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Effects of cooking methods on polyphenols, pigments and antioxidant activity in potato tubers

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ABSTRACT

Potato tubers, which are one of the richest sources of antioxidants, are always cooked before human consumption. The objective of this study was to understand the effects of various domestic cooking methods, i.e., boiling, microwaving and baking on total phenolics, flavonoids, flavonols, lutein, anthocyanins and antioxidant activities in 5 cultivars and 9 advanced selections with different skin and flesh colors after 6 months of storage. The three cooking methods reduced the levels of these compounds and the percentage of DPPH (2,2-Diphenyl-1-pikryl-hydrazyl) radical scavenging activity in all the cultivars and selections. Boiling minimized these losses. Red fleshed tubers contained more flavonoids, whereas purple tubers contained more flavonols. Despite severe loss of these compounds due to cooking, both the flesh types retained larger amounts of all these compounds due to higher initial levels. Decline in the radical scavenging activity is directly related to loss of these compounds due to cooking treatments in all white and colored flesh tubers. Red and purple fleshed tubers exhibited greater radical scavenging activity than yellow and white fleshed tubers after each of the cooking treatments. Correction procedures were introduced to exclude interfering compounds (ascorbic acid, other oxidizing agents and reducing sugars) in Folin-Ciocalteu Reagent (FCR) assay of estimating total phenolics in potato.

1. Introduction

Free radicals (e.g., reactive oxygen and nitrogen species) generated *in vivo* cause damage to DNA, lipids, proteins, and other biomolecules. Antioxidants are required to prevent the formation of free radicals and are found to oppose their actions *in vivo*. Many dietary compounds have been suggested to be effective antioxidants (Halliwell, 1996). Potato tubers which are a source of various polyphenols (Friedman, 1997) are one of the richest sources of antioxidants in the human diet (Brown, 2005; Lachman, Hamouz, Orsak, & Pivec, 2000). The main potato antioxidants are polyphenols, ascorbic acid, carotenoids, tocopherols, α-lipoic acid, and selenium (Lachman & Hamouz, 2005). Polyphenols are secondary plant compounds, which are divided into phenolic acids, flavonoids, stilbenes and lignans (Manach, Scalbert, Morand, Remesy, & Jimenez, 2004; Manach, Williamson, Morand, Scalbert, & Remesy, 2005). Phenolic compounds contribute to the taste, color and nutritional value (Cheynier, 2005) of potatoes. Common phenolic acids in potatoes include chlorogenic acid, caffeic acid, cinnamic acid, *p*-coumaric acid, ferulic acid, and sinapic acid (Friedman, 1997). The predominant phenolic acid in potatoes is chlorogenic acid, which constitutes about 80% of the total (Brown, 2005). Flavonoids are the most common group of plant polyphenols and provide much of the flavor and color to fruits and vegetables. More than 5000 different flavonoids have been described in plants. The six major subclasses of flavonoids are the flavones (e.g., apigenin, luteolin), flavonols (e.g., quercetin, myricetin), flavanones (e.g., naringenin, hesperidin), catechins or flavanols (e.g., epicatechin, gallocatechin), anthocyanidins (e.g., cyanidin, pelargonidin), and isoflavones (e.g., genistein, daidzein). Although most of the flavonoids in plants are attached to sugars (glycosides), they can occasionally be found as aglycones (Ross & Kasum, 2002). Flavonoids constitute up to 30 μg per 100 g fresh weight in white fleshed potatoes and this level is almost doubled in the red and purple fleshed potatoes. The predominant flavonoids in the potatoes are catechin and epicatechin (Brown, 2005). In addition to common polyphenols, red and purple fleshed potatoes contain acylated anthocyanins (Lachman & Hamouz, 2005). Anthocyanin levels are present up to 40 mg per 100 g fresh weight in red and purple fleshed potatoes (Brown, 2005). The main anthocyanin aglycones of potatoes are pelargonidin, cyanidin, delphinidin, peonidin, petunidin, and malvidin (Lachman et al., 2009). Acylated glucosides of pelargonidin are present in red fleshed potatoes. In addition, purple fleshed potatoes contain acylated glucosides of pelargonidin,

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malvidin, petunidin, peonidin, and delphinidin. Interestingly, the hydrophilic antioxidant activity of solidly pigmented flesh of red and purple potatoes has been shown to be comparable to Brussels sprouts or spinach (Brown, 2005). Flavonols such as rutin and kaempferol-rutinose are also present in potato tubers (Navarre, Shakya, Holden, & Kumar, 2010).

Potatoes are always cooked before being eaten, however, there is little published information on the effects of cooking on the properties of its constituents in different color fleshed potatoes (other than vitamin C). Recently, Blessington et al. (2010) published a study involving cooking methods and storage treatments on carotenoids, phenolics and antioxidant activity, but this study mainly focused on tubers of commercial cultivars and advanced selections with white or cream colored flesh. Unlike domestic cooking or overcooking, scientifically optimized microwaving (2 min 30 s at high in an 1100 W microwave), baking (375 °C for 30 min), boiling (18 min), steaming (15 min) and stir-frying in cold-pressed canola oil (18 min) of developmentally young (small sized) potatoes of three cultivars resulted in an increase in recoverable amounts of the total phenolics, chlorogenic acids, rutin, kaempferol-rutinose and vitamin C. These optimized cooking methods, which avoid overcooking, also increased antioxidant activities in these young potatoes (Navarre et al., 2010). In contrast, a report examining the effects of cooking procedures on mature potatoes showed that baking in an oven at 212 °C for 45 min, boiling in water for 30 min, or microwaving at 218 °C for 30 min, decreased chlorogenic acid to 0, 35, and 55% of the original amount, respectively (Dao & Friedman, 1992). Thus the main objective of the present study was to elucidate the effects of several domestic cooking methods on various polyphenols and antioxidants in mature stored potato tubers. Unlike earlier studies, the present study included a number of cultivars and advanced selections with different tuber skin and flesh colors.

FCR assay is a popular spectrophotometric assay of total phenolics which has been adopted by several researchers (Faller & Fialho, 2009; Mohdaly, Sarhan, Smetanska, & Mahmoud, 2010; Zhang et al., 2006). Singleton, Orthofer, and Lamuela-Raventós (1999) reviewed the measurement of total phenolics by FCR, as well as effects of various compounds that interfere with the FCR assay in natural samples, and suggested several methods for correcting the results. In the present investigation, we attempted to get more realistic values for total phenolics in potato tubers by modifying experiments and correcting for the most important compounds that interfere with the FCR assay.

2. Materials and methods

2.1. Tuber samples

Mature stored tubers from 5 cultivars and 9 advanced selections of potatoes with different skin and flesh colors were collected from the harvest of September, 2009 at San Luis Valley Research Center (Table 1). These tubers were stored for 6 months at 3.8 °C with 95% relative humidity.

2.2. Cooking methods

The present study tested three cooking methods (i.e., boiling, microwaving and baking). Five randomly selected tubers from each potato cultivar were tested with each cooking method essentially as described earlier by Pavek and Knowles (2009), pp. 1–124. First, the tubers were thoroughly cleaned with tap water and wiped with tissue paper. For boiling, the tubers were cooked in a sieved double-boiler for 1 h after water had come to boil. Tubers were microwaved after piercing the tuber twice on each side with a fork and cooking them for 10 min at the outer edge of a commercial microwave oven set at the highest level. The tubers were then turned over and moved to the center of the microwave where they were cooked an additional 10 min. In baking treatment, tubers were pierced twice on each side with a fork and baked at 204 °C for 1 h in a commercial oven after oven had come to prescribed temperature. Treated tubers and corresponding raw tubers were freeze-dried (FreeZone 6, Labconco, Kansas City, MO) at 0.12 mBar vacuum and −50 °C temperature. Freeze-dried samples were ground to a fine powder in a grinder and stored in air-tight plastic zipper bags at −80 °C until analyzed.

Table 1
Characteristics of potato cultivars and advanced selections.

Cultivar or selection	Tuber color	
	Skin	Flesh
Mesa Russet[a]	Russet	White
CO99256-2R	Red	White
Silverton Russet[a]	Russet	White
CO98012-5R	Red	White
CO95172-3RU	Russet	White
Colorado Rose[a]	Red	White
Russet Nugget[a]	Russet	White
VC0967-2R/Y	Red	Yellow
CO99045-1W/Y	White	Yellow
CO01399-10P/Y	Purple	Yellow
AC99329-7PW/Y	Purple and white	Yellow
Purple Majesty[a]	Purple	Purple
CO97222-1R/R	Red	Red
CO97226-2R/R	Red	Red

Letter codes in the selections after hyphen (-) represent color of skin and flesh. For example, PW/Y in AC99329-7PW/Y represents purple and white skin/yellow flesh. White color flesh is not represented by any letter. P = Purple; R = Red; RU = Russet; W = White; Y = Yellow.
[a] Cultivar.

2.3. Extraction of phenolics

Phenolic compounds were extracted using a previously described method with modifications (Mohdaly et al., 2010). Phenolics, flavonoids and flavonols were best extracted from potato with methanol. Freeze-dried samples from −80 °C were thawed to 4 °C without allowing moisture to enter the bags. After thorough mixing, a 4.0 g sample from each treatment was extracted with 40 mL of methanol overnight in an incubating orbital shaker at 25 °C and 150 rpm followed by filtration through Whatman (Number 40) filter paper and the residues were re-extracted under the same conditions. The combined filtrates were evaporated in a hood at room temperature under nitrogen gas with a Reacti-Vap nitrogen gas spray unit (Model 18780, Pierce Chemical Company, Rockford, IL) until the final volume was less than 15.0 mL. The final volume of extract was increased to 15 mL with methanol and kept at −80 °C prior to analysis. Concentration of the final extract was 266.667 mg mL^{-1}. For the experiments, these extracts were thawed to 4 °C, vortexed vigorously, and the solids were allowed to settle for 1 h and the supernatants were used for various assays.

2.4. Determination of total phenolics

Total phenolic content of the extract was determined by a previously described 96-well microplate method with modifications (Zhang et al., 2006). The extracts (10 μL) were mixed with 50 μL of distilled water in a 96-well flat-bottom assay plate (Costar 3370, Corning, NY). Fifty microliters of commercial FCR solution (MP Biomedicals, Solon, OH, Cat No. 195186) was added and mixed well for 1 min in a plate reader (Power Wave XS2, BioTek