A Role for Potato in Nutrition and Health

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Potato is by far the most eaten vegetable in the United States, although per capita consumption has steadily decreased over the last few decades. It is our belief that negative publicity about the health and nutritional value of potato can have a large impact on sales. News and media coverage of issues such as acrylamide in fries and chips, obesity, negative effects of carbohydrates, movies such as "Supersize Me," along with negative comments specifically about potato from a minority of nutrition and health researchers can confuse the consumer and create a negative perception of potato.

In actuality, potatoes contain many more ingredients than just carbohydrates and can be an especially rich source of several vitamins and health-promoting compounds. Potatoes are already known to be a good source of vitamins and minerals such as potassium and Vitamin C.

The impact of low-carbohydrate diets already made it very clear that consumer perception of the nutritional value of potato impacts sales. Given the huge amount of worldwide scientific research ongoing into how compounds present in foods affect health, it seems likely that in the years ahead, many consumers will become increasingly aware and demanding about the nutritional value of the foods they choose to purchase or not purchase.

One indication this is true was the decision by a major grocery chain with over 150 stores in the Northeast to voluntarily assign a health ranking of zero to three stars on over 27,000 products. The company's research indicated that 84% of the people they surveyed would use such a rating system to buy more nutritious food. Almost 80% of the products they rated received the lowest rating of zero stars. Fresh fruits and vegetables received the highest rankings.

Research Approach

Our group is devoting considerable effort towards the nutritional enhancement of potato because we believe that maximizing its nutritional potential would create many new marketing opportunities and is a way to provide valuable phytonutrients in the American diet. We are trying to find methods to even further increase the amounts of vitamins and phytonutrients in potatoes.

One of the approaches we are using is to take advantage of the considerable genetic diversity that exists amongst potato germplasm. Potato may have the most genetic diversity of any crop, with over 200 wild species existing in nature, growing in extremely varied environments ranging from humid jungle to arid mountain highlands. Some have estimated that only about 1% of the total genetic diversity available is actually used in domesticated potatoes. This means that superior genes for many traits likely exist amongst the pool of available potato germplasm. For example genes that give superior nutritional value, pest resistance, drought tolerance etc; the problem is how do we find these genes?

Some of our shorter term research goals are to determine how much particular vitamins/phytonutrients vary among different cultivars. Do some have substantially higher amounts than others? Of the thousands of compounds present in potatoes, which are health-promoting ? And which of these compounds are the best targets to attempt to increase? We measured several vitamins and many phytonutrients in numerous cultivars and wild potato species to begin to answer these questions, which is a first step towards producing potatoes that have the highest possible amounts of phytonutrients.

Folic Acid

We are focusing on both vitamins and phytonutrients. Vitamins all have recommended daily allowances (RDAs) and are essential for growth, whereas phytonutrients are health-promoting, but not essential for growth and do not have established RDAs. In a study funded by the Washington State Potato Commission, one of the vitamins we are studying is folic acid. We want to determine how much potatoes contain, how much it varies among varieties and what approaches might be used to increase its amounts even higher. If possible, increasing the amount of folic acid in potato would be an important contribution to the American diet and global health. Unlike many vitamins satisfactorily obtained in the diet, many people do not achieve the recommended dietary folate intake, even in the United States. Folic acid deficiency is one of the major nutritional deficiencies worldwide. Most pregnant women take a folic acid supplement because over 500,000 infants with severe birth defects are born each year due to folate deficiency. Furthermore, one scientific study suggested that up to 25% of all heart attacks and strokes may be linked to folate deficiency. A recent study reported that the children of mothers who took a folic acid supplement during pregnancy had a lower incidence of the three of the most common childhood cancers.

Very little is known about folate concentrations in potato because only a handful of varieties have ever had their folate concentrations measured. Consequently, it is not clear how important a source of folate potato can be. We measured folate in diverse potato germplasm to determine how much folate concentrations vary. We developed a microbial assay to examine about 80 varieties grown in both eastern and western Washington. Folate concentrations ranged from 521 to 1659 ng/g dry weight (**Figure 1**), which is over a 3-fold difference between the lowest and the highest folate concentrations. Thus far, yellow fleshed potatoes were observed to have the highest amounts of folate when compared to all varieties measured at harvest. Among the highest folate containing yellow cultivars are Satina, Carola and Golden Sunburst, along with some of the advanced lines in Chuck Brown's (USDA-ARS, Prosser, WA) breeding program and in the Oregon program. From the mature white-fleshed varieties we examined, Ranger Russet and Winema had amongst the highest folate levels, about 25% less than the top yellow fleshed cultivars.

We also measured folate concentrations in six wild potato species. Variation was almost as large in this small selection of wild species as it was in the much larger cultivar pool tested. This suggests wild species may have higher natural variation of folate than domesticated cultivars. Among the most commonly grown white-fleshed cultivars, differences (~1.3-fold) were not as large as in diverse advanced breeding lines or the wild species. According to our results, a 175 g raw potato serving (~6 ounces) would provide from 4.5 to 14.5% of the American RDA (400 μg). The effect of cooking remains to be determined. Folate is expected to survive cooking, and is boiled as part of our assay. Some studies have suggested folate levels slightly increase after cooking.

Effect of cold storage on folate concentrations: After harvest, potatoes without sprout inhibitor treatment were placed in cold storage for 7 months (**Figure 2**). All but one of nine cultivars analyzed had higher folate concentrations after storage compared to the concentration at harvest. Cultivar Cranberry Red showed the biggest change, increasing from 825 ± 9 to 1473 ± 76 ng/g dry weight, an increase of 78.5%. Two cultivars (Banana and Carola) showed little or no difference. While Carola had the 2nd highest folate concentration in **Figure 1**, that concentration would only qualify as the sixth highest in **Figure 2**. Thus, unlike Vitamin C which decreases during cold storage, folate seems to increase or at least be stable.

Folate gene expression: Nobody yet knows as to why within a given plant species, one variety might have more or less folate than another. Any effort to develop potatoes with higher folate concentrations would be much easier if we understood the genetic basis of differing tuber folate levels and the key genes involved.

Of the numerous genes involved in folate metabolism, we selected four for characterization and measured mRNA expression levels of two folate synthesis genes, GTP cyclohydrolase I (GCHI) and aminodeoxychorismate synthase (ADCS), and two genes involved in "using up" folate, γ-glutamylhydrolases (GGHs). RNA was extracted from three high-folate tubers (Asterix, Cranberry, and Fabula after 7 months in cold storage; folate concentrations of 1582, 1473, and 1515 ng/g dry weight, respectively) and three lower folate tubers (Norkotah, Russet Burbank and Gem; 869, 804, and 759 ng/g dry weight, respectively). **Figure 3** showed that GCHI was expressed at the same level in all cultivars. ADCS expression was similar in all lower folate germplasm, but varied among "high folate" germplasm. Asterix had higher ADCS mRNA expression than all other cultivars. GGHs, especially GGH1, were more expressed in lower folate cultivars, suggesting that this enzyme may be one determinant of folate concentrations in potato cultivars.

Folate during tuber development: We have begun to look at folate concentrations during tuber development using tubers supplied by Rick Knowles. Tubers were dug up every few weeks from shortly after initiation until harvest. Our results suggest folate concentrations are substantially higher in "new potatoes" than they are at harvest (**Figure 4**). Defender was found to have about twice as much folate early in the season as it did at harvest. Additional varieties will be examined and if these results are true for other varieties, then this could be important information for the "new potato" fresh market. If this trend holds for other varieties beyond the three tested so far, then "new potatoes" should contain much higher folate concentrations than shown in the mature tubers of **Figure 1.**

Potato Phytonutrients

What are some of the non-vitamin health-promoting compounds in potato? One group we are studying is the phenolic compounds, of which thousands of different types exist in plants. Phenolic compounds have numerous health promoting effects. Some are antioxidants; others appear to decrease the risk of specific diseases. Many of the health claims one might have heard about foods, including apples, tea, wine and chocolate are at least in part due to phenolic compounds.

We think phenolic compounds are amongst the phytonutrients with the most potential for enhancement in potato. Our work shows that some varieties and species have very high amounts of phenolics. We have further refined our ability to rapidly analyze tuber phenolics and have identified over 70 different compounds. Flavonoids continue to look promising in potato and we have identified over 7 different flavonoids and are finding over a 30-fold difference amongst different varieties. Currently, potatoes are not regarded as a significant source of flavonoids in the diet, but our data suggests potato has promise as a source of flavonoids. Glycoalkaloids are also of renewed scientific interest as some may have anti-cancer properties and others anti-pathogen/anti-pest properties. We have developed methods to analyze glycoalkaloids in tubers and have identified in wild species numerous potato glycoalkaloids in addition to solanine and chaconine. Besides possible nutritional benefits we are also exploring whether novel glycoalkaloids are involved in wireworm resistance and late blight resistance.

High phenolic potatoes in particular could be a substantial source of phenolics in the diet and compare very favorably to other vegetables. Many phenolics are colorless, so white-fleshed potatoes can have high amounts. Norkotah has high amounts among the white fleshed cultivars, about 4 mg/gram dry weight. *S. Pinnatisectum*, a white fleshed wild species has over 5 mg/gram dry weight total phenolics. The potatoes with the highest total phenolics we have yet found are a purple- fleshed advanced line from Prosser (PORO1PG22-1) and a red-fleshed advanced line from Colorado (CO97226-2R/R), both of which have over 6.5 mg/gram dry weight total phenolics and are the two highest varieties shown in **Figure 5**. We think it is likely that cultivars exist with even higher total phenolics and are screening more varieties.

Phenolics in New Potatoes: Similar to what we found with folates, we found higher levels of phenolic compounds were present in new potatoes from Defender, Umatilla and Burbank than from the same cultivars at fall harvest. For example, Umatilla had ~80% higher total phenolics at the new potato stage and some compounds were present in well over two-fold higher concentrations. We want to confirm and extend upon these findings using new potatoes from other varieties and we will identify which specific compounds change in concentration based on tuber size. If we are able to confirm that new potatoes from numerous varieties follow these same patterns, then this suggests that "new potatoes" may be especially rich in some vitamins and phytonutrients and this could be especially appealing to health conscious consumers.

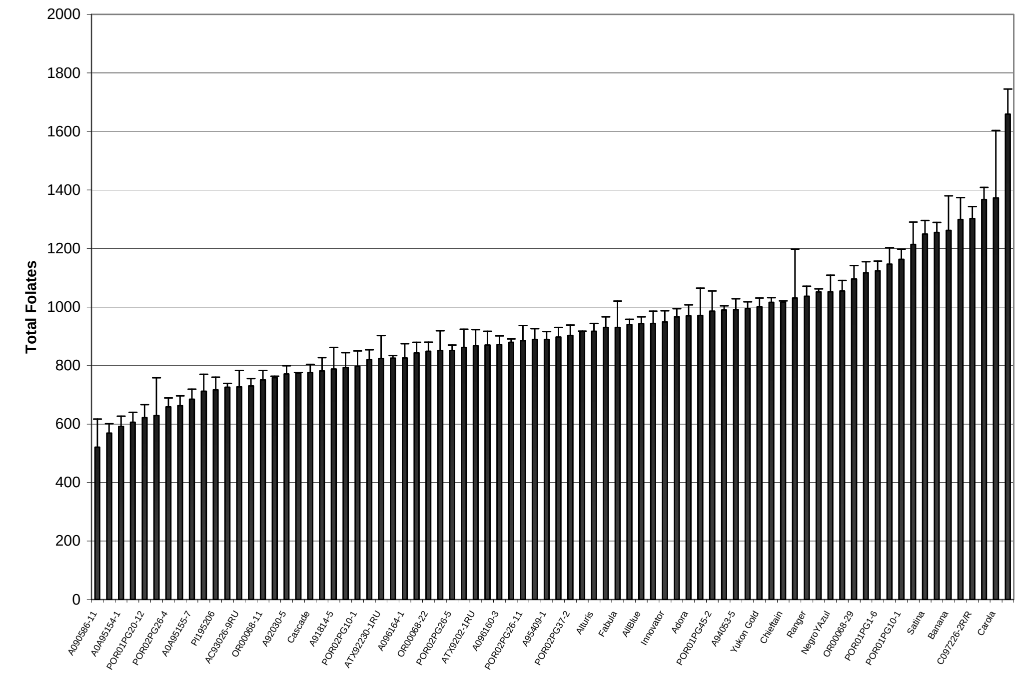

Figure 1. Total folates (ng/gram DW) in ~80 potato varieties. Standard error is shown.

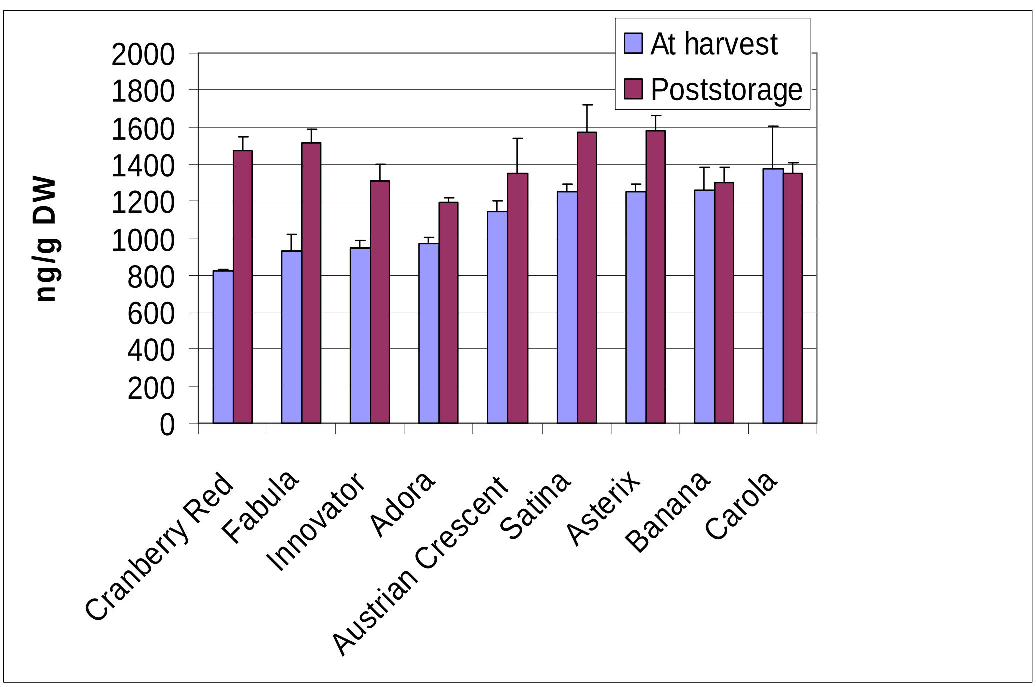

Figure 2. Comparison of folate levels in 9 cultivars at harvest or 7 months after harvest.

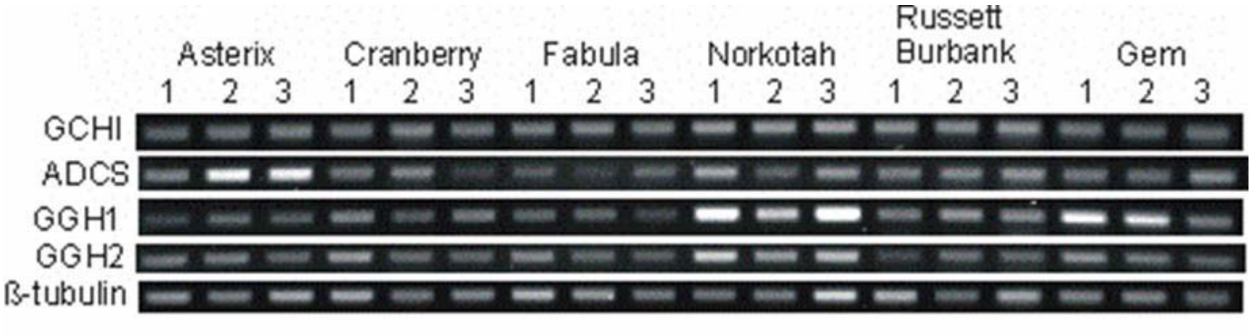

Figure 3. Analysis of four genes involved in folate metabolism in 6 cultivars. GGH1 decreases the stability of folate in plants and appears to be expressed at a higher level in genotypes with lower amounts of folate.

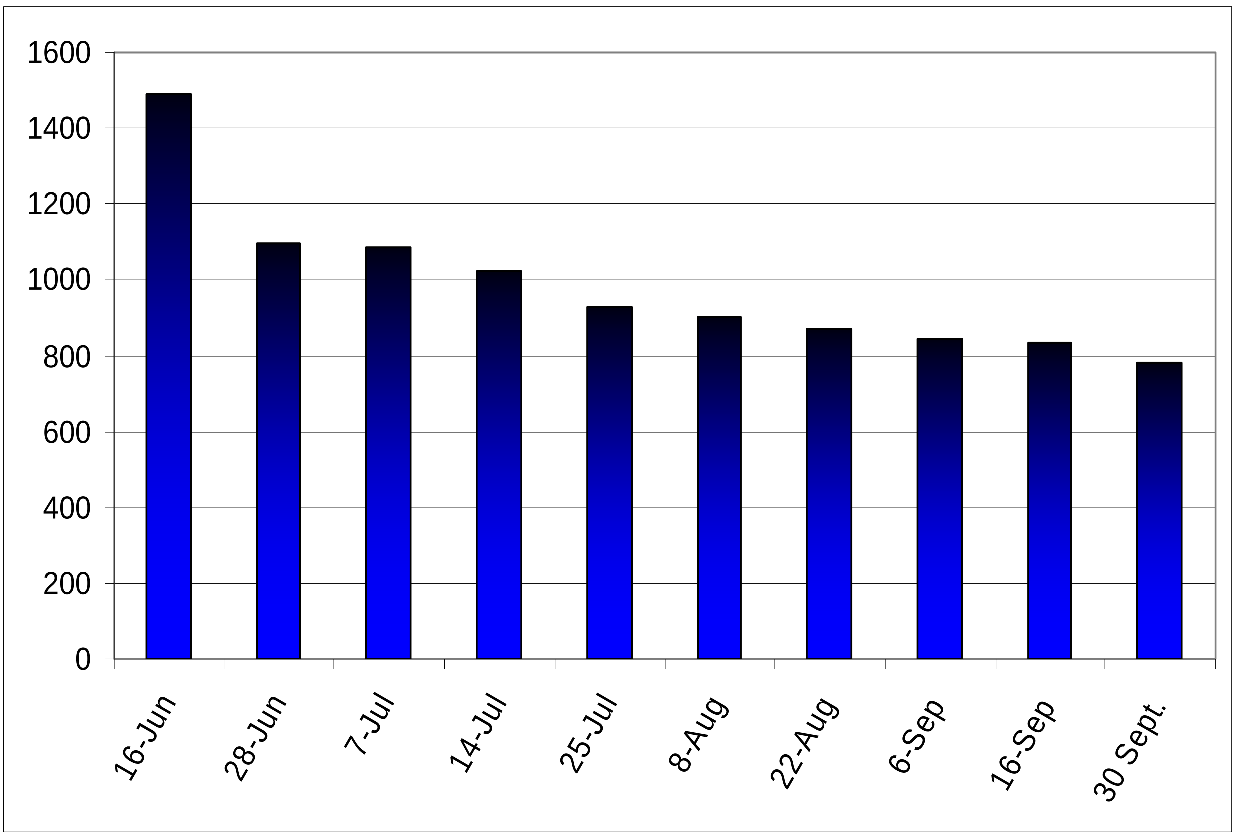

Figure 4. Folate levels in field grown Defender tubers, harvested at the indicated time points.

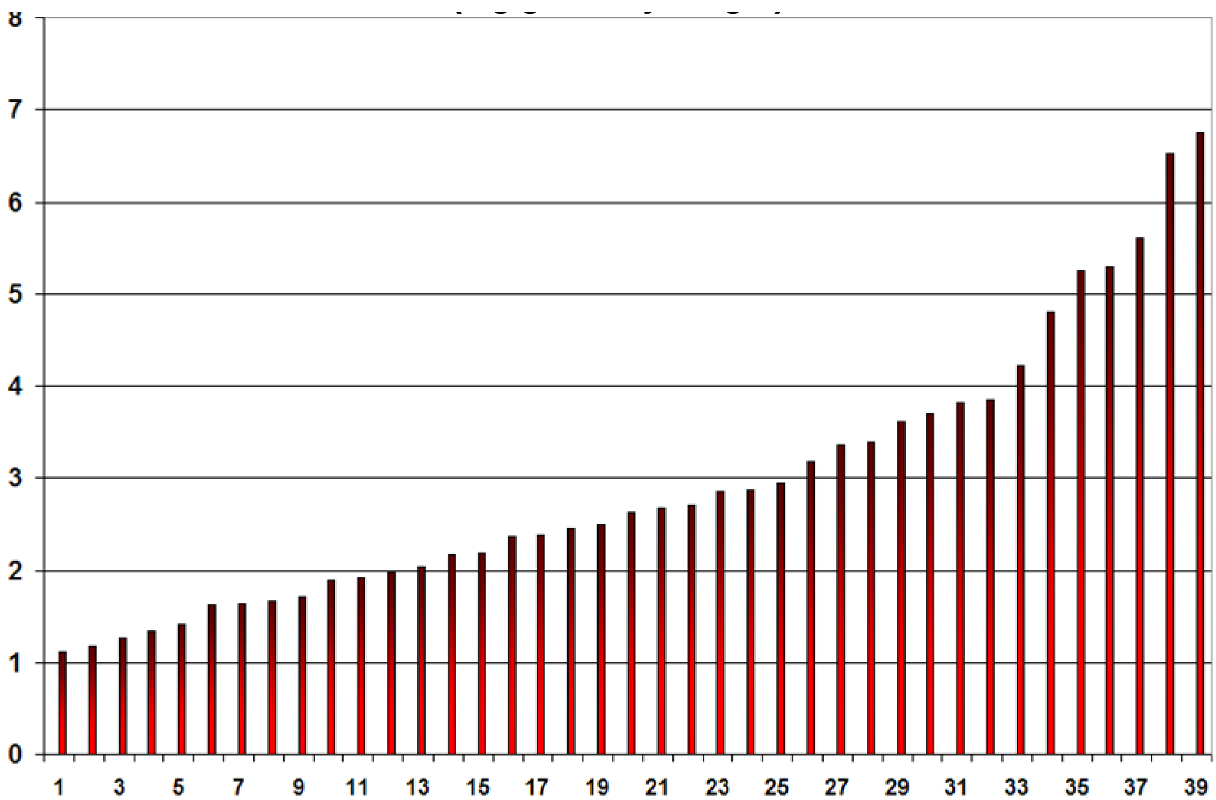

Figure 5. Total phenolics (mg/g DW) in 39 potato varieties. The range is substantial amongst the varieties.