A Review of Potatoes and Their Role in Global Health

Prepared by

Katherine A. Beals, PhD, RD, FACSM, CSSD

Introduction

Potatoes are the third most important food crop in the world after rice and wheat and the leading vegetable crop in the United States (IPC 2016). More than a billion people worldwide eat potatoes and global total crop production exceeds 300 million metric tons. Potatoes are grown in an estimated 125 countries throughout the world – from China's Yunnan plateau and the subtropical lowlands of India to Java's equatorial highlands and the steppes of the Ukraine (IPC 2016).

The potato is agriculturally unique in that it is vegetatively propagated, meaning that a new plant can be grown from a potato or piece of potato. The new plant can produce 5-20 new tubers, which will be genetic clones of the original plant. Potato plants also produce flowers and berries that contain 100-400 botanical seeds. These can be planted to produce new tubers, which will be genetically different from the original plant (IPC 2016).

There are more than 4,000 varieties of native potatoes and over 180 wild potato species (IPC 2016). The hardiness of potatoes make it possible for them to grow from sea level up to 4700 meters above sea level, in all kinds of environmental conditions. Potatoes are also an extremely efficient crop. One hectare of potato can yield two to four times the food quantity of grain crops. In addition, potatoes produce more food per unit of water than any other major crop and are up to seven times more efficient in using water than cereals (NPC 2016).

Potatoes contribute key nutrients to the diet including vitamin C, potassium, and dietary fiber (Weaver & Marr 2013). In fact, potatoes have a more favorable overall nutrient-to-price ratio than many other fruits and vegetables and are an affordable source of nutrition worldwide (Rhem and Drewnowski 2013). However, the impact of potato consumption on human health remains somewhat controversial. Animal studies and limited human clinical trials indicate that potatoes and potato components may favorably impact cardiometaboic health (McGill et al. 2013) and may aid in weight loss via their impact on satiety (Holt et al. 1995, Gelibter 2012, Ailen et al. 2016). Conversely there is some limited evidence from observational studies linking potato consumption to an increased risk of weight gain, type 2 diabetes and cardiovascular disease purportedly due to their high glycemic index (Borch et al. 2016).

This review will provide a comprehensive examination of the potato including its history, botanical origins, nutrient content and composition as well as a critical evaluation of the role of potatoes and potato nutrients in health and disease.

Potato Roots

The historical roots of the potato can be traced back to Peru where the Inca Indians first cultivated them in 200 B.C. The hardiness of potatoes made them the ideal crop for the mountainous regions of South America where fluctuating temperatures, poor soil conditions, and high altitudes made it difficult to cultivate wheat or corn. Potatoes didn't make their way into Europe until the early 1500s when Spanish conquistadors began carrying potatoes from South America back to their homeland aboard their ships. The Spanish sailors appreciated the "tartuffos" (as they were then called) for the protection they offered from scurvy (later found to be due to their ascorbic acid content) (Potatoes USA).

Potatoes were slow to gain popularity in the New World Colonies and the rest of Europe not only due to their reputation as a food for the poor but their botanical relationship to a variety of poisonous plants in the *nightshade* family (e.g., deadly nightshade). Nonetheless, over time farmers came to appreciate the potato's hardiness, particularly its resistance to the rigors of the damp European climates, and it soon began to displace other crops as a food staple. The potato particularly flourished in Ireland, where it was prized not only for its hardiness and ease of cultivation, but its nutritional value and economy. Potatoes could provide sustenance for nearly 10 people on just one acre of land and supported the growing population. By the 1800s potatoes not only supplied 80 percent of the calories in the Irish peasant's diet but were the predominant feed for cows and chickens. Unfortunately, this dependence on the potato proved lethal when, in 1845, the fungus *phytophthora infestans* literally wiped out all of the Irish potato crops. The infestation or “blight” as it was called lasted three years during which time more than one million people died of starvation or disease and another million emigrated to Canada or America (many of whom died en route) (Potatoes USA).

The popularity of potatoes in America grew relatively slowly just as it had in Europe. In the late 1800s, American Horticulturist Louis Burbank sought to improve the “Irish potato,” and developed a new variety of potato seedling that could grow two to three times more tubers, of better size, than any he had grown before. The seedlings, appropriately named “Burbank” were aggressively marketed to the West Coast. Within a few years, a more resistant mutation of the Burbank was discovered in Colorado. The mutation had a rough, reticulated or “russet” skin and was named *Russet Burbank* (Potatoes USA).

Today potatoes are grown in all 50 states of the United States and approximately 125 countries throughout the world. The potato continues to be valued for its durability and nutrient density. In October 1995, the potato became the first vegetable to be grown in space. The collaborative project between the National Aeronautics and Space Administration (NASA) and the University of Wisconsin, Madison was conducted with the goal of feeding astronauts on long space voyages and, perhaps, eventually feeding future colonies of space settlers (IPC and NPC 2016). The year 2008 was declared the *International Year of the Potato* by the United Nations, highlighting the fact that the potato is a staple food in the diet of the world’s population, and affirming the need to focus world attention on the role that the potato can play in providing food security and eradicating poverty (United Nations).

You say Potato, I say *Solanaceae* …

The potato belongs to the botanical family *Solanaceae*. Other members of this family include the tomato, chili pepper, eggplant, poisonous nightshade, belladonna, and the petunia. Despite the similarity of its name, the sweet potato is not related to the potato; but rather, belongs to the *Convolvaceae* family (a botanical family that also includes the morning glory).

Potato varieties have traditionally been broadly categorized according to their shape and color. They include: (1) Round Whites, (2) Long Whites, (3) Yellow Flesh, (4) Round Red, and (5) Blues/Purples, and (6) Russet (Table 1). Within these broad categories are numerous specific potato varieties (e.g., Russet Burbank, Yukon Gold, Red Pontiac). Recently, the terms "specialty" and "gourmet" have entered the potato vocabulary to describe almost any variety not fitting into the six major categories described above. The Russet Burbank remains the most commonly grown and consumed potato; however, there are an estimated 4,000 specific potato varieties, although *only* 100 are grown regularly (Potatoes USA; IPC and NPC 2016).

Potato Nutrition - More than Skin Deep

The nutritional data for the most commonly consumed forms of potatoes are listed in Tables 1 and 2. Note that there are two sets of data for raw (uncooked potatoes) - USDA and FDA. The USDA data is specific to the potato type analyzed, while the FDA data represents a “market-basket” analytic approach, utilizing a weighted average of the nutrients found in potato varieties available to US consumers (Potatoes USA). The following paragraphs provide an in-depth look at the nutrient content of potatoes.

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 amylose (straight chain glucose polymer) in a fairly constant ratio of 3:1 (Woolfe 1987). 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). Emerging research in animal models and some limited human studies suggests that RS may enhance satiety, positively affect body composition, favorably impact blood lipid and blood glucose levels and increase the amount of good bacteria in the colon (Birt et al 2013, Gentile et al. 2015, Higgins 2014, Higgins and Brown 2013, Keenan et al. 2015, Robertson 2012, Zhang et al. 2015).

Potatoes contain two of the five subcategories of RS: RS 2 which is found predominantly in raw potatoes and RS3 that is formed when potatoes are cooked and cooled such that the starch gelatinizes and retrogrades (McGill et al. 2013). 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). The results showed that the RS content of potatoes varied significantly by method of preparation and temperature but not variety. More specifically, regardless of potato variety, baked potatoes had more RS (3.6 grams of RS per 100 grams of potato) than boiled potatoes (2.4 grams of RS per 100 grams of potatoes). Also on average, chilled potatoes (whether originally baked or boiled) contained the most RS (4.3 grams of RS per 100 grams of potato) followed by chilled-and-reheated potatoes (3.5 grams of RS per 100 grams of potato) and potatoes served hot (3.1 grams of RS per 100 grams of potato).

Even processed potatoes (e.g., potato flakes) appear to retain a significant amount of resistant starch. Han and colleagues (Han et al. 2008) examined the effects of the consumption of various colored (white, red and purple) potato flakes on cecal fermentation and fecal bile acid excretions in rats. The results indicated that the ingestion of potato flakes was associated with an increase in bowel short-chain fatty acids (SCFA), probably through anaerobic bacterial activities and fermentation of residual starch actions that are helpful for the improvement of the colonic environment.

In addition to RS, potatoes contain dietary fiber—approximately 2 grams in a 5.3 oz potato or 7% of the Daily Value—which is contained both in the flesh and the skin. It is estimated that most Americans get only about half of the recommended amount (i.e., adequate intake (AI)) of dietary fiber and, thus, could benefit from consuming more fiber-rich foods. A recently published study examining the association between white potato consumption and dietary fiber intake indicated that when controlling for possible confounding variables (e.g., age, race, ethnicity, education, income, body mass index and energy consumed), white potatoes were positively associated with higher dietary fiber intakes among both adults and children (Storey and Anderson 2013). Specifically, potatoes provided more than 6% of dietary fiber to adults and almost 7% to children, while providing only 3% of total energy, suggesting potatoes have favorable fiber-to-calorie ratio.

Potato crude protein is comparable to that of most other root and tuber staples. It is also comparable on a dry basis to that of other cereals and, with the exception of beans, exceeds that of other commonly consumed vegetables (Wolfe 1987). Protein quality is often expressed In terms of its “biological value” which takes into account the amino acid profile of the protein along with its bioavailability. Egg protein has a biological value of 100 and is considered the reference protein. Potatoes have a relatively high BV of 90 compared with other key plant sources of protein (e.g., soybean with a BV of 84 and beans with a BV of 73) (McGill et al. 2013). It is a common misconception that plant proteins are missing or lacking in essential amino acids. Potatoes contain all nine essential amino acids and their amino acid profile is comparable to other key vegetable proteins. In addition, potatoes have lower levels of the sulfur-containing amino acids, which have been shown to increase calcium excretion and may negatively impact bone mineral density (Thorpe and Evans 2011).

Peptides isolated from potato protein have been shown to have antioxidant activity in vitro and some limited evidence from human studies suggests they may have a favorable impact on serum lipids and may enhance satiety (Kudo et al. 2009, Hill et al. 1990, Liyanage et al. 2008). 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.

Micronutrients

Potatoes contain a variety of essential vitamins and minerals (Table 2) most notably vitamins C and B6 and the minerals potassium, magnesium, and iron. A medium (5.3 oz) potato provides 27 mg of vitamin C qualifying it as an "excellent source" of vitamin C per FDA guidelines. And while potatoes may not rival the vitamin C content (in mg) of citrus fruits and peppers, they do contribute significantly to daily vitamin C requirements. In fact, data indicates that potatoes rank 5th in terms of dietary sources of vitamin C for Americans (Cotton et al. 2004; O'neil et al. 2012). Potatoes are also a good source of vitamin B6 (> 12% of the US daily value per serving) and a dietary source (>2% of the US daily value) of folate, riboflavin, and thiamin.

Potassium is a mineral that is under-consumed by the majority of Americans with only 3% meeting their daily requirement (Drewnowski et al. 2013). Potatoes provide one of the most concentrated and affordable sources of potassium (Table 2)–significantly more than those foods commonly associated with being high in potassium, such as bananas, oranges, mushrooms, etc. (Drewnowski et al. 2013). Magnesium is another nutrient under-consumed by the majority of Americans. A medium (5.3 oz) potato with the skin provides 48 mg of magnesium and recent research indicates potatoes contribute 5% of the total magnesium intake in the diets of Americans (Freedman and Keast 2012). And, while the iron content of potatoes is not particularly high (1.3 mg or 6% of the US daily value), the bioavailability of iron in potatoes exceeds that of many other iron-rich vegetables owing to extremely low or non-existent levels of antinutrients, chelators and ligands that inhibit iron absorption (e.g., tannins, oxalates, Phytates) and high levels of vitamin C, which has been shown to enhance iron absorption.

Phytonutrients

Potatoes also contain a variety of phytonutrients, most notably carotenoids and phenolic acids (Brown et al. 2004, Liu 2013) and are the largest contributor of vegetable phenolics to the American diet (Song et al. 2010). 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. 2004). Total carotenoid content of potatoes ranges widely from 35 µg to 795 µg per 100 g fresh weight. Dark yellow cultivars contain approximately 10 times more total carotenoid than white-flesh cultivars (Brown et al. 2008). 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). The anthocyanins in greatest amounts in potatoes include acylated petunidin glycosides (purple potatoes) and acylated pelargonidin glycosides (red and purple potatoes) (Brown et al. 2004, Liu 2013). Chlorogenic acid, a polyphenolic compound, is a secondary plant metabolite and constitutes up to 90% of the total phenolic content of potato tubers (Liu 2013). It is distributed mostly between the cortex and the skin (peel). Finally, quercitin is a flavonoid found in highest amounts in red and russet potatoes and has demonstrated anti-inflammatory properties in animal studies and in a limited number human clinical trials (Kawabata et al. 2015).

Glycoalkaloids are produced in potatoes during germination and serve to protect the tuber from pathogens, insects, parasites and predators (Wolfe 1980). The primary glycoalkaloid in potatoes is α- solanine and is found in the highest levels in the outer layers of the potato skins around the “eyes.” In high concentrations, glycoalkalods are toxic to humans if ingested. However, amounts in potatoes available for human consumption are generally very low and removal of sprouts and peels before cooking will eliminate all glycoalkoloids (Lui 2013).

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 percent) of the nutrients are found within the potato itself (Table 2). As is true for most vegetables, processing does 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) (Table 2) (Woolfe 1987). Vitamin C is probably most impacted since it is not only water-soluble but, also, heat and oxygen labile (McGill et al. 2013, Lui 2013).

Potatoes in the American Diet

Potatoes have long held the prominent position of one of America's favorite vegetables (Synnovate/ Potatoes Attitudes and Usage 2014) and for good reason. Not only are potatoes delicious and versatile; but, research shows that when people consume potatoes as part of a meal they frequently include another vegetable with them thereby increasing total vegetable servings at the meal (Drewnowski and Rehm 2011).

Research shows that potatoes make significant contributions of key shortfall nutrients to diets of children, adolescents, and adults (Freedman and Keast 2011, Storey and Anderson 2013). Using NHANES 2003-2006 data, Freedman and Keast (2011) examined the contribution of potatoes to nutrient intakes among children and adolescents. The results indicated that potatoes contributed 10% of daily intake of dietary fiber, vitamin B_6, and potassium and 5% or more of thiamin, niacin, vitamin C, vitamin E, vitamin K, phosphorus, magnesium, and copper. In a more recent study, Storey and Anderson (2013) examined the intake and nutrient contribution of total vegetables, white potatoes and French fries in Americans aged 2 and older, based on national dietary intake survey data from NHANES 2009-2010. Individuals who consumed white potatoes had significantly higher total vegetable and potassium intakes than did non-consumers. In addition, the proportion of potassium and dietary fiber contributed by white potatoes was higher than the proportion they contributed to total energy. Among white potato consumers aged 14-18 years, white potatoes provided 23 percent of dietary fiber and 20 percent of potassium but only 11 percent of total energy in the diet.

Potatoes are also one of the best nutritional values in the produce department, providing significantly better nutritional value per dollar than most other raw vegetables (Drewnowski et al. 2013). Drewnowski and Rehm (2013) examined the nutrient density per unit cost of 46 commonly consumed vegetables, and found that potatoes and beans were the least expensive sources of not only potassium but fiber, too. Specifically, potassium-rich white potatoes were almost half the cost of most other vegetables, making it more affordable to meet key dietary guidelines for good health.

Potatoes and Potato Nutrients in Health and Disease

Potatoes contain a number of nutrients and nutritional components that may be linked to health promotion and disease prevention. These nutrients along with research supporting their possible roles in human health are described in the paragraphs below.

Blood Pressure/Hypertension

It is estimated that between 29%-32% of American adults suffer from hypertension (depending on the data source) and another 1 in 3 have pre-hypertension (CDC websites). Research suggests that diets rich in potassium and low in sodium reduce the risk of hypertension and stroke (Apel et al. 2006, Adrogue and Madias 2014, Seth et al. 2014, Zhang et al. 2013, Yang et al. 2011). Although data from individual clinical trials have been somewhat inconsistent, three meta- analyses of these trials have documented a significant inverse relationship between potassium intake and blood pressure in both non-hypertensive and hypertensive individuals (Appel et al. 2006). Seth et al. (2014) 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). The US Food and Drug Administration (FDA) has approved a health claim for potassium and blood pressure which states*, "Diets containing foods that are good sources of potassium and low in sodium may reduce the risk of high blood pressure and stroke*" (FDA Food Labeling Guide, Appendix C: Health Claims).

Given their high potassium and low sodium content, potatoes would seem to be an ideal food to incorporate into a dietary pattern for managing hypertension. Nonetheless, very few studies have specifically examined the role of potatoes in blood pressure regulation and/or hypertension treatment. 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). However, closer examination of the study results actually shows that the association varied depending on which cohort was used as well as which potato groupings were examined. In some cases the positive association between potato intake and hypertension was seen only in women and in others potato consumption was actually associated with *lower* risk for hypertension in men. Furthermore, 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.

In sharp contrast to the above-described epidemiological study, two published human experimental trials indicate that potatoes can positively impact blood pressure. Nowson et al. (2004) examined the effect on blood pressure of two different self-selected diets: (1) a low-sodium, high-potassium diet rich in fruit and vegetables (LNAHK) and (2) a high- calcium diet rich in low-fat dairy foods (HC) with a (3) moderate-sodium, high-potassium, high-calcium diet high in fruits, vegetables and low-fat dairy foods (OD) for four weeks. In order to achieve a higher potassium intake, the subjects on the LNAHK diet and OD diets were given a list of potassium rich foods and instructed "to eat a potato a day." The results indicated both the LNAHK and OD produced significant decreases in blood pressure compared to the HC diet; however the decrease was greatest in the LNAHK diet. In a more recent study, Vinson et al. (Vinson et al. 2012) fed purple-pigmented potatoes (Purple Majesty cultivar) to 18 overweight (average BMI of 29), hypertensive adult subjects for four weeks in a cross-over design. Subjects in the experimental group consumed six to eight (~138 g) small, microwaved purple potatoes twice daily, while those in the control group did not consume potatoes. The results showed that consumption of purple potatoes significantly reduced diastolic BP by 4 mmHg (4.3% reduction) and also reduced systolic BP by 5 mmHg (3.5% reduction) compared to baseline. There were no significant changes in weight, fasting glucose, serum lipids, or HbA1c during the potato consumption period.

Weight Management/Obesity

Overweight and obesity have increased significantly during the last three decades both in the US and globally (Ng et al 2014; Flegal et al. 2016). Although it is generally accepted that dietary patterns along with other key lifestyle behaviors (e.g., physical activity) are more important than single foods when it comes to obesity and weight management, potatoes have been singled out both in research and the popular press as being somehow uniquely obesogenic. In a highly publicized study, Mozaffarian and colleagues (2011) from Harvard university examined the association between specific foods and weight gain in three large cohorts (Nurses Health Study I and II and the Health Professionals Follow-up Study). The results indicated that four-year weight gain was significantly associated with the intake of potato chips, potatoes, sugar-sweetened beverages and unprocessed and processed red meats. It should be noted, however, that this study suffered from a number of methodological limitations, most notably the failure to statistically control for energy intake.

A recently published systematic review sought to scientifically summarize the existing research regarding the relationship between potato intake and obesity (Borch et al. 2016). In this review, the authors identified nineteen total studies - 13 observational studies (five cohorts, six cross-sectional and two ecological) and six short-term intervention studies. Of the 13 observational studies, five did not specify the types of potatoes studied, while the rest examined five or fewer categories (i.e., potato chips, French fries, mashed, boiled and baked potatoes) but did not account for mode of preparation or consumption. Of these 13 studies, six found a positive association between potato consumption and weight gain (including the aforementioned study by Mozaffarian et al (2011), while seven found no association. The six short-term intervention studies identified were all single meal, satiety studies with a duration of two-to-four hours. Three of the intervention studies found that boiled or mashed potatoes increased satiety compared to energy-equivalent amounts of white bread, French fries, white or brown pasta, white or brown rice, or whole-meal bread; while two found no difference in satiety and one found decreased feelings of satiety for mashed potatoes only compared to energy equivalent amounts of bean meal (Bor et al. 2016).

In the only long-term intervention study to date to examine the specific role of potatoes in weight management, Randolph and colleagues (2014) studied the effects of potato consumption on weight loss in free-living adults (Randolph et al. 2014). In a 12-week, 3-arm, randomized control trial, 90 overweight men and women were randomly assigned to one of three dietary interventions: (1) low GI, calorie reduced diet (500 kcal/d); (2) high GI, calorie reduced diet (500 kcal/d); (3) control group (counseled to follow basic dietary guidance including the Dietary Guidelines for Americans and the Food Guide Pyramid). All three groups were instructed to consume five-to-seven servings of potatoes per week (approximately one potato per day) and were provided with a variety of recipes for potato dishes. Modest weight loss was observed in all three groups (~2% of initial body weight) with no significant difference in weight loss between the groups.

Glycemic Response/Type 2 Diabetes

Because of their carbohydrate content and supposed high glycemic index, potatoes are not only frequently restricted in diabetic dietary guidance; but, are also implicated in the development of the disease. Halton and colleagues from Harvard University prospectively examined the association between potato consumption and risk for developing diabetes in a large cohort of women (i.e., the Nurses Health Study) who were followed for 20 years (Halton et al. 2006). The authors concluded that potatoes (including baked, boiled, mashed and French fries) were positively associated with risk of type 2 diabetes and cite the GI of potatoes as the likely mechanism for the increased risk. In fact, a closer look at the results of the study shows that, once BMI was included in the statistical model as a cofactor, the association no longer remained significant for baked, boiled or mashed potatoes. It should also be noted that the authors did not control for other dietary factors that could account for the association, specifically red meats. In the discussion section of the paper the authors themselves admit to this statistical faux pas, “White potatoes and French fries are large components of a ‘Western pattern’ diet. This dietary pattern is characterized by a high consumption of red meat, refined grains, processed meat, high-fat dairy products, desserts, high-sugar drinks, and eggs, as well as French fries and potatoes. A Western pattern diet previously predicted a risk of type 2 diabetes. Thus, we cannot completely separate the effects of potatoes and French fries from the effects of the overall Western dietary pattern" (Halton et al. 2006). Finally, the hypothesized mechanism for the association (i.e., the "high GI" of potatoes) is unfounded. In fact, the GI of potatoes is highly variable and depends upon the type, processing and preparation. In a study examining the GI of potatoes commonly consumed in North America, reported GI values ranged from intermediate (boiled red potatoes consumed cold: 56) to moderately high (baked US Russet potatoes: 77) to high (instant mashed potatoes: 88; boiled red potatoes: 89) (Fernandes et al. 2005). Another study examined the GI of eight varieties of commercially available potatoes in Great Britain and reported a range from 56 to 94 (Henry et al. 2005). French fries are reported to have a GI lower than boiled potatoes (Leeman et al. 2008).

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). Again it should be emphasized that observational studies cannot show cause and effect, only an association. Moreover, it is difficult to tease out the effects of single foods from larger dietary patterns and make any definitive conclusions relative to the risk of type 2 diabetes. Thus, randomized controlled intervention trials investigating the relationship between potatoes and type 2 diabetes are needed to separate potato consumption from other known risk factors.

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). Potatoes contain a number of nutritional components capable of supporting “gut health” as defined by Bischoff, most notably fiber and RS. 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, RS undergoes colonic fermentation and can function as a pre-biotic, supporting and enhancing the proliferation of the colonic microbiota (Higgins).

Finally, potatoes are gluten free, thus they are a key source of nutrient dense carbohydrates in the diets of those with celiac disease and/or gluten sensitivity. According to the National Foundation for Celiac Awareness, an estimated 1 in 133 Americans, or about 1% of the population, suffers from celiac disease and would benefit from reducing or eliminating foods containing gluten. However, eliminating foods with gluten can predispose individuals to nutrient deficiencies. Shepherd and Gibson (2013) examined dietary intakes from 55 men and women who had been following a gluten-free diet for two years and found inadequate intakes of fiber 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.

Summary/Conclusion

The potato has been a dietary staple for centuries; its resilience has allowed it to flourish when other less hardy crops have failed. Potatoes contribute important nutrients to the diet including potassium, vitamin C and dietary fiber and increase overall vegetable consumption among children, teens, and adults in the United States. Potatoes and potato nutrients have been shown to have favorable impacts on blood pressure, satiety and gut health. There is currently a lack of experimental data regarding the impact of potato consumption on obesity, weight management and/or diabetes; however a recent systematic review concluded that existing observational studies do not provide strong evidence that intake of boiled, baked, or mashed potatoes increase the risk of obesity or type 2 diabetes. Randomized controlled intervention trials investigating the relationship between potatoes and various health outcomes and disease states are needed to separate potato consumption from other known risk factors. Until then, dietary guidance should continue to stress moderate consumption of high energy and low nutrient dense foods and liberal consumption of nutrient dense vegetables including potatoes prepared in a healthful way.

References

International Potato Center. Potato facts and figures. http://cipotato.org/potato/facts/ Accessed July 21, 2016.

National Potato Council. Potato facts. http://www.nationalpotatocouncil.org/potato-facts/ Accessed July 21, 2016.

Agriculteral Marketing Resource Center. April 2012 (revised). Potato profile. Available at: http://www.agmrc.org/commodities_products/ vegetables/potatoes/ Accessed July 21, 2016.

Drewnowski A, Rehm CD. Vegetable cost metrics show that potatoes and beans provide most nutrients per penny.PLoS One. 2013 May 15;8(5):e63277.

Weaver C, Marr ET. White vegetables: a forgotten source of nutrients: Purdue roundtable executive summary. Adv Nutr. 2013 May 1;4(3):318S-26S.

McGill CR, Kurilich AC, Davignon J. The role of potatoes and potato components in cardiometabolic health: a review. Ann Med. 2013;45(7):467-73.

Geliebter A, Lee M, Abdillahi M, Jones J. Satiety following intake of potatoes and other carbohydrate test meals. Ann Nutr Metab. 2013;62:37-43.

Holt SHA, Brand-Miller JC, Petroz P, et al. A satiety index of common foods. Eur J Clin Nutr. 1995;49:675-690.

Akilen R, Deljoomanesh N, Hunschede S, Smith CE, Arshad MU, Kubant R, Anderson GH. The effects of potatoes and other carbohydrate side dishes consumed with meat on food intake, glycemia and satiety response in children. Nutr Diabetes. 2016 Feb 15;6:e195.

Borch D, Juul-Hindsgaul N, Veller M, Astrup A, Jaskolowski J, Raben A. Potatoes and risk of obesity, type 2 diabetes, and cardiovascular disease in apparently healthy adults: a systematic review of clinical intervention and observational studies. Am J Clin Nutr. 2016 Jul 13. pii: ajcn132332. [Epub ahead of print]

Potato History and Fun Facts. Potatoes USA website. http://www.potatogoodness.com/all-about-potatoes/potato-fun-facts-history/ Accessed July 26, 2016.

United Nations General Assembly Session 60 *Resolution 191*. *International Year of the Potato, 2008* **A/RES/60/191** page 1. 22 December 2005. Retrieved 2007-11-18.

Woolfe JA. *The Potato in the Human Diet*. New York: Cambridge University Press. 1987, pp10.

Higgins JA. Resistant starch: metabolic effects and potential health benefits. J AOAC Int. 2004;87:761–8.

Brit DF. Resistant starch: Promise for improving health. Adv Nutr. 2013; 4:587-601.

Gentile CL, et al. Resistant starch and protein intake enhances fat oxidation and increases feelings of fullness in lean and overweight/obese women. Nutr J. 2015;14:113-123.

Higgins JA. Resistant starch and energy balance: Impact on weight loss and weight maintenance. Crit Rev Food Sci Nutr. 2014;54:1158-1166.

Higgins JA, Brown IL. Resistant starch: a promising dietary agent for the prevention/treatment of inflammatory bowel disease and bowl cancer. Curr Opin Gastroenterol. 2013;29:190-194.

Keenan MJ, et al. Role of resistant starch in improving gut health, adiposity, and insulin resistance. Adv Nutr. 2015 Mar 13;6(2):198-205.

Robertson MD. Dietary resistant starch and glucose metabolism. Curr Opin Clin Nutr Metab.Care. 2012;15:362-367.

Zhang L, et al. Effect of dietary resistant starch on prevention and treatment of obesity-related disease and its possible mechanisms. Biomed Environ. 2015;28:291-297.

Raatz SK, et al. Resistant starch analysis of commonly consumed potatoes: Content varies by cooking method and service temperature but not by variety. Food Chem. 2016 Oct 1;208:297-300.

Thorpe MP, Evans EM. Dietary protein and bone health: harmonizing conflicting theories. Nutr Rev. 2011;69(4):215-30.

Kudo K, Onodera S, Takeda Y, Benkeblia N, Shiomi N. Antioxidative activities of some peptides isolated from hydrolyzed potato protein extract. J Funct Foods. 2009;1:170–6.

Liyanage R, Han KH, Watanabe S, Shimada K, Sekikawa M, Ohba K, et al. Potato and soy peptide diets modulate lipid metabolism in rats. Biosci Biotechnol Biochem. 2008;72:943–50.

Hill AJ, Peikin SR, Ryan CA, Blundell JE. Oral administration of proteinase inhibitor II from potatoes reduces energy intake in man. Physiol Behav. 1990;48:241–6.

Cotton PA, Subar AF, Friday JE, Cook A. Dietary sources of nutrients among US adults, 1994-1996. J Am Diet Assoc. 2004;104:921-930.

O'Neil CE, Keast DR, Fulgoni VL, Nicklas TA. Food sources of energy and nutrients among adults in the US: NHANES 2003–2006. Nutrients. 2012 Dec 19;4(12):2097-120

Brown CR. Breeding for phytonutrient enhancement of potato. Am J Potato Res. 2008;85:298–307.

Liu RH. Health-promoting components of fruits and vegetables in the diet. Adv Nutr. 2013 May 1;4(3):384S-92S.

Brown CR, Culley D, Yang C-P, Durst R, Wrolstad R. Variation of anthocyanin and carotenoid contents and associated antioxidant values in potato breeding lines. Journal of the American Society for Horticul- tural Science. 2005;130:174–80.

Song W, Derito CM, Liu MK, Dong M, Liu RH. Cellular antioxidant activity of common vegetables. J Agric Food Chem. 2010;58:6621–9.

Kawabata K, Mukai R, Ishisaka A. Quercetin and related polyphenols: new insights and implications for their bioactivity and bioavailability. Food Funct. 2015;6(5):1399-1417

Freedman MR, Keast DR. White potatoes, including French fries, contribute shortfall nutrients to children's and adolescents' diets. Nutr Res. 2011;31:270–7.

CDC/NCHS, National Health and Nutrition Examination Survey, 2011–2014. http://www.cdc.gov/nchs/data/databriefs/db220.htm Accessed July 25, 2016.

CDC Hypertension fact sheet. Accessed July 25, 2016. http://www.cdc.gov/dhdsp/data_statistics/fact_sheets/fs_bloodpressure.htm.

Appel LJ, Brands MW, Daniels SR, Karanja N, Elmer PJ, Sacks FM. Dietary approaches to prevent and treat hypertension. A scientific state- ment from the American Heart Association. Hypertension. 2006;47: 296–308.

Adrogué HJ1, Madias NE2. The impact of sodium and potassium on hypertension risk. Semin Nephrol. 2014;34:257-72.

Seth A, Mossavar-Rahmani Y, Kamensky V, Silver B, Lakshminarayan K, Prentice R, Van Horn L, Wassertheil-Smoller S. Potassium Intake and Risk of Stroke in Women With Hypertension and Nonhypertension in the Women's Health Initiative. Stroke. 2014;45:2874-80.

Yang Q, Liu T, Kuklina EV, et al. Sodium and potassium intake and mortality among US adults: prospective data from the Third National Health and Nutrition Examination Survey. Arch Intern Med 2011;171:1183–91.

Zhang Z1, Cogswell ME, Gillespie C, et al. Association between usual sodium and potassium intake and blood pressure and hypertension among U.S. adults: NHANES 2005-2010.

Borgi L, Rimm EB, Willett WC, Forman JP. Potato intake and incidence of **hypertension**: results from three prospective US cohort studies. BMJ. 2016 May 17;353:i2351

Nowson CA, Worsley A, Margerison C, et al. Blood pressure response to dietary modifications in free-living individuals. J Nutr. 2004;134:2322-9.

Vinson JA, Demkosky CA, Navarre DA, Smyda MA. High-antioxidant potatoes: acute in vivo antioxidant source and hypotensive agent in humans after supplementation to hypertensive subjects. J Agric Food Chem. 2012;60:6749–54.

Ng M, Fleming T, Robinson M, Thomson B, Graetz N, Margono C, Mullany EC, Biryukov S, Abbafati C, Abera SF, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980–2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet. 2014;384:766–81.

Flegal KM, Kruszon-Moran D, Carroll MD, Fryar CD, Ogden CL. Trends in Obesity Among Adults in the United States, 2005 to 2014. JAMA. 2016 Jun 7;315(21):2284-91.

Mozaffarian D, Hao T, Rimm EB, Willett WC, Hu FB. Changes in diet and lifestyle and long-term weight gain in women and men. N Engl J Med. 2011;364(25):2392-404.

Randolph JM[1], Edirisinghe I, Masoni AM, Kappagoda T, Burton-Freeman B.
Potatoes, glycemic index, and weight loss in free-living individuals: practical implications. J Am Coll Nutr. 2014;33(5):375-84.

Halton TL, Willett WC, Liu S, Manson JE, Stampfer MJ, Hu FB. Potato and french fry consumption and risk of type 2 diabetes in women. Am J Clin Nutr. 2006;83:284–90.
Fernandes G, Velangi A, Wolever TM. Glycemic index of potatoes commonly consumed in North America. J Am Diet Assoc. 2005;105:557–62.

Henry CJ, Lightowler HJ, Strik CM, Storey M. Glycaemic index values for commercially available potatoes in Great Britain. Br J Nutr. 2005; 94:917–21.

Leeman M, Ostman E, Bjork I. Glycaemic and satiating properties of potato products. Eur J Clin Nutr. 2008;62:87–95.

Shepherd SJ, Gibson PR. Nutritional inadequacies of the gluten-free diet in both recently-diagnosed and long-term patients with coeliac disease. J Hum Nutr Diet. 2013;26:349-58.

Bischoff SC. ‘Gut health’: a new objective in medicine? ***BMC Med***. 2011;9:24.

Higgins JA. Resistant starch: metabolic effects and potential health benefits. J AOAC Int. 2004;87:761–8.

Table 1 Energy and Macronutrient Content of Different Potato Varieties and Preparation Methods

Potato variety	Serving size	Calories	Total CHO (g)	Fiber (g)	Fat (g)	Protein (g)
Raw Potato+	5.3 oz	110	26	2	0	4
Russet (baked w/skin)*	1 small (138 g)	134	30	3	0	4
Russet (baked w/o skin)*	1 small (138 g)	128	30	2	0	3
Russet (microwaved w/skin)*	1 small (138 g)	145	33	3	0	3
Russet (microwaved w/o skin)*	1 small (138 g)	138	32	2	0	3
Potatoes (boiled in skin)	138 g	120	28	2.5	0	2.5
Potatoes (boiled w/o skin)*	138 g	119	28	2.5	0	2
Red Potatoes (baked w/skin)	1 small (138 g)	123	27	2.5	0	3
White Potatoes (baked w/skin)*	1 small (138 g)	130	29	3.0	0	3
Potato skin (raw)*	1 skin (38 g)	22	5	1	0	1

* USDA Standard Reference 28 + FDA nutrition label information.

Table 2 Selected Micronutrient Content of Different Potato Varieties and Preparation Methods

Potato variety	Serving size	Vit. C (mg)	B1 (mg)	B2 (mg)	B3 (mg)	B6 (mg)	Folate (mcg)	Potassium (mg)	Ca (mg)	Mg (mg)	Iron (mg)	Zn (mg)
Raw Potato⁺	5.3 oz	27	.12	.03	1.6	.2	24	620	20	33	1.1	0.4
Russet (baked w/skin)*	1 small (138 g)	11.5	.10	.07	1.9	.50	36	759	25	41	1.5	.48
Russet (baked w/o skin)*	1 small (138 g)	18	.14	.03	1.9	.41	12	540	7	34	.5	.40
Russet (microwaved w/skin)*	1 small (138 g)	21	.18	.04	2.4	.48	17	617	15	55	1.7	.76
Russet (microwaved w/o skin)*	1 small (138 g)	21	.18	.03	2.2	.44	17	567	7	34	.57	.46
Potatoes (boiled in skin)	136 g	18	.15	.03	2.0	.41	14	515	7	30	.43	.41
Potatoes (boiled w/o skin)*	125	9	.12	.02	1.6	.34	11	410	10	25	.39	.34
Red Potatoes (baked w/skin)	1 small (138 g)	17	.10	.07	2.2	.30	37	752	12	39	1.0	.55
White Potatoes (baked w/skin)*	1 small (138 g)	17	.07	.06	2.1	.30	52	751	14	37	.90	.48
Potato skin (raw)*	1 skin (38 g)	4	.01	.01	0.4	.09	6	157	11	9	1.2	.13

* USDA Standard Reference 28   ⁺ FDA nutrition label information.