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Effect of peeling and three cooking methods on the content of selected phytochemicals in potato tubers with various colour of flesh

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ABSTRACT

The impact of peeling and three cooking treatments (boiling, baking and microwaving) on the content of selected phytochemicals in white-, yellow-, red- and purple-fleshed potatoes was investigated. Ascorbic acid and chlorogenic acid contents were determined by HPLC-DAD, total anthocyanin content by pH-differential spectrophotometry, glycoalkaloid, α-chaconine and α-solanine contents by HPLC-ESI/MS/MS. All cooking treatments reduced ascorbic and chlorogenic acid contents, total glycoalkaloids, α-chaconine and α-solanine with the exception of total anthocyanins. The losses of ascorbic and chlorogenic acids were minimised with boiling and total anthocyanin levels retained the highest. Boiling of peeled tubers decreased contents of total glycoalkaloids (α-chaconine and α-solanine) and appeared as the most favourable among the three tested methods. Moreover, due to higher initial levels, red- and purple-fleshed cultivars retained higher amounts of antioxidants (ascorbic acid, chlorogenic acid and total anthocyanin) after boiling and may be healthier as compared with white or yellow cultivars.

1. Introduction

Potato (*Solanum tuberosum* L.) is one of the world's most important crops, ranking fifth in terms of human consumption and sixth in worldwide production with 324 million tonne production (FAOSTAT, 2012). The potato tubers are a versatile, carbohydrate-rich food consumed worldwide, prepared and served in a cultivar of ways (Murniece et al., 2011). Potatoes account for only about 2% of the world's dietary energy supply. Beyond supplying energy and good quality protein, potato is also an important source of vitamins and minerals. Many of the compounds present in potato are important because of their beneficial effects on health, and are therefore highly desirable in the human diet (Ezekiel, Singh, Sharma, & Kaur, 2011). Among the most important micronutrients present in potato are antioxidants, such as ascorbic acid (AA) and various polyphenols, such as chlorogenic acid (CGA) and its conjugates, which may play a partial role in preventing diseases related to ageing. CGA concentration represents about 90% of the total phenolic compounds in the potatoes (Finotti, Bertone, & Vivanti, 2006). In flesh-coloured potatoes, important constituents are red or purple pigments; anthocyanins (AN) also possessing high antioxidant activity (Lachman et al., 2009; Lachman et al., 2012). These parameters are important in human nutrition and also in food processing. For the evaluation of nutritional quality of different potatoes it is important to also include anti-nutrients, such as main glycoalkaloids α-solanine and α-chaconine.

Potato tubers particularly serve as a source of vitamin C (Burgos, Auqui, Amoros, Salas, & Bonierbale, 2009). Ascorbic acid (AA) is an essential component of most living tissues. As an antioxidant, it plays an important role in the protection against oxidative stress. AA is an important scavenger of free radical species, such as reactive oxygen species that can cause tissue damage resulting from lipid peroxidation, DNA breakage or nucleic base alterations, and may contribute to degenerative diseases such as coronary heart disease or cancer. In addition, due to its participation in the oxidation of transition metal ions, AA also plays an important role in enhancing the bioavailability of non-hem iron (Teucher, Olivares, & Cori, 2004). The Food and Agriculture Organisation indicated that the recommended nutrient intake of vitamin C ranges from 25 to 45 mg d^{-1}, depending on age. However, based on available biochemical, clinical, and epidemiological studies, the current recommended dietary allowance for AA is suggested to be 100–120 mg d^{-1} for adults to achieve cellular saturation and reduce risk of heart disease, stroke and cancer in healthy individuals (Naidu,

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2003). Newly harvested potato tubers have been reported to contain up to 460 mg AA kg^{-1} fresh matter (FM) (Han, Kosukue, Young, Lee, & Friedman, 2004) depending primarily upon the cultivar, the maturity of the tubers at harvest, the sampling method, and — to almost as great an extent — the environmental conditions under which they were grown. Several authors have described considerable reduction in the levels of AA during cooking and storage in potatoes as well as in vegetables, with losses that vary widely according to cooking method (Lešková et al., 2006).

Of the three caffeoylquinic acids quantified, chlorogenic acid (CGA) was the most abundant in all genotypes and constituted on average 83% of the total chlorogenic acid isomers (Navarre, Pillai, Shakya, & Holden, 2011). Cryptochlorogenic acid (4-O-caffeoylquinic acid) was more abundant than neochlorogenic acid (3-O-caffeoylquinic acid) in all genotypes and on average it represented 12% of the total chlorogenic acids, whereas neochlorogenic acid comprised 5% of the total. Potatoes were among the best vegetable sources of total phenolic acids (Mattila & Hellström, 2007), with contents varying from 79 mg kg^{-1} (cooked and peeled Rosamunda cultivar) to 520 mg kg^{-1} (cooked peeled Van Gogh cultivar). Especially rich in phenolic acids have been found the coloured-flesh potato cultivars, as reported by Ieri, Innocenti, Andrenelli, Vecchio, and Mulinacci (2011) for the Vitelotte Noire and found a total content of phenolic acids of 858.5 mg kg^{-1} FM (800.7 mg kg^{-1} FM 5-caffeoylquinic acid and 57.8 mg kg^{-1} FM 3-caffeoylquinic acid).

Until now fresh fruits and red wine have been commonly indicated as rich sources of anthocyanins in the human diet, but red-blue or purple potatoes can also contribute to increasing intake of these interesting pigments. Ieri et al. (2011) detected as many as 24 different pigments in the anthocyanin profiles of the pigmented cultivars. In accordance with the results obtained by Lachman et al. (2009), anthocyanin pigments are acylated glycosides of pelargonidin, peonidin, petunidin, malvidin and delfinidin glycosylated with rutinose and glucose and acylated with caffeic and ferulic acids. In addition to the fact that they can serve as varietal pigmented potato fingerprints, they also possess strong antioxidant activity.

Potato steroidal glycoalkaloids (SGAs) serve as natural defence compounds against pathogens and insects (Friedman, 2004; Lachman, Hamouz, Orsák, & Pivec, 2001). α-Solanine and α-chaconine are the two major glycoalkaloids present in potato (95% of total SGAs). They appear to be unaffected by food processing (baking, boiling and frying) (Finotti et al., 2006). The toxicity of these compounds may be due to adverse effects on the central nervous system, with disruption of the cell membranes, on the digestive system and general body metabolism (Friedman, Roitman, & Kozukue, 2003). For these reasons there are informal guidelines, limiting the total glycoalkaloid concentration in potato to 200 mg kg^{-1} FM of non-peeled tubers. SGAs can be hazardous for human health. Available information suggests that the susceptibility of humans to poisoning is high and very variable. Oral daily doses in the range of 1–5 mg kg^{-1} body weight (b.w.) are marginally to severely toxic to humans. Cases of toxic effects are well known, but only after consumption of potatoes with SGAs levels above 2000 mg kg^{-1} (Ruprich et al., 2009).

Nutritional quality of potato tubers can be evaluated as the balance between nutritional and anti-nutritional compounds affected mainly by processing and cooking treatments. We therefore studied changes in the contents of ascorbic acid, chlorogenic acid, total anthocyanins and glycoalkaloids in raw and processed/cooked yellow and colour-fleshed potato cultivars. The aim was to prove if there are differences in nutritional quality among them and to evaluate the effect of processing methods with the aim to choose appropriate processing methods and cultivars.

2. Material and methods

2.1. Chemicals

Solvents (of analytical or HPLC grade as required) were obtained from Merck (Germany), and methanol (MeOH) GR from Lach-ner (Neratovice, Prague, CR). Standards of cyanidin, delphinidin, malvidin, peonidin, pelargonidin and petunidin were purchased from Fluka (Buchs, Switzerland). Ascorbic acid was supplied by Dr. Kulich Pharma, Ltd., Hradec Králové, Czech Republic. Standards of chlorogenic acid ⩾ 95%, α-chaconine ⩾ 95% and α-solanine ⩾ 95% were purchased from Sigma–Aldrich (St. Louis, MO, USA). Metaphosphoric acid was purchased from Penta, Czech Republic. Methanol for HPLC was from Fluka, gradient grade; ⩾99.8% (GC), United Kingdom. Deionised water was prepared in a MILLIPORE Simplicity UV Water Purification System.

2.2. Plant material

Potatoes (*S. tuberosum* L.) for analyses were grown in the exact field experiment in experimental station Přerov nad Labem, Czech Republic, in 2010. Six cultivars (HB Red, Rote Emma, Blaue St Galler, Valfi, Violette and Agria) with purple, red and yellow coloured flesh were evaluated. Seed tubers were obtained both in the Czech Republic (Bank of Potato Genetic Sources, Potato Research Institute, Havlíčkův Brod), and from abroad (Table 1). Recent growing technology was used. For analyses only mechanically and physiologically undamaged tubers of 60–100 g weight were used. In the field trials, a field sample was collected (by means of main random sampling) of ca. 20 kg weight, from which a laboratory average sample was separated and used for further analyses. A laboratory sample (ca 1 kg, which corresponded to about 15 tubers) consisted of randomly selected potato tubers, which were subsequently divided in quarters. All operations during sample preparation were performed very quickly to avoid degradation of the sample. Culinary experiments were provided two months after the harvest. The tubers were stored until they were analysed in a cooling box at 4–7 °C and relative humidity of 95%. Cooking experiment was conducted in three technological repetitions.

2.3. Sample preparation

Following treatments were used prior to analyses of fresh tubers and cooking processing:

a. fresh non-peeled,
b. fresh peeled (peeling removed approximately 15% of the tuber mass); potatoes were peeled with a standard kitchen peeler, thickness of peel was 1–2 mm,
c. non-cut peeled as in b) boiled in water in a beaker, 15 min (from start point),
d. microwaved in a microwave oven, 750 W, 10 min non-peeled tubers were cut into small cubes 1.5 × 1.5 × 1.5 cm,
e. baked in a hot air oven, 45 min, 180 °C, non-peeled tubers were diced into small pieces 1.5 × 1.5 × 1.5 cm.

2.4. Total anthocyanin content (TAC) assay

For TAC determination by pH-differential spectrophotometry (Lapornik, Prošek, & Wondra, 2005), fresh tubers were cut in small pieces and then 50 g of homogenised samples were extracted with 70% methanol for 1 min in a blender. Next, the mixture was left for 24 h in a refrigerator at 4 °C. The mixture was then filtered and finally 1.0 ml aliquots were pipetted to 10 ml 2% HCl (pH 0.8) or to 10 ml citrate buffer (pH 3.5), which was prepared from 0.2 mol l^{-1}