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Original Research Article

Macronutrient contents of potato genotype collections in the *Solanum tuberosum* Group Phureja

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ABSTRACT

Macronutrient contents of 94 genotypes from the Colombian Central Collection (CCC) and 13 genotypes from the Native Collection (NC) of diploid potatoes (*Solanum tuberosum* Group Phureja) were evaluated, considering six genotypes, four diploid and two tetraploid potato commercial cultivars, as control. Dry matter, protein, soluble dietary fibre (SDF) and insoluble dietary fibre (IDF), fat, and ash contents were determined in entire boiled tubers. Macronutrient contents varied widely among the 113 genotypes. Protein contents found in CCC and NC (1.8–17.2 g/100 g dry weight, DW) were greater than those in commercial cultivars (3.1–9.5 g/100 g DW). Total dietary fibre (TDF), SDF, and IDF were greater in CCC and NC (9.4–27.1 g/100 g DW, 1.6–6.6 g/100 g DW, and 6.4–20.9 g/100 g DW, respectively) than in the commercial cultivars (9.0–15.3 g/100 g DW, 2.7–4.4 g/100 g DW, and 6.4–12.3 g/100 g DW, respectively). Several genotypes from CCC and NC are good candidates as parental materials for developing new cultivars, with the highest protein content in CCC-76 (17.2 ± 0.3 g/100 g DW) and NC-8 (16.7 ± 0.7 g/100 g DW) and the highest TDF in CCC-110 (27.1 ± 4.0 g/100 g DW).

1. Introduction

Potato is the most important non-cereal food crop in the world being cultivated in more than 150 countries, with an annual production of about 330 million tons, produced in an area of around 19.2 million ha. The average yield is 20 ton/ha (FAO, 2017). It is the main source of basic nutrients for many developing countries, also generating some income for their livelihood.

Plant agriculture is facing important global challenges, to grow enough food for the growing population worldwide, while reducing its competition for the use of freshwater, and applying more environmentally friendly practices. The potato crop can help to face these challenges, as potato is very efficient in the use of water, producing more food per unit of water than the other major crops. Potato produces 5600 kcal of dietary energy per each cubic meter of water applied to the crop in comparison to 3860 kcal; 2300 kcal; and 2000 kcal produced by corn, wheat, and rice, respectively (FAO, 2008). Therefore, an increase in the proportion of potato in the diet would alleviate pressure on water resources.

According to the Food and Agriculture Organization of the United Nations, in the case of animal products, producing 1 kg of grain fed beef requires 13,000–15,000 L of water, this is 4000 L per capita per day, while having a diverse diet based on potato, groundnut, onion, and carrot would require just 1000 L of water per day per capita of water consumption (FAO, 2008).

Based on world food production data reported from 2009 to 2015, potato delivers per acreage more edible biomass and energy than any other food crops. Potato can feed and alleviate malnutrition in the wold, where 805 million among 7.3 billion people in the world suffer from malnutrition (WHPFS, 2015), and 165 million children under five are affected by stunting (Unicef, WHO-The World Bank, 2014). Potatoes are directly consumed, or processed into chips, French fries, and other food products (Gebhardt, 2013). The tubers contain starch as the most abundant nutrient (Kita, 2002) and are considered to be an interesting source of other nutrients such as proteins of high quality and bioactive compounds such as dietary fibre, phenolic compounds, and carotenoids. In commercial cultivars, the protein content represents up to 4.2 g/100 g fresh weight (FW) (Bártová et al., 2015; Ritter et al., 2008), the total dietary fibre up to 3.3 g/100 g FW (Jiménez et al., 2009), the phenolic compounds up to 450 mg/100 g dry weight (DW) (Narváez-Cuenca et al., 2013), and the carotenoids up to 1.5 mg/100 g DW (Burmeister et al., 2011).

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In Colombia, protein intake is insufficient in 36% of the population (ENSIN, 2005). Whereas the protein in potato is of very high quality, its amino acid profile is better than any of the other tubers and vegetables (Bártová et al., 2015; Choi et al., 2016; Galdón et al., 2012). Potato protein has a high biological value (BV, 90–100) as compared with whole egg (BV 100), soybean (BV 84), and beans (BV 73) (Camire et al., 2009). Furthermore, 52% of mortality in Colombia is related to cardiovascular diseases (DANE, 2013), and a dietary fibre intake, by consuming e.g. potato, can significantly reduce these problems (Weickert and Pfeiffer, 2008). An important strategy to reduce malnutrition is to improve the nutritional and bio-active compound contents of crops that are largely consumed by the local population, combined with an effective nutritional program (Haddad, 2013; Mba et al., 2012).

Developing new potato cultivars with novel traits such as high nutritional and bio-active compounds contents is important in breeding programs, in addition to desirable and traditional breeding traits of agronomic values such as yield and resistance to diseases and pests (Holand, 2007; Manolio et al., 2009; Sun and Wu, 2015). The Colombian Central Collection (CCC) of potatoes is maintained by Universidad Nacional de Colombia. A fraction of this collection belongs to *Solanum tuberosum* Group Phureja which is the Colombian Potato Working Collection used in breeding programs because of its value as genetic resource (Juyó et al., 2015; Rodríguez et al.,2009). This working collection constitutes diploid genotypes, and most of them collected from Nudo de los Pastos, a region located at south of Colombia, considered as a biodiversity centre of potato (Juyó et al., 2015). Furthermore, genotypes from Nariño province, called Native Collection (NC) are preserved by native communities who employ them as food but also in different uses such as medicinal uses. Recently, new potato cultivars, from the Phureja group, with higher nutritional content as compared to traditional Colombian commercial cultivars were delivered (Peña et al., 2015). Nevertheless, the parents used in that breeding program were not nutritionally characterized. Efforts on the characterization of nutritional contents of potato collections for breeding programs have been made. For instance, individual carotenoid contents were evaluated in 23 accesions of *Solanum tuberosum* Group Phureja (Burgos et al., 2009); iron, zinc, calcium, total carotenoids, and antioxidant activity were evaluated in 74 accesions belonging mostly to the Andigenum group (Andre et al., 2007); and macronutrient contents were recently evaluated in 44 accesions from the Andigenum group (Calliope et al., 2018). Despite these efforts, no information on the macronutrient contents in a large collection of potatoes from the Phureja group is available. The objective of this study was, therefore, to perform the proximate analysis in tubers of 94 genotypes from the diploid potato Working Collection of *S. tuberosum* Group Phureja that belongs to the CCC, and 13 genotypes from the Native Collection and to compare their macronutrient levels with the six control genotypes, four diploid and two tetraploid commercial cultivars.

2. Materials and methods

2.1. Chemicals

Kits for the measurement of soluble dietary fibre (SDF) and insoluble dietary fibre (IDF) were purchased from SIGMA-ALDRICH (St. Louis, MO, USA). All other chemicals were of analytical quality from J. T. Baker (Center Valley, PA, USA).

2.2. Plant material

Macronutrient contents in 94 genotypes from the Colombian Central Collection (CCC) accessions and 13 genotypes from the Native Collection (NC), were evaluated, considering six genotypes (four diploid: Criolla Colombia, Criolla Galeras, Criolla Paisa, and Criolla Guaneña and two tetraploid: Diacol Capiro and Pastusa Suprema commercial cultivars) as control. The CCC accessions were collected in 1970–1980 and since then they have been maintained and propagated as clones, producing tubers in greenhouse conditions by Universidad Nacional de Colombia. NC are grown by native people at the south region of Colombia and they are not commercially available. CCC, NC, and commercial cultivars used as control were sown at the end of September 2012 and harvested in January 2013, in a rural area in Facatativá (4°49′N with 74°22′W, 2650 m above sea level, mean temperature of 13 °C, and average precipitation of 83 mm), a representative potato crop production region in Colombia. The experiment was conducted as a randomized complete block, with 113 potato genotypes, three blocks at different soil gradients, and with three biological replicates. The experimental units consisted of three plants per replicate. The tubers were harvested at maturity, stored at 4 °C for less than two days, and then were conditioned for further analysis.

2.3. Conditioning of samples

Tubers were washed with potable water and classified according to the size based on equatorial diameter measured using a gauge. According to Cevipapa (2005) potato tubers in Colombia are usually boiled and ate as such or used in preparations such as soups. Preparations can include peeled or unpeeled potato tubers. Because nutritional contents such as dietary fibre and protein are affected by domestic cooking (Tian et al., 2016) in this research unpeeled boiled potato tubers were used in the analysis. The whole unpeeled tubers (10–12 tubers per replicate) were boiled at 92 °C with different volumes of distilled water according to their equatorial diameter: 3.0–3.9 cm boiled during 20 min in tuber weight:water (g:mL) ratio of 1:3, 4.0–5.3 cm boiled during 25 min in a ratio of 1:4, and greater than 6.0 cm boiled during 30 min in a ratio of 1:3. After boiling tubers were cooled in an ice bath for 5 min and left to dry at room temperature. A sample was taken to determine water content and the remaining material was cut into slices, frozen in liquid nitrogen, stored at −80 °C, freeze-dried, ground to less than 0.2 mm particle size, enclosed in sealed polyethylene bags, and stored in a desiccator at room temperature until use.

2.4. Macronutrient measurement

The macronutrients were analyzed based on the methods recommended by the Association of Analytical Chemists (AOAC, 1995). Protein content was evaluated based on the Kjeldahl method (AOAC 970.22), using a conversion factor of 6.25. SDF and IDF were estimated by the enzymatic-gravimetric method (AOAC 985.29). Total dietary fibre (TDF) was calculated as the sum of SDF and IDF. Water content was determined with a vacuum stove at 70 °C (AOAC 931.04). Fat content was measured by the Goldfish method with petroleum ether as extraction solvent (AOAC 963.15). Ash content was evaluated based on the calcination method at 550 °C (AOAC 972.15). The carbohydrate content was calculated by subtracting the sum of per cent ash, fat, protein, SDF, and IDF from 100. Dry matter content was estimated by subtracting the water content (in per cent) from 100. Energy (E, kcal/100 g DW) was calculated by the formula:

$$E = [(\text{g Protein}/100\,\text{g DW}) \times (4\,\text{kcal/g})] + [(\text{g Carbohydrate}/100\,\text{g DW}) \times (4\,\text{kcal/g})] + [(\text{g Fat}/100\,\text{g DW}) \times (9\,\text{kcal/g})].$$

2.5. Statistical analysis

Each macronutrient content was expressed as the average of three biological replications and its standard deviation as g/100 g of boiled unpeeled potato, in both FW and DW basis, except for the water and dry matter contents, which were expressed only in FW basis. Correlation among variables were evaluated by the Pearson method ($p < 0.05$) using Statgraphics Centurion version XV software (StatPoint Inc., Warrenton, VA, USA). A normalized Principal Component Analysis