Nutrient Status of Potato: Assesssment of Future Trends

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The potato is well-known to the U.S. population and is a frequently eaten item in the diet. The majority of people are familiar with its carbohydrate content, but other components of potato are not commonly recognized. As a result, certain misconceptions exist identifying the potato as a non-nutritive starchy food. However, potato should be considered to be rich in many different constituents that have important health benefits. This paper seeks to dispel gaps in knowledge of the nutrient composition of potato. In addition, it will discuss current research that offers the chance to breed even more phytonutrient-rich varieties in the future.

Potatoes originated in the Andes of South America. They were introduced by Spanish conquerors to Europe in about 1570. For at least a century potato was little more than a curiosity in botanical gardens. However, by the 1700s it had become an important part of the diet in certain countries. One of the reasons for broad adoption certainly is the productivity of potato. Table 1 presents productivity figures for major crops of the world. Potato is only surpassed by sweet potato in dry matter and calorie production per day. In protein production only cabbage and wheat produce more per day. The conclusion that must be drawn from this is that the potato is among the top crops in its ability to produce in a given area of cultivation. This is not hard for Washingtonians to believe, because this state has the highest yields in the world. Some farms produce yields right at the theoretical maximum for potato.

Table 1. Productivity of major world crops in terms of dry matter, megacalories (Mcal), and protein per hectare per day.

Crop	Dry Matter Kg/ha/ day	Energy Mcal/ha/ day	Protein Kg/ha/ day
Cabbages	12	29	1.6
Tomatoes	8	25	1.3
<u>Potatoes</u>	<u>18</u>	<u>54</u>	<u>1.5</u>
Yams	14	47	1.0
Sweet Potatoes	22	70	1.0
Wheat	14	40	1.6
Rice	18	49	0.9

Potato is a good source of vitamins and minerals. Potatoes are best known as a source of vitamin C. A good way of measuring the content of these substances is by referring to the Recommended Daily Allowance (RDA). A 1/3 pound portion of potato supplies 50% of RDA for vitamin C. The RDA of vitamin C is 60 mg for an adult. One of the popular new varieties, Ranger Russet has 29 mg per 100 g fresh weight (FW). If this variety is used as basis of measure than 1/3 pound would supply two-thirds of the RDA (Figure1). Potato is also a good source of vitamin B6 and calcium and is a very rich source of potassium, supplying 400 to 550 mg per 100 g FW (there is no RDA established for potassium).

It is very instructive, for instance, to look at the nutrient composition of different potato products in the USDA Nutrient Database (http://www.nal.usda.gov/fnic/foodcomp/cgi-bin/nut_search_new.pl). The reader will note that potatoes are classified as red skinned white skinned, or russet. The diversity of level of nutrients over many different varieties is largely unexplored. This knowledge gap necessitates that researchers and industry partners interested in a true assessment aggressively carry out their own analyses over a range of genotypes. Nutrient content has rarely been used to market a variety. An exception is the variety "Butte," developed by USDA/ARS, Aberdeen, Idaho (Pavek et al., 1976). Although "Butte" is not grown in mainstream potato production, it has survived as a variety for home gardeners, and is advertised in a number of seed catalogs as a high protein potato. Protein contents in "Butte" and "Russet Burbank" are 7.8 and 6.5 % of dry matter, respectively.

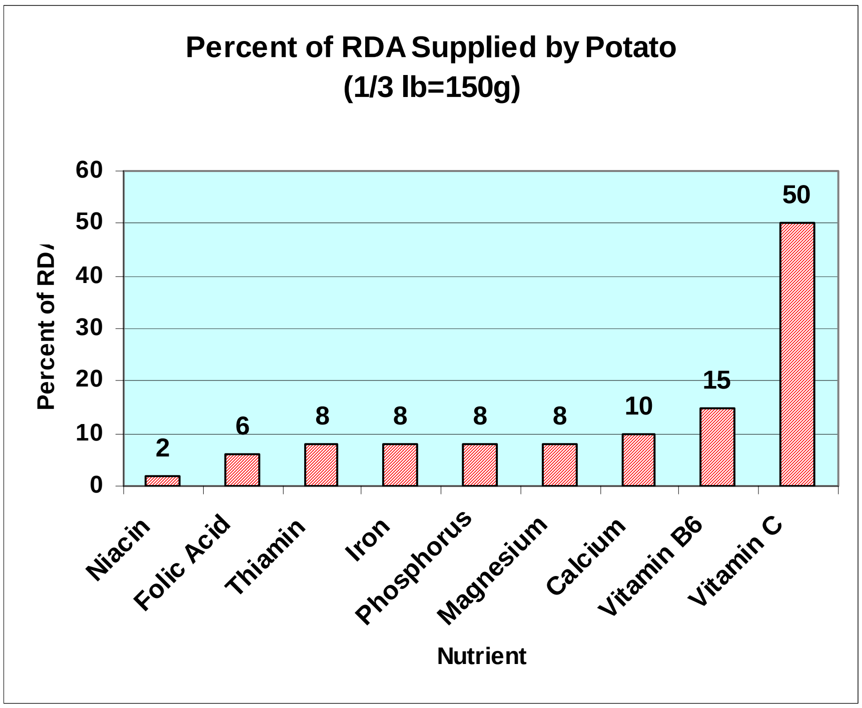

Figure 1. Percent of Recommended Daily Allowance (RDA) of vitamins and minerals supplied by 1/3 pound (150 grams) of potato.

Vitamin C

The potato is a good source of vitamin C. In general potato has 15 to 20 mg per 100 g FW of vitamin C. However, there is considerable variation in content due to genetic differences among varieties. The cultivar "Ranger Russet" has one of the highest levels at 29 mg for a widely grown new cultivar. Studies in the U.S. and Europe have shown variation between 11 and 30 mg per 100 g FW in North American varieties and breeding lines (Love et al. , 2002) and 18 to 36 mg in six European varieties and 27 breeding lines (Dale et al., 2003), respectively. Dale et al. (2003) also documented the large reduction in vitamin C content that occurs during storage, averaging 45%. Recent reports of genetic variability report a high heritability for vitamin C content, $h^2 = 0.96$, and an upper value of 40 mg in the range of values (Pavek and Corsini 2003).

The high heritability means that it should be relatively easy to select high vitamin C parents in a breeding program and produce high vitamin C progeny. Relatively little is known of the contribution of vitamin C in potato to antioxidant value. However, one study (Chu et al. 2002) has estimated that vitamin C extracted from an unidentified potato obtained from a grocery store contributes 13.3 % of the total antioxidant activity. Although a modest value, higher vitamin C concentrations available in breeding materials might contribute to an overall higher total antioxidant value. The RDA of vitamin C is 60 mg for an adult, indicating that a 100 gram portion of the highest level of vitamin C known in potato could possibly provide 2/3 of the RDA. Iron availability in foods is often inhibited by certain compounds present in small grains or food legumes. The vitamin C in potato enhances iron absorption. Diets designed for high iron availability often have potato as one of the components.

The collections of Andean varieties of potato at the International Potato Center contain many representatives with red and purple anthocyanins in the flesh. The research effort at USDA/ARS Prosser, WA has developed new genotypes with high levels of these pigments in the tuber flesh that are adapted to the Northwest climate and day length regime. An important attribute of these pigments is that they are potent antioxidants in the diet (Brown et al., 2003). Antioxidants are measured by a variety of methods, but one of the most widely used is the Oxygen Radical Absorbance Capacity (ORAC). A summary of analyses of red and purple flesh potatoes is presented in Table 2.

It is evident that anthocyanin in the flesh ranges from 17 to almost 40 mg per 100 g FW. White flesh varieties have no anthocyanin. However, white flesh varieties have substantial antioxidant activity by themselves ranging from 93 to 138 mg Trolox equivalents per 100g FW. Nonetheless the anthocyanin-rich potatoes have from two to three and half times greater ORAC values (Brown et al., 2004). Diets rich in anthocyanins or related phenolic compounds have been associated with a reduced incidence and severity of certain kinds of cancer and heart disease (Hertog et al. 1993).

Table 2. Total anthocyanins in purple and red flesh breeding lines.

Breeding lines	Skin/Tuber flesh Type/1	Total Anthocyanins mg / 100 g FW	Anthocyanin ORAC mg / 100 g/2
Purple skin / Purple flesh			
PA97B29-2	P/P	17.0	200
PA97B29-4	P/P	20.1	233
PA97B29-6	P/P	17.3	210
Red skin / red flesh			
NDOP5847-1	R/R	37.8	355
PA97B35-1	R/R	24.3	275
PA97B36-3	R/R	15.0	213
PA97B37-7	R/R	31.5	353
PA99P9-2	R/R	26.9	303
PA99P9-4	R/R	24.5	198
PA99P10-2	R/R	27.2	288
PA99P20-1	R/R	20.8	260
PA99P20-2	R/R	26.8	245
PA99P32-5	R/R	23.8	213
POR00PG1-4	R/R	35.1	255
POR00PG2-1	R/R	22.2	238
POR00PG2-7	R/R	28.1	290
POR00PG2-11	R/R	29.6	275
POR00PG2-16	R/R	24.3	290
POR00PG3-1	R/R	19.8	255
Norkotah Russet	R/R	0	93
Ranger Russet	White	0	105
Russet Burbank	White	0	138

\1Key to skin and tuber flesh types: R = red, P = purple.
\2Anthocyanin ORAC = trolox equivalents

Taking a cue once again from the unusual attributes of certain Andean cultivars, another class of pigment that can be at high levels in potatoes is the carotenoids. Carotenoids are especially interesting from the standpoint of eye health. The two carotenoids most abundant in the retina of the eye, lutein and zeaxanthin, are also present in the flesh of intensely yellow potato cultivars. Yellow flesh varieties have always existed outside of the Andes (Only the US, Canada, Great Britain, Egypt, and Uruguay prefer white flesh varieties). In South America, a type of potato, with very high value in the market, called Yellow Potato (*Papa Amarilla*) have much higher levels of carotenoids than potatoes in the rest of world.

Table 3 shows the levels of carotenoids in a number of yellow flesh, dark yellow flesh (Yellow Potato) and white varieties. As a general rule white flesh varieties have 50 to 100 micrograms per 100 g FW, light yellow flesh varieties 100 to 250 micrograms, and dark yellow types 500 to 800 micrograms of total carotenoid (Table 3) (Brown et al., 2004). There are no dark yellow flesh varieties commercially available yet in North America, but advanced materials are in trials. Diets rich in carotenoids have been implicated in the reduced incidence and severity of macular degeneration and cataracts in the elderly population (Olmedilla et al., 2001).

Table 3. Total carotenoid and respective ORAC values of light yellow, dark yellow, and white flesh breeding lines and cultivars.

Variety of Breeding line	Skin/Flesh Type[\1]	Total Carotenoid μg / 100 g FW	Carotenoid ORAC μg / 100 g FW[\3]
Yellow flesh cultivars breeding lines			
Adora	W/Y	227	3.8
Divina	W/Y	271	2.6
Fabula	W/Y	179	4.6
Ilona	W/Y	176	4.6
Morning Gold	W/Y	101	2.6
Provento	W/Y	191	4.1
Satina	W/Y	248	4.3
Yukon Gold	W/Y	194	2.3
POR00PG4-2	W/Y	250	2.8
Dark Yellow flesh breeding lines			
91E22	W/DY	795	6.6
PA99P11-2[4/]	PR/DY	509	6.0
PA99P1-2[4/]	PR/DY	525	5.0
PA99P2-1[4/]	PR/DY	738	6.0
POR00PG4-1	W/DY	634	5.1
White flesh cultivars			
Norkotah	RT/W	40	3.9
Ranger	RT/W	71	4.2
Burbank	RT/W	58	3.7
A8893-1	RT/W	56	3.2
A9014-2	RT/W	55	2.4
A90586-11	RT/W	99	2.0
A9045-7	RT/W	64	2.6
A90490-1	RT/W	101	2.8
A91790-13	RT/W	75	2.7
A92030-5	RT/W	54	3.2
A93157-6LS	RT/W	66	2.5

[\1]Key to skin and tuber flesh types: R = red, PR = partially red, Y = yellow, DY = dark yellow, RT = russeted skin, W = white (unpigmented) [\3]Carotenoid ORAC = α-tocopherol equivalents.

Future Varieties

At present the potato is a good source of vitamin C, vitamin B6, potassium, calcium, magnesium, and thiamin. White flesh potatoes contain the carotenoid lutein that is an important constituent of the human retina. Dark yellow flesh varieties possess two to three times higher levels of carotenoids than yellow flesh potato. Yellow flesh potatoes are relatively new to the American consumer, but one variety, “Yukon Gold,” has been expanding rapidly and recently the seed production reached 5,000 acres. Potatoes with solidly pigmented flesh are still uncommon to the consumer. The red and purple flesh cultivars, “All Red” and “All Blue,” are occasional items in the grocery store. It is technically possible to produce potatoes with much higher levels of vitamin C, carotenoids, and anthocyanins. It has been estimated that at present vitamin C accounts for 13% of the total antioxidant potential of white flesh potato. Breeders can certainly double the average level of vitamin C from 20 to 40 mg thereby increasing antioxidant capacity due to this vitamin, as well as providing the other benefits attributed to this vitamin

The adoption of dark yellow flesh varieties could increase the amount of carotenoid available by as much as eight-fold over white flesh potato and the antioxidant potential due to carotenoid can be increased by three to four times. Yellow flesh is probably the easiest change in visual impact of potato for the American consumer in that it is not radically different from white flesh. Anthocyanin pigmentation in the flesh will definitely require some promotional education to help consumers make the transition. Since the potato most familiar to the American consumer is not red or purple, people will need to be educated that these colors are produced by completely natural compounds present in many foods that are beneficial. Anthocyanins are potent antioxidants that nutritionists advocate including in liberal amounts in the healthy diet. At present the American population consumes almost no anthocyanin in the potatoes in their diet. The option of increasing this is certainly available. A recent book “The Color Code: a Revolutionary Eating Plan for Optimal Health,” (Joseph et al., 2002) recommends choosing a diet on the basis of colors to achieve a high antioxidant status, and balanced diet neither too high or low in calories. Red, purple, and yellow flesh potatoes are included in the recommendations in this book.

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