Breeding Potato with High Carotenoid Content.

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Introduction

Potato contains a number of important nutrients. It is a source of high quality protein, vitamin C, and niacin. Less well known are athe classes of pigments. This may be the case as we in North America have long used only white flesh varieties. Skin types are usually cream or tan, russeted, with a few red-skinned varieties and rarely a purple skinned type.

Antioxidants in Human Health

It is not widely known that potatoes contain carotenoids. White flesh potatoes as well as yellow, dark yellow and orange flesh potatoes contain substantial amounts of xanthophylls (a kind of carotenoid that is not a precursor to vitamin A). White, yellow and orange flesh potatoes have lutein and zeaxanthin. Epidemiological studies have shown that populations with a high consumption of these and other carotenoids in yellow-orange fruit and dark green leafy vegetables have lower rates of various cancers, including those of the mouth, pharynx, larynx, esophagus, lung, stomach, cervix, and bladder (Ziegler, 1991; Block, G. 1992). Although some of the carotenoids in foods is destroyed by cooking, lutein is one that is most stable to heat. Lutein is more available from cooked than raw foods (Micozzi, M. S. et al., 1992; Micozzi et al., 1990).

The predominant carotenoids in potato flesh, lutein and zeaxanthin, are those found in abundance in the human retina. These compounds are thought to protect photreceptor cells from light generated oxygen radicals, playing a key role in preventing advanced macular degeneration (Schalch, 1992). High levels of lutein in the serum are also correlated with reduced lung cancer. (Khackik, et al. 1995).

Since we are unaware as a general public that potato can supply these compounds in the diet, it is worth examining the results of analyses. Carotenoids are lipid soluble compounds. Their non-polar structures suggests that they are likely to be associated with membranes in cells. Studies of lycopene, a carotenoid present in high concentrations in tomato, for instance, indicate that ingested of lycopene stays in the body for days as indicated by studies of blood serum (www.lycopene.com). Hence, unlike the highly water soluble anthocyanins and phenolics in general, which are passed through the body and excreted in urine in a matter of hours, carotenoids are long-term antioxidant residents in the body.

The carotenoids of potato are primarily lutein and zeaxanthin, but others may occur. However all of these xanthophylls, which unlike beta-carotene, are not vitamin A precursors, bur they are significant antioxidants. They must be extracted using organic solvents like chloroform. We have extracted carotenoids from potato and determined the concentration and antioxidant potential as measured by the Oxygen Radical Absorbance Capacity (ORAC).

Results

In table 1 are shown the total carotenoid contents and ORAC values of the lipid extraction fraction of standard varieties and advanced numbered breeding lines. Total carotenoid content ranges from about 50 to 100 micrograms per 100 grams fresh weight (gFW), while ORAC ranges from 1.9 to 4.2 micrograms tocopherol equivalents per 100 gFW. The carotenoid levels and ORAC values of clones which look yellow, very yellow or orange are shown in table 2. By appearance alone these clones are obviously pigmented, and their values start where the white fleshed genotypes left off. Total carotenoid ranges from 100 to nearly 900 micrograms per 100 gFW. The ORAC values vary from 2.4 to 6.6 micrograms tocopherol equivalents per 100 gFW, a three-fold range. Clones with codes beginning with PA or POR are products of athe USDA/ARS breeding program. It is apparent that the breeding program is leading the way to higher carotenoid levels while the presently commercially available named varieties are limited to the lower third of the total range. This data is presented graphically in figure 1 depicting the regression relationship between total carotenoid content and ORAC. Although the correlation is statistically significant, the $R^2 = 0.57$ suggests that more than 40 % of the variation in ORAC is not explained by covariation with total carotenoid content. Total carotenoid content is a predictor of antioxidant potential, but it is likely that other compounds not accounted for by the total carotenoid content, i.e., lipid soluble components that are, perhaps, not carotenoids may influence antioxidant potential. Brown and coworkers showed that total xanthophylls content in orange flesh potatoes was four to five times that of white flesh potato (Brown et al., 1993)

Evidence has emerged that indicates that already extant varieties in the Andes have even higher total carotenoid contents. The cultivar "*Yema de Huevo*" (Egg Yolk) was measured at 1683 while genotype "703280" possessed 2020 micrograms per 100 gFW. These native cultivars of the Peruvian Andes are like *in planta* bioreactors for xanthophyll synthesis.

Summary

In summary, it is apparent that traditional breeding can lead to large increases in carotenoid content. Our white flesh and commercially available yellow flesh are at the bottom of the known range of total carotenoid content. Increasing the carotenoid levels will affect the appearance of potato flesh and substantially increase the value of these potatoes as a high antioxidant food. New market niches and means of promoting products will emerge with these high carotenoid "functional food" type of potatoes.

Table 1. Total carotenoid content and ORAC of white fleshed varieties and advanced clones.

	Average of two sample reps:	
Sample ID	Carotenoid content (ug/100 gfw)	lipid ORAC, ug/100gfw (tocopherol equiv)
A92030-5	53.4	3.2
A9014-2	54.4	2.4
A8893-1	56.4	3.2
R. Burbank.	57.6	3.7
A9045-7	63.6	2.6
A93157-6LS	65.1	2.5
A9304-3	70.6	3.6
Ranger R.	71.0	4.2
A91790-13	74.4	2.7
A90586-11	98.7	1.9
A90490-1	100.5	2.8

Table 2. Total carotenoid content and ORAC of lipid soluble fraction from yellow, very yellow and orange flesh colors.

Sample ID	Carotenoid content (ug/100 gfw)	lipid ORAC, ug/100gfw (tocopherol equiv)	Flesh color[1]
MORNING GOLD	100.8	2.6	Y
ILONA	175.5	4.6	Y
FABULA	178.5	4.6	Y
YUKON GOLD	187.1	2.4	Y
PROVENTO	190.3	4.1	Y
ADORA	226.8	3.8	Y
SATINA	247.5	4.2	Y
POR00PG4-2	249.4	2.8	VY
DIVINA	271.1	5.1	VY
PA99P35-1	405.5	4.6	VY
PA99P35-2	421.1	4.2	VY
PA99P11-2	508.9	6.0	VY
PA99P1-2	525.1	5.0	VY

POR00PG4-1	633.8	5.1	VY
PA99P2-1	737.5	5.9	VY
91E22 (OR4)	795.2	6.6	OR
PA99P1-1	859.9	5.2	OR

[1]Flesh color: Y=yellow, VY=very yellow, and OR=orange

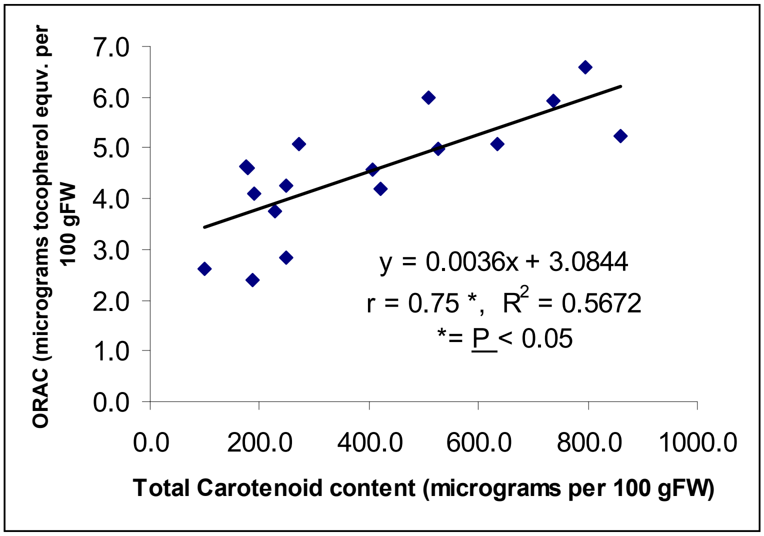

Figure 1. Relationship between total carotenoid content and ORAC of the lipid soluble fraction of potatoes ranging in flesh color ranging from yellow to orange. Approximately 0.3 gram of carotenoid from these potatoes provides 1 microgram tocopherol equivalent of antioxidant activity.

References:

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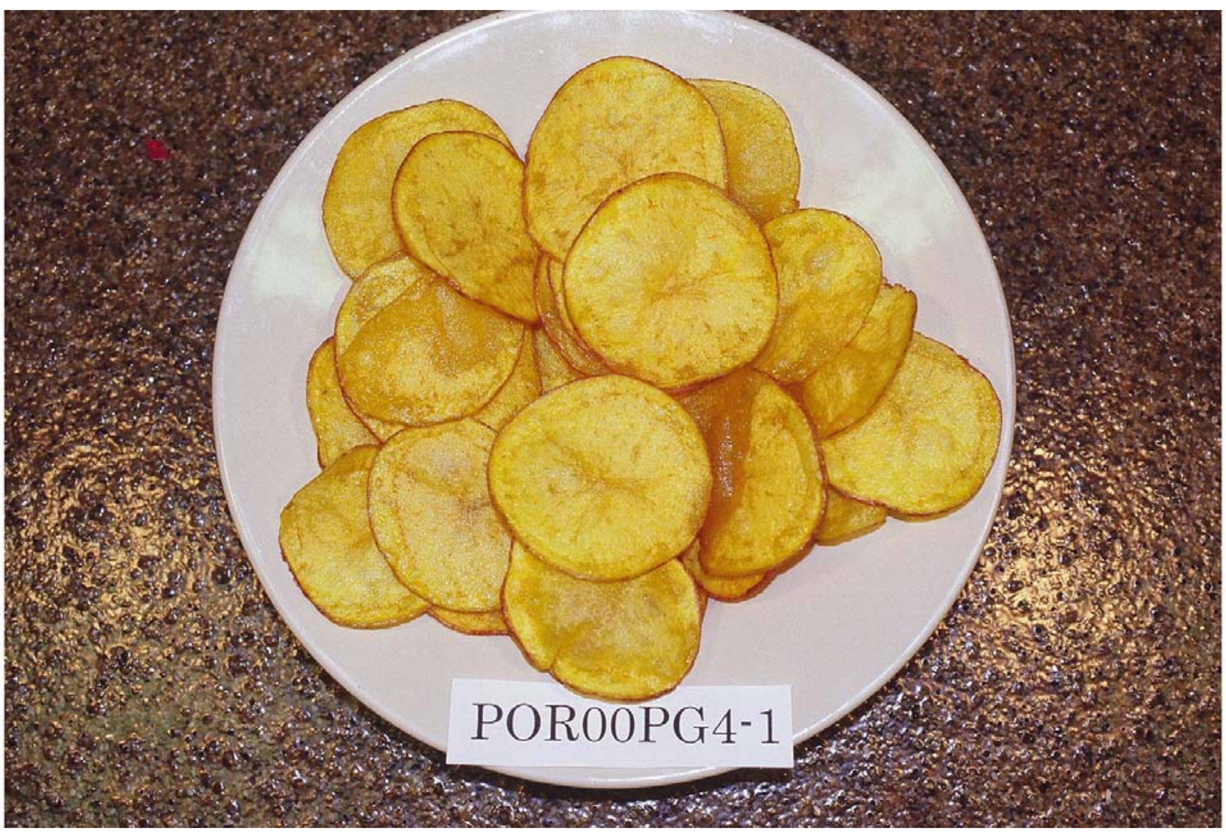
Yellow flesh potato in raw form rich in carotenoids



Potato chips made from clone seen in raw sliced form above