fatty acids which have been shown to lower the pH of the gut, reduce toxic levels of ammonia in the GI tract, and act as pre-biotics by promoting the growth of beneficial colonic bacteria (Higgins 2004; Brit 2013) [47, 13].

A recent study examined the amount of RS in three popular potato varieties (Yukon Gold, Red Norland and Russet Burbank) prepared in two different ways (baked and boiled) and served at three different temperatures (hot, chilled for six days, and chilled followed by reheating) (Raatz *et al*. 2016) [67]. Even processed potatoes (e.g., potato flakes) appear to retain a significant amount of resistant starch. Han and colleagues (Han *et al*. 2008) [42] examined the effects of the consumption of various coloured (white, red and purple) potato flakes on cecal fermentation and fecal bile acid excretions in rats.

Potato crude protein content is comparable to that of most other root and tuber staples with approximately 2–4 g in a medium potato (depending on the nutrition data utilized as well as the potato variety and preparation methods). It is also comparable on a dry basis to that of cereals and, with the exception of beans, exceeds that of other commonly consumed vegetables (Woolfe 1987; US FDA 2018) [83].

In fact, a recent study examining the protein and amino acid content of commercially available plant-based protein isolates found that potato protein was superior to other plant-based and was similar to animal-based proteins in terms of essential amino acid content (Gorissen *et al*. 2018) [37]. However, it should be emphasized that these peptides are found in relatively low concentrations in the whole potato, and whether the concentrations found in potatoes as consumed are sufficient to produce the effects seen in studies using higher concentrations of isolates remains to be determined.

3.2 Micronutrients

Potatoes contain a variety of essential vitamins and minerals most notably vitamins C and B6 and the minerals potassium, magnesium, and iron. In fact, data indicate that potatoes rank 5th in terms of dietary sources of vitamin C for Americans (Cotton *et al*. 2004; O'Neil *et al*. 2012) [22, 64]. Potatoes also contain the B vitamins riboflavin, thiamin and folate and are a good source of vitamin B6 (12% of the US daily value per serving). Potassium is a mineral that is under-consumed by the majority of Americans with only 3% meeting their daily requirement (Drewnowski and Rehm 2013; DGA 2015) [27].

A common misconception when it comes to potato nutrition is that all of the nutrients are found in the skin. While the skin does contain approximately half of the total dietary fiber, the majority (> 50%) of the nutrients are found in the flesh. As is true for most vegetables, processing and preparation methods do impact the bioavailability of certain nutrients in the potato, particularly water-soluble vitamins and minerals. Nutrient loss appears to be greatest when cooking involves water (e.g., boiling) and/or extended periods of time at high temperatures (e.g., baking) (Bethke and Janksy 2008; Woolfe 1987) [9, 83]. Vitamin C is probably most impacted since it is not only water-soluble but, also, heat and oxygen labile (McGill *et al*. 2013; Liu 2013) [60, 59].

3.3 Phytonutrients

Potatoes also contain a variety of phytonutrients, most notably carotenoids and phenolic acids (Brown *et al*. 2005, Liu *et al*. 2013, McGill 2013) [14, 59, 60] and are the largest contributor of vegetable phenolics to the American diet (Song *et al*. 2010) [75]. Carotenoids, such as lutein, zeaxanthin, and violaxanthin, are found mostly in yellow and red potatoes, although small amounts are also found in white potatoes (Brown *et al*. 2005) [14]. Total carotenoid content of potatoes ranges widely from 35 µg to 795 µg per 100 g fresh weight. Anthocyanins are phenolic compounds that are widely distributed among flowers, fruits and vegetables and impart colors ranging from shades of red to crimson and blue to purple (Hou 2003; Liu 2013) [51, 59].

The anthocyanins in greatest amounts in potatoes include acylated petunidin glycosides (purple potatoes) and acylated pelargonidin glycosides (red and purple potatoes) (Brown *et al*. 2005) [14]. Chlorogenic acid, a colorless polyphenolic compound, is a secondary plant metabolite and constitutes up to 80% of the total phenolic content of potato tubers (Brown 2005) [14]. It is distributed mostly between the cortex and the skin (peel). Finally, quercetin is a flavonoid found in highest amounts in red and russet potatoes (Brown 2005) [14] and has demonstrated antioxidant and anti-inflammatory properties *in vitro* and *in vivo* (Kawabata *et al*. 2015) [54]. Further research is needed to determine what role, if any these compounds, may play in mitigating inflammatory responses in humans.

Similar to other plant phytonutrients, glycoalkaloids not only have toxic effects but also beneficial effects including cholesterol-lowering, anti-inflammatory, antiallergic and antipyretic effects (Friedman 2006) [33]. Research also suggests that glycoalkaloids have anti-bacterial and antiproliferative (Re: cancer cells) properties *in vitro* (Friedman 2006) [33], however, these effects have not been studied sufficiently *in vivo*. All of this information notwithstanding, it bears emphasizing that amounts of glycoalkaloids in potatoes available for human consumption are generally low and removal of sprouts and peeling of the tissue approximately 3–4 mm from the outside before cooking removes nearly all of the glycoalkaloids (Friedman 2006) [33].

4. Potatoes in the Diet

The 2015–2020 Dietary Guidelines for Americans identified a number of "shortfall" micronutrients, i.e., vitamins and minerals that are currently consumed in inadequate amounts by Americans. These included, but are not limited to, potassium and fiber (2015 DGA). Research indicates that potatoes make significant contributions of key shortfall nutrients to diets of Americans (Freedman and Keast 2011, Storey and Anderson 2013) [34, 77]. Using NHANES 2003–2006 data, Freedman and Keast (2011) [34] examined the contribution of potatoes 205 to nutrient intakes among children and adolescents. The results indicated that potatoes contributed 10% of daily intake of dietary fiber, vitamin B6, and potassium and 5% or more of thiamin, niacin, vitamin C, vitamin E, vitamin K, phosphorus, magnesium, and copper. Research also suggests that adding potatoes to a meal may improve the overall nutrient quality of the meal. Using data from 4-cycles (2001–08) of the National Health and Nutrition Examination Survey (NHANES), Drewnowski (2011) [28] evaluated the impact of white potato consumption (baked, roasted, or boiled) on energy and nutrient intakes in children and adolescents aged 4–18 yr. Approximately 10,600 lunches and 11,500 dinners were characterized by place (at-home or away from home) and by source of food (e.g., store or school cafeteria). The results indicated meals containing white potatoes had significantly higher amounts of vitamin C, potassium and fibre per 1000 cal than meals that did not contain potatoes.

Potatoes are also economical, providing significantly better nutritional value per dollar than many other raw vegetables (Drewnowski and Rehm 2013) [27]. Drewnowski and Rehm (2013) [27] examined the nutrient density per unit cost of the 46 most frequently consumed vegetables as part of the National School Lunch Program (NSLP) and found that potatoes and beans were the least expensive sources of not only potassium but also fibre. Specifically, potassium-rich white potatoes were almost half the cost of most other vegetables, making them more affordable to meet key dietary guidelines for good health.

5. Potato Nutrients in Health and Disease

Potatoes contain a number of nutrients and nutritional components that may play a role in health promotion and reducing the risk of chronic disease. These nutrients along with research supporting their possible roles in human health are described in the paragraphs below.

5.1 Blood Pressure/Hypertension

It is estimated that 29%–32% of American adults suffer from hypertension (depending on the data source) and another 1 in 3 have pre-hypertension (CDC 2018). Research indicates that diets low in sodium and rich in potassium may reduce the risk of hypertension and stroke (Adrogué and Madias 2014; Appel *et al*. 2006; Seth *et al*. 2014; Yang *et al*. 2011; Zhang *et al*. 2013) [1, 5, 72, 84, 86]. Seth *et al*. (2014) [72] examined the association between potassium intake and stroke in a cohort of 90,137 post-menopausal women and found that a high potassium intake was associated with a lower risk of all stroke and ischemic stroke, as well as all-cause mortality in older women, particularly those who are not hypertensive (Seth *et al*. 2014) [72].

A recent epidemiological study using data from Harvard's well-known Nurses Health Study I and II and Health Professionals Follow-up Study cohorts concluded that a "Higher intake of baked, boiled, or mashed potatoes and French fries was independently and prospectively associated with an increased risk of developing hypertension" (Borgi *et al*. 2016) [12]. While the study recommends substituting non starchy vegetables for potatoes in order to ameliorate the potential increased risk of hypertension, the results actually indicate this substitution was beneficial only for the two

female cohorts. In the male cohort, substituting non-starchy vegetables for potatoes actually increased the risk of hypertension. What's more, substituting potatoes with other starchy vegetables (e.g., peas, lima beans, corn and sweet potatoes) did not reduce the risk of hypertension in any of the cohorts. It should also be emphasized that epidemiological studies of this nature can only show an association, not causation. Nowson *et al*. (2004) [63]

5.2 Weight Management/Obesity

Overweight and obesity have increased significantly during the last three decades both in the US and globally (Flegal *et al*. 2016) [31]. Although it is generally accepted that dietary patterns along with other key lifestyle behaviours (e.g., physical activity) are more important than single foods when it comes to obesity and weight management (Dietary Guidelines for Americans 2015), potatoes have been singled out both in research and the popular press as being somehow uniquely obesogenic.

A recently published systematic review sought to scientifically summarize the existing research regarding the relationship between potato intake and obesity (Borch *et al*. 2016) [11]. In this review, the authors identified five observational studies that investigated the association between intake of potatoes and overweight and obesity. Study durations (i.e., the length of subject follow-up) ranged between 2 and 20 y, and 170,413 subjects were included with BMIs that ranged from normal to obese.

Two of the five studies examined showed a positive association with measures of adiposity; however, both studies had moderate risk of bias due to methodological weaknesses. The authors concluded that existing epidemiological research does not provide convincing evidence to suggest an association between intake of potatoes and the risks of obesity. More clinical/experimental trials that can test for causality are needed. Nonetheless, there is evidence to suggest that potatoes do not need to be excluded from a weight management diet (Randolph *et al*. 2014) [14].

Research from single-meal studies suggests that boiled potatoes are more satiating than equal calorie portions of other common carbohydrate-rich foods (e.g. rice, bread and pasta) (Holt *et al*. 1995; Leeman *et al*. 2008; Geliebter *et al*. 2013) [50, 57, 35].

There are currently no published clinical trials examining potato consumption as a causative factor in development of diabetes. A recent systematic review of the existing observational studies identified five which showed a positive association between potato consumption and increased risk of type 2 diabetes (including the previously mentioned study by Halton and colleagues), five showed no association and two actually showed that potatoes were associated with a decreased risk (Borch *et al*. 2016) [11].

5.3 Gut Health - While there is currently no official definition of "gut health," in an article published in the peer-reviewed journal, Biomed Central Medicine, Bischoff listed some specific signs of gastrointestinal (GI) health, including normal bowel function, effective absorption of nutrients and subsequent adequate nutritional status, absence of GI illnesses, normal and stable intestinal microbiota and effective immune status (Bischoff 2011) [10].

Potatoes contain a number of nutritional components which may play a role in supporting "gut health" as defined by Bischoff, most notably fiber and RS; however, the research is still based largely on animal and *in vitro* studies. As previously mentioned, both fiber and resistant starch escape digestion in the small intestine and enter the colon where they can provide fecal bulk thus helping to maintain normal bowel function. In addition, results from a systematic review and meta-analysis suggest that some types of RS undergo colonic fermentation and may function as a pre-biotic, supporting the proliferation of the colonic microbiota (Higgins and Brown 2013; Shen *et al*. 2017) [48, 73].

Shepherd and Gibson (2013) [74] examined dietary intakes from 55 men and women who had been following a gluten-free diet for two years and found inadequate intakes of fibre and several micronutrients, including thiamin, folate, magnesium, calcium and iron. Potatoes provide a number of those nutrients and thus are a key food for someone needing or wanting to follow a gluten-free or gluten-restricted diet.

6. Dietary and nutritional aspects for human health

Potato tuber consists of about 77% water, 20% indigestible carbohydrates, and other health-beneficial ingredients such as protein, fiber, vitamin (ascorbic acid), potassium, magnesium, etc., Consumption of potatoes is a good source of energy and other nutrients (positive value), but on occasion, potato also may cause some undesirable health issues such as indigestion and allergic reactions (negative value).

(i) Positive health benefits: Raw potato must be processed prior to human consumption to make starch and other nutrients bio available. The nutritional value of potatoes along with its taste and ease of cooking has made it the most popular vegetable and snack in the world. Potatoes are affordable, nutritious, a good source of vitamin C (ascorbic acid), protein, and rich source of carbohydrate energy. People in underdeveloped countries, who are unable to afford high-energy diets such as meat and milk products, use potatoes as their prime source of nutrient energy. In the seventeenth century potato became famous across Europe as a crop that could save people during famines. Also, at times when and where other crops failed, due to severe winter conditions, potatoes typically relied upon to contribute toward food supplies.

In addition to ascorbic acid (vitamin C), the new pigmented varieties contain several phytochemicals that are antioxidants. Antioxidants are compounds that hinder the oxidative processes and thereby delay or prevent oxidative stress (Wilcox *et al*., 2004) [82]. Oxidative stress is associated with a wide range of chronic and acute disease processes like heart diseases, cancer, neurodegenerative, and other diseases. When free radicals are generated *in vivo*, many antioxidants act in defending from oxidative stress (Halliwell and Gutteridge, 2007) [40].

Traditionally potatoes (white) have been perceived as staple food similar to rice, etc. a source of sustenance energy. However, the introduction and availability of colored potatoes have attracted consumers' and researchers' interests alike for reasons other than purely a source of energy (Lachman *et al*., 2005) [56].

(ii) Allergic reactions (Negative reactions): Potatoes are not commonly associated with toxicity. As part of the maturing processes, potato tubers accumulate small quantities of alkaloids but are bitter at high concentrations, which may

cause some discomfort when consumed. The two major alkaloids (up to 95% of the total) in potato tubers are a-solanine and a-Chaconine, which are present in approximately 2 to 3 ratio. They are generally detected and quantitated using time-consuming and less efficient gas chromatography-mass spectrometry/ liquid chromatography-ultra violet (GC-MS/LC-UV) techniques. However, very recently, the use of matrix-assisted laser desorption/ionization mass spectrometric imaging (MALDI-MSI) technique has been reported for the spatial distribution of glycoalkaloids in potato tubers. The method is rapid because it reduces complex time-consuming preparative steps for analysis (Ha *et al*., 2012) [39].

The concentrations of glycoalkaloids are affected by the environmental and genetic (varietal) factors. Total glycoalkaloid levels below 100 mg kg are deemed safe for human consumption. However, the concentrations around 200 mg kg could cause serious health issues. Research has shown that peeling of the skin prior to processing removes a good portion of alkaloids-to a non-effect level (Friedman, 2006; Friedman and Levin, 2009) [33, 90].

Marketing and eating French fries and potato crisp with skin as snack are current trend among the younger generation, probably skin as a source of dietary fiber. This has raised concerns of the safety of potato products (Rytel *et al*., 2011) [71]. A recent study reported the glycoalkaloid contents in seven colored potatoes that ranged between 127 mg kg/1 and 272 mg kg/1 dry weights. This study also reported that thermal processing either by baking or frying of potatoes with skin reduced the glycoalkaloids by up to 93% (Tajner-Czopek *et al*., 2012) [78]. In addition to natural toxicants, over the years many case studies have been reported showing sensitivity to raw potatoes in adults (mainly oral due to exposure of heat-labile allergen) and cooked potatoes in children. Major potato allergic symptoms include contact dermatitis, asthma, rhino conjunctivitis, wheezing, or even anaphylaxis. As early as 1966, but in 1989 it was confirmed that housewives exposed to aerosolized potato particles while peeling developed bronchial asthma (Quirce *et al*., 1989) [66]. Immediate contact allergy reaction (contact urticarial) is more common as occupational hazard, but recently a non-occupational allergic reaction to a 41-year-old woman was reported (De Lagran *et al*., 2009) [23]. In children, allergic reactions are mainly due to cooked potatoes when they are exposed as part of their initiation of solid food (De Swert *et al*., 2007; Monti *et al*., 2011) [24, 61]. Allergic reactions have been attributed to proteins, and to date four allergenic proteins have been identified in potatoes, the main being the soluble glycoprotein patatin, also referred to as Slot 1. A recent study reported substantial difference of patatin activity between cultivars and individual isoforms (Barda *et al*., 2012) [7]. Protein in potato is higher than other dietary tubers and cereal, and up to 40% of which could be patatin, responsible for allergic reactions in children (Barda *et al*., 2012) [7].

7. Effect of processing on potatoes into edible food products

Potatoes have been known to mankind for centuries. It contains mostly water and 60% to 80% of the solid is indigestible substance, which is of no nutritional value to human. It is, therefore, potato is processed prior to eating. The main process involves heat (boiling, baking, microwaving and frying) to break down the starch. Most often skin of mature potato is not eaten.

Thus, some of vitamin C is lost. By nature, a potato does not add much fat to diet, but is flat (less tasty). Taste is the king for food. Hence, potato edible products require the addition of fat, salt to make them tasty and highly desirable, but are cause of serious health concerns- especially for the onset of obesity and other related health issues. While use of heat in the preparation of potato dish is almost essential, this also initiates several chemical reactions between the endogenous chemicals such as reducing sugars, amino acids. The most common and highly desirable reaction for aromatic and tasty product is the Maillard reaction a reaction between sugar and amino acid. But, a chemical reaction and the end product are highly dependent on the nature and abundance of constituents during the process.

This could lead to the production of the highly undesirable toxic substance acrylamide in high-temperature baked products derived from high starch and proteinous raw material. Potato is one such raw material, and has been shown to produce acrylamide in large quantities when processed at elevated temperature. The most common potato products that are consumed globally are: baked, boiled, mashed, French fries, potato chips. In addition, potato flour is used in cake, pancakes. Researchers have also provided an excellent account of the processing effect on nutrient content of potatoes (Camire *et al*., 2009) [19].

8. Starchy nature of potatoes to healthy components

Globally potato is the most commonly consumed noncereal staple food by general public, nutritionally well-known predominantly for its starchy carbohydrate. However, potato is also a good source of vitamins and other healthy phytonutrients of great importance (Hejtmankova *et al*., 2009) [46].

Generally the skin and/or fleshes of potatoes varieties are white, yellow, or saffron yellow but potato cultivars in which skin and/or fleshes are red, purple, blue, or orange are also prevalent, and are referred to as colored or pigmented potatoes. Several researchers (Rodringuez-Saona *et al*., 1998; Stelljes, 2001; Fossen *et al*., 2003; Brown *et al*., 2004; Brown, 2005, 2006; Eichhorn and Winterhalter, 2005; Lachman and Hamouz, 2005; Reyes *et al*., 2005; Jansen and Flamme, 2006; Zhang *et al*., 2009) [70, 76, 32, 17, 14, 15, 29, 52, 85] have identified many phytochemicals in pigmented potatoes with antioxidative properties. These phytochemicals are polyphenols, anthocyanins, carotenoids, ascorbic acid, flavanoids, Tocopherols, and alpha-linoleic acid.

A recent crossover study reported results from 18 hypertensive individuals with an average BMI of 29, who were fed microwaved purple potatoes and no potatoes for four week and then changing the feed for next four weeks. At the end of the experiment, there was no significant effect on body weight, but there were significant decreases in blood pressures-diastolic 4.3% (4 mm), and systolic by 3.5% (5 mm) (Vinson *et al*., 2012) [80]. The data support the health benefits of purple potatoes. The idea behind microwave cooking is to preserve beneficial phytochemicals that can help lower blood pressure in overweight and obese people. This study supported the already-held views that potato chips and French fries lose their nutritive value because of high-temperature frying/cooking.

9. Potential negative health effects of processed potato products

There is a serious public concern globally of cancer risk from consuming potato products processed at high temperature, which may contain acrylamide. The same concern also extends to several processed foods produced from high starch-containing ingredients and cooked at high temperatures. Published data clearly establish potato chips, French fries, as one of the major dietary sources of acrylamide for adults and children/ adolescent, which is alarming particularly in Western countries where French fries and chips are consumed regularly as part of meal or snack (Pedreschi and Zuniga, 2009) [65]. In Canada, it is estimated that almost 70% of acrylamide intake is from French fries and potato chips (Health Canada, 2008) [44].

The two recent articles have thoroughly reviewed the published literature on the formation of acrylamide in potato products and other baked products (Akhtar, 2012; Vinci *et al*., 2012) [2, 79]. The Acrylamide Toolbox 2011 (FDE, 2013) and a recent review article (Lineback *et al*., 2012) [58] are very important sources of information that trace the scientific activities with future considerations and needs for the processing industries. In following pages only the salient features and the most recent advances would be highlighted.

10. Summary and future perspectives

Potatoes are now grown globally. The developed countries has seen continuous decline in potato production from 190 million tonnes in 1990 to 155 million tonnes in 2006. During the same period, the production in developing countries has leaped from 89 million tonnes to 159 million tonnes (Geohive, 2013) [36]. The potato has been a dietary staple for centuries and remains a popular and frequently consumed vegetable today. Potatoes contribute important nutrients to the diet including potassium, vitamin C and dietary fiber. Observational data indicate that potato consumption is associated with an increase in overall vegetable consumption and dietary nutrient density among children, teens and adults in the United States. Research suggests that potato nutrients and components may have favorable impacts on blood pressure, satiety and 412 gut healths. The consumption of potatoes also dramatically increased in both the food deficit and low-income areas. This is not surprising because prices for other staple foods, e.g., rice, wheat, and corn have been increasing at much higher rates than potatoes (Anderson, 2010) [3] due to high cost of fuels and energy, and becoming expensive to afford.

The study found that potatoes marketed as organic had statistically significant (p<0.0001) more copper and magnesium, less iron and sodium, but similar amounts of other minerals such as calcium, potassium, and zinc compared to conventional potatoes (Griffiths *et al*., 2012) [38]. Although authors did not report on the cost-health benefit, they mentioned that it would not be able to distinguish between the two groups using the readily available techniques. Thus, it could be concluded that currently it would be difficult to justify the extra cost for organic potatoes. Potatoes produce more energy per unit land and time (216 MJ ha /1 day /1 versus 159 and 121 for corn and rice, respectively) (Anderson, 2010) [3]. It is thus prudent to make concerted efforts to promote potatoes as source for dietary energy in poor and poverty-stricken countries. Currently about 2% of the world's dietary energy is achieved from potatoes. Future advances in processing technologies for snacks will be dictated by consumers' demands for healthy, tasty, aromatic, appetizing, and nutritious products. Reducing acrylamide contents while maintaining finish fried product quality such as flavor, color, texture, crispness in fried potato production will remain a challenge for the food industry. Recent literature and regulatory actions in Canada, US, European Union provides ample examples of future direct actions and trends (Health Canada, 2009) [45].

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