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Sugars Influence Potato Phytonutrients

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Potato Phytonutrients

Our group is researching how the nutritional content of potatoes is affected by genetics and environment. Potato cultivars with optimal amounts of phytonutrients are important in this era where more emphasis is being placed on the healthfulness of foods than ever before. Negative comments from some nutritionists impact consumption by negatively affecting consumers' perception of potatoes. Some consumers believe potatoes only contribute "empty calories" to their diet and are unaware of the potassium, vitamin C, polyphenols and other nutrients provided by potatoes. In reality, potatoes are affordable, with a recent study showing potatoes, along with beans, provide the most nutrients per dollar out of over 90 foods studied.

Those who follow the mainstream media or scientific literature will be aware of the ongoing vigorous debate about healthy vs unhealthy foods, the causes of the obesity epidemic and what steps should be taken to promote a healthy diet. Various recent popular press articles discussed an ongoing "sea change" in fast food consumption and suggested that increasing numbers of younger customers are "attracted to the better-for-you" offerings. In this context, nutrition research and outreach programs that educate consumers about the nutritional content of potatoes are essential. Research supporting the healthfulness of potatoes can provide data that positively influence both the public and health-professionals, and ensure potatoes remain a nutrient-dense food with a key role in providing global food security in the coming years.

New cultivars with superior traits vital for production, profitability, and processing are being developed in the Pacific Northwest's Tri-State Breeding Program. At the same time it is critical that future cultivars preserve and maximize the nutritional content of potatoes. One limitation for developing higher-phytonutrient potatoes is the lack of knowledge about the biological mechanisms that control the amounts present in a given cultivar. Scientists do not yet fully understand why some potatoes have more phytonutrients than others. Understanding what controls tuber phytonutrient content would make it easier to further increase amounts in new cultivars and shed light on the best ways to manage the crop for optimal phytonutrient content.

What are phenolics and why are they important?

Phenolics are a diverse group of compounds, many of which are antioxidants. There are thousands of different phenolics in plants, and the ones present in potatoes include the polyphenol chlorogenic acid, and anthocyanins, which are the pigments responsible for red, purple, and blue coloration in specialty potato skins and flesh. Extensive literature demonstrates phenolics reduce the risk of various diseases, promote cardiovascular health, mental acuity, and reduce inflammation. Besides their role in human nutrition and potato appearance, these compounds influence flavor, plus have multiple roles in potatoes including increased disease resistance and abiotic stress tolerance. As described in this article, we found a relationship between tuber sugars and phytonutrients called phenolics.

Sugars

Most consumers probably know potatoes contain carbohydrates, but don't know much about the type of carbohydrates provided. Potatoes contain primarily complex carbohydrates (starch), but relatively small amounts of simple sugars like fructose and glucose (monosaccharides) and sucrose (disaccharide). Complex carbohydrates are important in the diet. The World Health Organization recommends that 50-75% of total daily calories should come from complex carbs. Apart from their role in human nutrition, what about the role of sugars in plants? Our research found sugars influence the amount of potato antioxidants and phenolics. If potato plants grown in tissue culture are provided extra sugar for growth, leaves turn red (**Figure 1**) due to increased anthocyanins, the pigments responsible for red skin color. These plantlets produce increased amounts of many additional phenylpropanoids besides anthocyanins, including chlorogenic acid, the major polyphenol in potatoes (**Figure 2**). Besides its various health-promoting effects, the antioxidant chlorogenic acid is thought to slow the intestinal uptake of glucose and to mask bitter tastes.

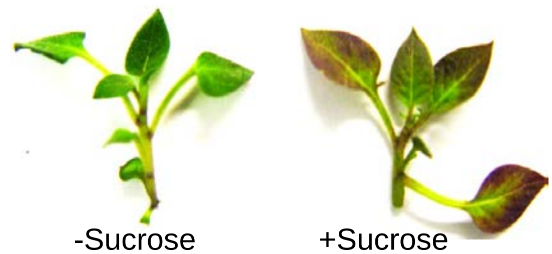


Fig. 1 Potato plants grown in tissue culture in the presence or absence of sucrose

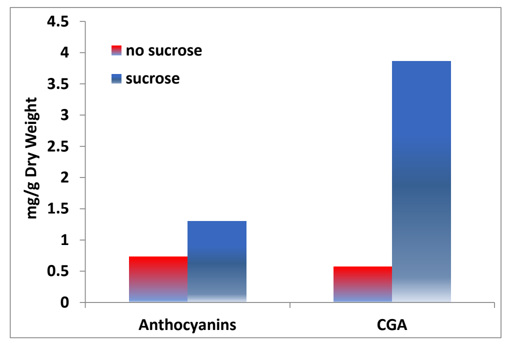


Fig. 2 Increase in anthocyanins and chlorogenic acid (CGA) in plants fed sucrose.

Sugar levels in the field

These data show sugars influence phenylpropanoid concentrations in lab grown plants, but don't show whether sugars influence phytonutrient concentrations in the field. This is an important question because potatoes can behave differently in the lab versus field. Immature potatoes (baby potatoes) harvested 60-80 days after planting have higher amounts of many phytonutrients than at maturity. At 72 days after planting, when phytonutrient levels of compounds like chlorogenic acid were highest, sucrose levels were also highest (**Figure 3**). Moreover, amounts of both decreased as tubers matured.

In a separate study, the amount of total phenolics and sugars in mature and immature tubers from five breeding lines and one cultivar was measured. All but one of the genotypes had higher amounts of total phenolics in baby potatoes. The percent change in immature tubers is shown in **Figure 4**. Likewise, four of the five genotypes with higher phenolics also had higher sugars. For example,

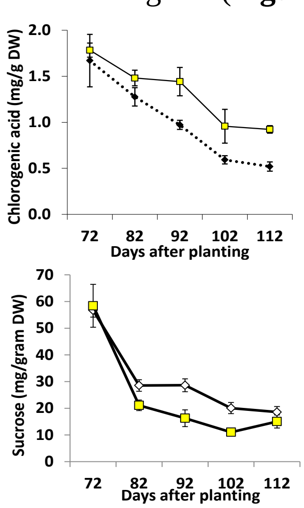


Fig. 3. Potatoes from a yellow and white cultivar were harvested at the days indicated after planting and chlorogenic acid (top) and sucrose (bottom) concentrations were measured.

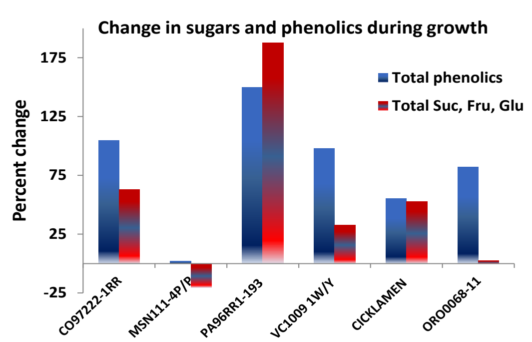


Fig. 4. The percent change is shown in potatoes harvested either early or late in the season from the same cultivars.

phenolics in immature PA96RR1 potatoes compared to mature potatoes were over 125% higher and sugars over 175% higher. Only MSN111 didn't have an appreciable increase in phenolics in its immature tubers, and interestingly this genotype actually had lower sugars in its immature than mature tubers.

Potatoes with red- or purple-flesh had higher amounts of total phenolics, and as shown in **Figure 5**, higher amounts of sugars. The yellow-flesh potatoes measured in this study had higher amounts of phenolics than white potatoes, and also higher sugars, so this is also consistent with a role for sugars in influencing tuber phenolic amounts.

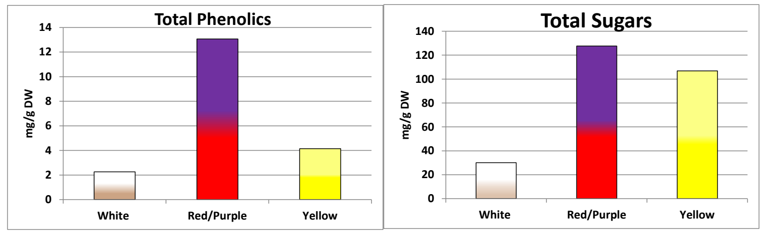


Fig. 5. Total phenolics and total sugars (sucrose, fructose and glucose) were measured in different white (n=48), red or purple flesh (n=7) or yellow flesh (n=9) potatoes.

To assess the relationship between sugars and phenolic amounts in the field, amounts were measured in over 100 different potato samples representing different genotypes, developmental stages, and locations. Total phenolic content ranged from 1.6 to 17.0 mg/g dry wt and sucrose from 4.7 to 132 mg/g dry wt. Overall, a modest positive correlation was seen between sucrose and phenolic concentrations. Environment is known to influence phenolics. When the same cultivar was grown in Idaho, North Dakota, or Washington, the phenolic concentrations varied between locations, and sucrose was highest in the potatoes with higher phenolics (**Table 1**).

zebra chip disease causes major changes in potato metabolism, including sugars and phenolics. Compared to healthy tubers of the same cultivars, tubers infected with zebra chip disease had higher amounts of phenolics, and also higher amounts of sucrose (**Table 2**).

Table 1. Total phenolics and sugar composition in tubers grown in different locations

Cultivar	Location	Total phenolics	Glucose	Fructose	Sucrose
		mg/g dry weight			
Ranger Russet	Caldwell	2.26 ± 0.17	7.77 ± 0.57	2.86 ± 0.64	27.35 ± 1.05
Ranger Russet	Othello	2.54 ± 0.21	7.11 ± 1.13	3.37 ± 0.72	32.25 ± 1.06
Ranger Russet	North Dakota	2.84 ± 0.11	6.11 ± 1.13	1.37 ± 0.72	38.25 ± 1.06
Russet Burbank	Caldwell	2.59 ± 0.31	4.72 ± 0.17	1.20 ± 0.30	21.25 ± 0.80
Russet Burbank	Othello	2.75 ± 0.38	6.94 ± 0.53	2.73 ± 0.47	26.15 ± 0.99
Russet Burbank	North Dakota	2.94 ± 0.26	3.33 ± 0.47	0.93 ± 0.20	41.39 ± 0.94

Table 2. Phenolics and sugars in potatoes with or without Zebra chip disease

Status	Total phenolics	Glucose	Fructose	Sucrose
		mg/g DW		
Healthy	1.79 ± 0.17	3.20 ± 0.16	2.10 ± 0.32	8.00 ± 0.92
Healthy	1.70 ± 0.05	3.00 ± 0.20	1.80 ± 0.22	10.21 ± 0.85
Healthy	1.62 ± 0.08	2.60 ± 0.12	1.32 ± 0.18	14.10 ± 0.62
Zebra Chip Infected	4.66 ± 0.20	4.95 ± 0.24	3.56 ± 0.41	38.56 ± 1.02
Zebra Chip Infected	4.39 ± 0.12	6.01 ± 0.61	3.80 ± 0.64	32.00 ± 1.30
Zebra Chip Infected	5.63 ± 0.91	5.87 ± 0.54	4.32 ± 0.82	36.65 ± 1.50

Summary

Historically, the role of tuber sugars is thought to be that of an energy and carbon source for the plant. However, these findings suggest a wider role for sugars in tuber physiology than previously realized. Potato sugars have largely been studied in terms of the potential of excessive amounts of reducing sugars like fructose and glucose to cause an unacceptably dark fry color or sugar ends, but these data suggest sugars influence additional important traits. Our data was strongest for sucrose but doesn't preclude a role for the reducing sugars. In some other plants sucrose, but not reducing sugars, was found to control phenolic levels, whereas in grapes glucose was effective. Besides their role in human nutrition, phenolics have diverse roles in potatoes, including in flavor, disease and pest resistance, abiotic stress tolerance, sprouting, flavor and appearance. Consequently, identifying factors that influence the amounts and types of tuber phenolics has implications for producing a crop with improved skin appearance, flavor, stress resistance, and human nutritional value.

Volunteer Potato Outlook - 2016

Marc Seymour and Rick Boydston, USDA-ARS, Prosser, WA

Winter soil temperatures are being recorded at four depths (2 ¾”, 4 ¾”, 6 ¾”, and 8 ¾”) at the USDA-ARS Research Farm at Paterson, WA. Data have been collected since the first week of November 2015 beneath fallow ground that was chisel-plowed and planted to winter wheat in September. Soil temperatures during the period from November 1 to February 2 were insufficiently low to kill tubers at all but the shallowest depth monitored.

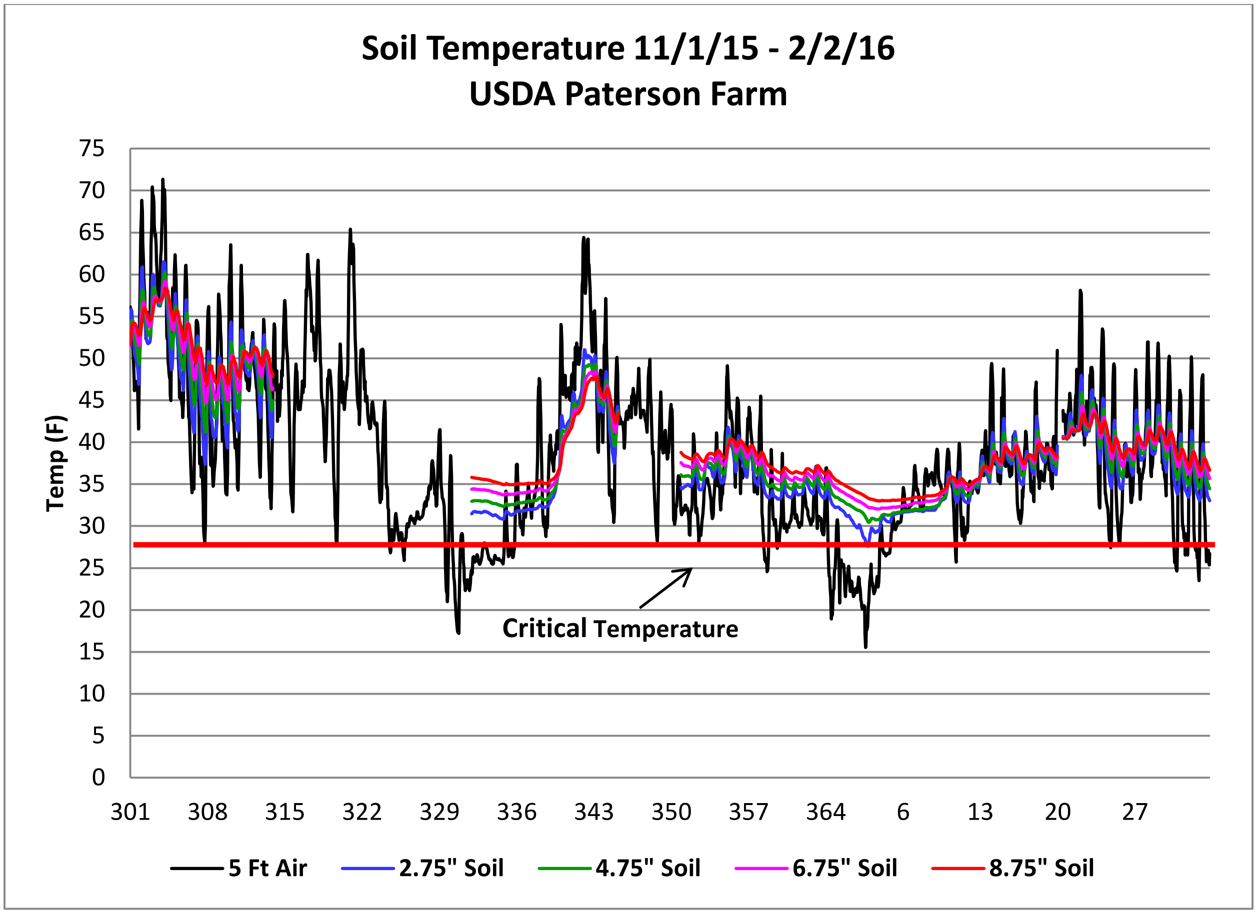
Potato tubers are normally killed when they reach temperatures ≤ 28° F. Air temperature briefly reached about 17° F on November 27 but rapidly climbed to >20° F the same day. Data were lost between November 10 and November 27 but it is very unlikely that temperatures were sufficiently low to kill tubers at even the shallowest depth. Cold conditions returned to the Lower Basin on January 3 and soil temperatures at 2 ¾” deep reached 27.50 F, low enough to kill tubers at that depth.

The vast majority of potato tubers left in the field are in the upper 8 inches of the soil profile unless deep post-harvest tillage, such as mold board plowing was done. Previous research on post-harvest tuber depth (Newberry and Thornton, 2004) and data generated in the Lower Columbia Basin (Boydston, unpublished) indicated that between 38% - 45% of tuber leavings are located in the top 2” of the soil profile, depending upon post-harvest tillage practices. Based on these data we estimate that only about 40% of tubers at the Paterson farm were killed by low temperatures in January. As a result volunteer potato plants will likely be a common occurrence in areas of the Columbia Basin that experienced similar air temperatures in the absence of snow or vegetative cover.

The table below shows mimimum air and soil temperature data from AgriMet and AgWeatherNet stations in Oregon and Washington from November 1 to February 2. We suspect that the minimum soil temperatures at Odessa were not that cold due the presence of snow cover, despite having relatively cold air temperatures. Minimum soil temperatures from the AgWeatherNet station at Warden indicate that minimum soil temperatures at 2 inches killed all tubers at that depth and deeper, although at 8 inches deep tubers were not affected. The AgriMet Hermiston data are remarkably similar to data collected at the Paterson farm although minimum soil temperature at 2” was almost 1° F warmer than at Paterson. At all stations other than Warden soil minimum temperatures at ≥2” were unlikey to affect the viability of tubers.

SITE	**Minimum Air Temperature**	**Minimum Temperature 2”**	**Minimum Temperature 4”**	**Minimum Temperature 8”**
AgriMet Echo, OR	12.8	30.3	32.4	NA
AgriMet Hermiston, OR	12.09	28.3	31.5	NA
AgriMet Odessa, WA	-3.4	29.7	32.6	34.9
AgWeatherNet Warden, WA	1.5	25.8	NA	32.4

The graph below shows air and soil temperatures at the Paterson Farm from November 1 to February 2. Air temperature for the periods in which there is no soil temperature data were downloaded from the AgWeatherNet station at the Paterson farm.



2015 Potato Cultivar Yield and Postharvest Quality Evaluations

See: http://potatoes.wsu.edu/

POTATO VIRUS DETECTION TRAINING

JUNE 20TH, 2016
OTHELLO, WA

For growers, inspectors, regulators and anyone interested in learning more about detection of PVY, PMTV and TRV in field applications. The workshop will be held at the WSU Othello Agricultural Research & Extension Center, 1471 W. Cox Rd., Othello, WA from 9am-3:30pm. Lunch will be provided. For those who can spend more time, you are also welcome to attend the **WSU Commercial Seed Lot Evaluation June 21st and WSU Potato Field Day on 23rd,** both in Othello, as well as the **OSU Potato Field Day at the OSU Research Center in Hermiston, OR on June 22nd.** Come and make a week of it! Register for the event at http://bit.ly/wsu-potatovirusworkshop . For more information about the event email pbg-potatovirus@cornell.edu .

USDA NIFA WASHINGTON STATE UNIVERSITY

Field identification of PVY (strains O, N-Wi and NTN) on 40 popular cultivars

Tuber symptoms of PVY, PMTV and TRV

Learn about new diagnostic assays for viruses and their vectors

Talk with experts from the USDA, UID, MTSU, WSU and UWI

REGISTER FOR THE EVENT AT
http://bit.ly/wsu-potatovirusworkshop

FOR MORE INFORMATION
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