Potato Progress

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Potatoes: Nutrition and Food Security

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These are interesting times for the potato. Its introduction and cultivation in the West greatly reduced hunger and increased food security for millions of people. Some believe the introduction of potato enabled the population increases seen in Europe in the 17-1800s and fueled the industrial revolution. Flash forward to the present day, where the healthfulness of potatoes has been questioned by some nutritionists, creating doubts among the public about potatoes. While a majority of nutritionists support moderate consumption of potatoes as part of a healthy diet, others advocate that potatoes be eaten sparingly and argued that potato consumption is a major cause of the obesity epidemic and increase in diabetes. This article will look at some obesity data, discuss potato nutrition and finally examine the potential of potatoes to provide food security to a growing global population.

The obesity epidemic. A much publicized study by Harvard scientists in 2011 claimed potatoes are a leading cause of weight gain. Over the last two decades there has been a disturbing increase in the percentage of obese or diabetic Americans. 155 million U.S. adults , about 50% of the population, are overweight or obese. These increases have alarmed health officials, who point out the tremendous personal toll of obesity and diabetes, and the effect on soaring health costs. In 2013 the American Medical Association classified obesity as a disease. Some estimate obesity-related illnesses account for nearly 21% of annual medical spending. Total direct and indirect costs of obesity to the economy are in the hundreds of billions, and include expenses such as an estimated 4 billion dollars of extra gasoline to transport the added weight. A 2012 Gallup-Healthways poll reported on the 10 most obese metro areas, and Kennewick-Pasco-Richland ranked 9th at 33.2%. The McAllen metro region in Texas was the most obese (38.8%) and that community could potentially save 250 million dollars annually by reducing the obesity rate to 15%. In 1995 no state had an obesity rate over 20%, but by 2012 all states exceeded 20%. At the current rate, by 2030 an astonishing 44% of Americans will be obese according to CDC projections.

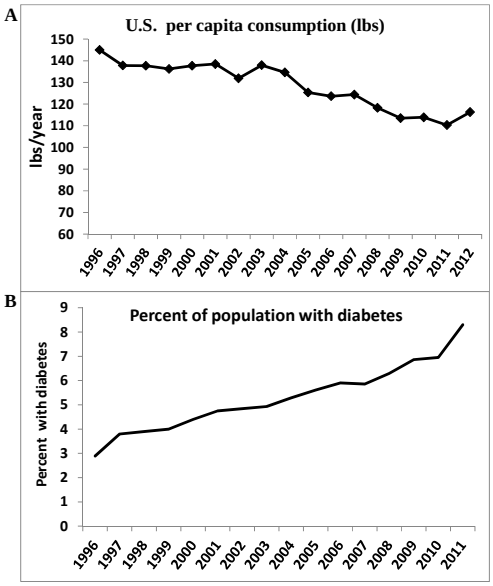

Fig. 1. (A) Annual potato consumption 1996-2012. (B) Percentage of population with diabetes 1996-2011

Given the claims that potato consumption is involved, it is interesting to note that during the period obesity has been rapidly increasing, potato consumption has undergone a significant decrease as shown (**Fig. 1A)**. Not only fresh potato consumption decreased, but also French fries (USDA-Economic Research Service data). According to the Organization for Economic Cooperation and Development, Mexico and the United

States are the first and second most obese countries, while they rank 105th and 44th in per capita potato consumption according to the most recently available FAO data (2009). If potatoes are a major contributor to obesity, it is curious that obesity was not problematic in European countries in the past when potato consumption was far higher than present day. German annual potato consumption in 1900 was 628 lbs. per person and still over 300 lbs. in the 1950s. CDC data show a disconcerting increase in the percent of people with diabetes to 8.9% in 2011. From the 1970s until the mid-90s, the diabetes rate varied little, but began a steep rise in the mid-90s (**Fig. 1B**) during the same time potato consumption was decreasing.

Basic potato nutrition: Some foods are seen as "empty calories," meaning they provide calories but little nutritive value. A number of people have the misperception that potatoes are empty calories, and fail to realize that potatoes are actually a nutrient-dense food. For a food to be nutrient-dense, it must provide an equal or greater amount of nutritional value as it does calories. **Fig. 2** shows the percentage of the recommended daily values of various nutrients in a 3.5 ounce (100 grams) portion of baked potato with skin (data from nutritiondata.self.com and USDA SR-21). This serving would provide 97 calories or 5% of the daily value, but as seen provides a greater percentage of various nutrients than it does calories. The nutritional quality of potato protein is among the highest in plants. Not shown in this list are potato phytonutrients like carotenoids and antioxidants. Unlike vitamins, these do not have recommended daily allowances, but are nonetheless important for health and valued by many consumers to the extent that they influence purchasing decisions.

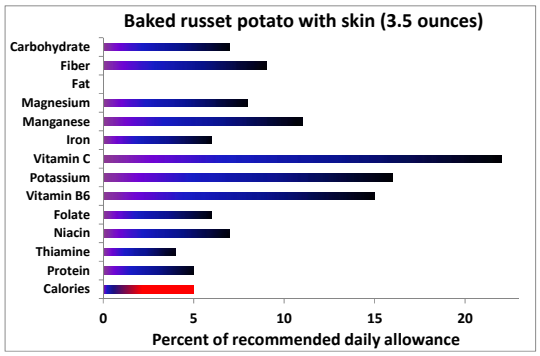

Fig. 2. Amount of nutrients in 3.5 ounces of baked potato. The percentage of the RDA is shown.

Potato Nutrition Research: The Washington State Potato Commission has been supportive of efforts to maximize the nutritional content of potatoes, funding work on antioxidants, B-vitamins and sponsoring a human feeding study. Likewise, developing potatoes with enhanced nutritional characteristics is a goal of the Tri-State Breeding Program of Idaho, Oregon and Washington.

Potatoes provide an opportunity to increase consumer phytonutrient intake. If scientists were debating which foods to nutritionally enhance, it would make sense to target a staple food like potatoes, because even small increases in their phytonutrient content would impact dietary intake. If breeders doubled the amount of vitamin C in a food that people only eat a handful of times a year, then this is not going to have as much impact as would even a 15% increase in potato vitamin C, because per capita consumption is over 115 lbs./year. Additional rationale for choosing potatoes is their affordability and potential to feed the growing global population.

A major focus area of the Navarre lab is antioxidants. The two major antioxidants in potatoes are vitamin C and phenolics. Red- and purple-flesh potatoes typically have much higher amounts of antioxidants than white potatoes and this is due to phenolics.

Baby potatoes: We found that "baby" or "new" potatoes harvested 60-80 days after planting typically contain higher amounts of antioxidants than at maturity. For example, in a high-antioxidant purple cultivar, phenolics decreased from 14 to 10 mg/g DW (dried weight) during development, lutein and violaxanthin decreased 30-70%, the major anthocyanin decreased from 6.4 to 4 mg/g and in some, but not all, cultivars total protein decreased 15-30%. Collectively, data now reveal that baby potatoes contain higher amounts of phenolic acids, flavonols, anthocyanins, carotenoids, protein and some vitamins.

Select red- and purple-flesh baby potatoes have especially high amounts of antioxidants and some advanced breeding lines contain 15-19 mg/g DW of anthocyanins. The ORAC antioxidant values of these potatoes (> 300 µmol Trolox equivalents/g DW) rival kale and spinach. Studies are increasingly documenting health-promoting benefits of purple potatoes, including purple baby potatoes that reduced blood pressure in a human feeding study conducted by Joe Vinson and funded by ARS. Likewise, a WSPC funded human feeding study by Boon Chew showed anti-inflammatory effects of

high-antioxidant potatoes. These findings are important because they support the rationale for developing such potatoes—i.e. we hypothesized that potatoes with even higher amounts of phytonutrients would contribute to a healthy diet, and now human feeding studies are validating this premise. We and others have now published several peer-reviewed scientific papers on the phytonutrient content of baby potatoes; this scientific information could be used by the potato industry to publicize the nutritional merits of baby potatoes, which may especially appeal to health-conscious consumers and present a palatable, inexpensive source of phytonutrients.

A high-antioxidant white potato? White potatoes are consumed in far greater quantities than yellow-, red- or purple-flesh potatoes, so a goal is to develop a high-antioxidant white potato. The major antioxidant in most potatoes is chlorogenic acid, a colorless compound. However, for reasons not yet understood, red and purple potatoes contain much more of this colorless antioxidant than do white or yellow. Despite evaluating over 100 different types of white potatoes for antioxidants, we've yet to find any that have the amounts found in red/purple types. Therefore finding a white breeding line with higher antioxidants will likely require screening a large number of lines to improve the odds. For it to be feasible to screen lots of lines, fast methods are needed; otherwise it is too labor intensive to do such screening.

We are trying to develop such fast, crude methods. An approach that appears to have promise is using a leaf press to extract the juice from tuber slices, which is then assayed in 96-well microplates. This method needs further evaluation and optimization, but so far we used it to analyze all of the year one white-flesh TriState breeding lines advanced from the Klamath Falls 2012 trial. Also analyzed were over 100 genotypes being used as parental material in the TriState program. Normally a breeding line will not be evaluated for phytonutrient content until many years into its development, but this screening has potential to identify and fast-track a promising antioxidant line early in its development. While screening this germplasm for antioxidants, we also measured phenolics, polyphenol oxidase activity and browning (rapid browning/bruising is undesirable). Only about a 2-fold difference in antioxidants was observed in the over 100 TriState early lines screened, which is further evidence that lots of breeding lines will have to be evaluated to find one with unusually high antioxidants.

Why do some potatoes have more phytonutrients than others? We don't really know yet. But understanding what controls tuber phytonutrient content would make it easier to further increase amounts in new cultivars and shed light on the best way to manage the crop for phytonutrient content. We are studying the mechanisms that determine the amount of antioxidants in potatoes. Transcription factors have a role somewhat like traffic cops and are expected to be important regulators of how much of a phytonutrient is made. After analyzing 15 transcription factors for their involvement in tuber antioxidant content, we identified a specific transcription factor that appears to be a key regulator of both colorless and colored potato antioxidants and we are currently analyzing its role in greater detail. Another interesting finding is that tuber sugars appear to influence the amount of potato antioxidants. We consistently find that potatoes with higher amounts of sugars have higher amounts of antioxidants. And if we feed potato plantlets extra sugar, the amount of antioxidants increases. These findings are also relevant to developing white potatoes with increased antioxidants.

Vitamin B_6: B_6 deficiency is relatively common is the U.S. and can lead to neurological disorders, diabetes and other maladies. B_6 withstands high temperatures, and potatoes are an excellent source that can provide over 20% of the RDA in a single serving. The Hellmann lab at WSU has been studying B_6 biochemistry and evaluating diverse potato germplasm for B_6 content, along with the effects of development and storage. B_6 concentrations ranged from ~17 ug/g DW in one TriState breeding line to 27 in Clearwater Russet. A 3.5 ounce portion of Clearwater Russet would provide about 36% of the RDA, emphasizing the potential to develop potatoes with even higher amounts of nutrients. Results also suggested that B_6 concentrations were fairly consistent during development. Interestingly, concentrations increased significantly during cold storage, up to 43% in Defender after 227 days.

Calories per acre and food security: The United Nations forecasts global population will increase to 8.1 billion by 2025. A new study (Ray et al., PLoS One, 2013) suggests global crop production needs to double by 2050 to meet needs. Also pressuring food production will be increased

meat and dairy consumption in countries with rising affluence, and competition for acreage with biofuel crops. Consequently, it is notable that potatoes yield more calories per acre than corn, wheat, rice or soybean, with potatoes often cited as producing about 9.2 million calories per acre (for example, Wikipedia). However, this number does not reflect yields in the Pacific Northwest, which are often above 30 tons per acre. From the USDA database, a baked russet potato is listed as having 97 calories per 100 grams, which is about 440 calories per pound. Using these values, potato production in the Northwest produces ~26 million calories per acre compared to 7.5, 7.4, 3.0 and 2.8 million for corn, rice, wheat and soybeans respectively (Food & Nutrition Encyclopedia p.1104). Norkotah Russet would provide about 150,000 grams of potassium per acre, 6,700 g of vitamin C and 19,000 g of phenolics. While many locations may not be able to replicate yields reached in the Northwest, this nevertheless shows the potential for increased yields with better management. The importance of potato in food security is further highlighted by a new study that concluded potatoes and beans provide the most nutrients per dollar out of 98 vegetables studied (Drewnowski, et al., 2013). These data suggest a key role for potatoes in providing global food security, including in impoverished nations. Strikingly, those suggesting potatoes be replaced in the diet with other foods have not provided data on the affordability of the replacement or how much more land would be required to produce an equivalent amount of energy and nutrition.

Conclusion: A panel of experts evaluated 29 popular diets and ranked the DASH diet the best (http://health.usnews.com/best-diet). The DASH diet (Dietary Approaches to Stop Hypertension) was developed by researchers at the National Institute of Health and is based on the USDA food pyramid plan. The diet allows potatoes and encourages increased potassium intake (potatoes are a good source) and reduced sodium intake. The plan is available for free at http://www.nhlbi.nih.gov/health/public/heart/hbp/dash/new_dash.pdf. Given the ongoing "obesity epidemic" and its recent classification as a disease, obesity is understandably likely to remain a key focus of health professionals. Consequently, it is helpful for the industry to be proactive and highlight tasty reduced calorie potato recipes like those listed at various potato commission websites as part of outreach efforts. Substantial solid scientific evidence from numerous different groups supports the nutritional importance of potatoes in the diet. Such data can form the backbone of efforts to educate people and organizations about the role of potatoes in providing a nutritious and affordable food source. Phytonutrient-rich potatoes can appeal to health-conscious consumers in the short term and contribute to global food security in the long term.

Annual Northwest Potato Conferences

Idaho Potato Conference: January 21-23, Pocatello, Idaho
http://web.cals.uidaho.edu/potatoconference/

Washington-Oregon Potato Conference: January 28-30, Kennewick, Washington
http://www.potatoconference.com/