Original research article

Nutrient composition and starch characteristics of eight European potato cultivars cultivated in South Africa

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A B S T R A C T

The nutrient composition and starch properties of eight potato cultivars (Electra, Fianna, Innovator, Mondial, Navigator, Panamera, Savanna and Sifra) were evaluated, to determine their value to human nutrition and to inform decisions for culinary usage. Potatoes that had been cultivated under the same agronomic conditions were used. The results showed that there were significant differences ($P < 0.05$) in the parameters measured. Fianna and Innovator had the highest dry mass of 22 and 21%, respectively, while Electra had the lowest (16%). Innovator, together with Navigator, displayed the highest starch content (17.9% fresh weight [fw]), with the highest proportion of amylose (27.2% dry weight [dw]). However, Fianna and Panamera had the highest protein content (2.87 and 2.53% fw, respectively). Electra had the highest calcium (10.2 g $100 \, g^{-1}$ fw) and iron (2.91 g $100 \, g^{-1}$ fw) content. This represents a contribution of 3 and 32%, respectively, to the population-weighted estimated average dietary requirement of Africa. Innovator also contained the lowest aluminium contribution (12%) to the tolerable weekly intake limit set by the FAO. In addition to low amylose, the starch of Mondial had a high swelling power, oil absorption capacity and gelatinisation enthalpy, and a greater frequency of small-sized granules.

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1. Introduction

Potato (*Solanum tuberosum*) is an important food crop and a staple in many countries. The crop is mostly considered to be a source of energy, which is provided mainly by the carbohydrate content. It is a good source of potassium, copper, phosphorous, iron, zinc, magnesium and manganese (White et al., 2009; Lewu et al., 2010). This makes it a valuable candidate for contributing to the alleviation of mineral deficiencies associated with dietary constraints. In South Africa, potato has grown in popularity and its consumption is currently peaking at 38 kg per capita (Department of Agriculture, Forestry and Fisheries, 2016). This means it ranks third of all the crops produced in the country and comes after maize and wheat, which are at 75 and 49 kg per capita, respectively. While many potato cultivars are produced in the country, a knowledge of the nutritional content is required. Earlier records on the nutritional composition of potatoes do not consider genotypic differences (Lewu et al., 2010). Even the information

recorded in the South African food composition tables is based on an unidentified cultivar (Wolmarans et al., 2010). Recently, van Niekerk et al. (2016) gave a broad account of the nutritional content of eleven selected cultivars in the country, and started the conversation on the contribution of cultivars to nutrition in the region. Genetic variation in the mineral content of potatoes is well documented in literature (White et al., 2009; Nassar et al., 2012), with lower contents sometimes being associated with high yield capacity. Although the final content of most minerals depends on whether the skin is present or not, and on the method of processing, preparation and cooking, the potato is considered to be a nutritious food (Lewu et al., 2010; Subramanian et al., 2011; Ezekiel et al., 2013; Furrer et al., 2016; van Niekerk et al., 2016). The most popular cooking methods for potato are boiling, frying and roasting (Badenhorst, 2014). However, South African consumers prefer to use potatoes in stews and for making French fries. Knowing the compositional characteristics of potatoes prior to processing is important, as this determines the structural changes that occur during processing, and it can be used to categorize potatoes, according to specific cooking methods.

On the other hand, a number of studies have reported the nutritional quality of potato cultivars grown in different regions (Murniece et al., 2011; Šimková et al., 2013; Chung et al., 2014).

These studies indicate significant differences in the nutrient quality, due to genetic influence, which is also affected by other factors such as agro-climate, agronomy and storage conditions. With the major component of potato dry mass being starch, understanding the cultivar-specific characteristics of starch is necessary to add value to informed decisions regarding processing. Potato starch has a semi-crystalline structure and is composed of amylose and amylopectin, which occur roughly in a 3:1 ratio (Alvani et al., 2011; Šimková et al., 2013). The amylopectin component accounts for the crystallinity, while amylose represents the amorphous component. Amylopectin is structurally branched and amylose is a linear polymer. The ratio of these components affects the swelling capacity, water solubility, the water absorption capacity, and the barrier and mechanical properties of starch and starch films (Alvani et al., 2011). Amylose is generally slower to digest, compared to amylopectin, resulting in a high amylose content and contributing to a lower glycaemic index in potatoes (BeHall and Howe, 1995; Ek et al., 2014). For this reason, potatoes with a high amylose content are favoured by diet-conscious individuals. The polymer content is lower in waxy potatoes and generally decreases with potato development (Liu et al., 2003; Noda et al., 2004; Ezekiel and Rana, 2009; Šimková et al., 2013; Jansky and Fajardo, 2016). According to the description provided by Furrer et al. (2016), waxy potatoes are low in starch (16–18% fresh weight [fw]) and have a high proportion of amylopectin; whereas floury potatoes are higher in starch (20–22% fresh weight [fw]) and have a high proportion of amylose. Amylose content has also been shown to be higher in cultivars with a tolerance to cold-induced sweetening than in those that are susceptible (Jansky and Fajardo, 2014), making a high amylose content potato favourable for processors. Generally, potato starch has a higher swelling power and solubility than corn, rice and wheat starch, while the granules are larger, smoother and more regular (Singh et al., 2003; Chandra and Samsher, 2013). These properties are indicative of the interaction between the amorphous and crystalline components of its starch. Hence, it is necessary to quantify the amylose content in potato cultivars grown in South Africa.

The present study aims to give a detailed account of the nutrient content and starch properties of selected cultivars. Representative samples of cultivars that are popular and those that are new in the South African potato industry, were selected.

2. Materials and methods

2.1. Reagents

The following chemicals were purchased from Sigma Aldrich (Gauteng, South Africa): ethanol (99%), anthrone (97%) and sucrose bioxtra powder (99.5%). Vanadium pentoxide and the Alfalfa standard were purchase from LECO Africa (Kempton Park, South Africa). Phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), zinc (Zn), copper (Cu), manganese (Mn), iron (Fe) and aluminium (Al) standard solutions were purchased from Separations (Johannesburg, South Africa). Acetic acid, sodium hydroxide (NaOH), iodine, potassium iodide, potato amylose, perchloric acid (70–72%), hydrochloric acid (HCl; 32%), sulphuric acid (98%) and glucose were purchased from ACE (Johannesburg, South Africa).

2.2. Potato sample preparation

Eight potato cultivars (Electra, Fianna, Innovator, Mondial, Navigator, Panamera, Savanna and Sifra) were planted at the Ukulinga Research Farm at the University of KwaZulu-Natal, Pietermaritzburg, South Africa (30°24′E, 29°40′S), under the same growing conditions and irrigation. The cultivars were planted in a randomised complete block design, with three replications. Each replicate was planted in a plot with seven rows placed 0.9 m apart. Plants were placed 0.3 m apart in the same row. Soil moisture was monitored twice a week, using a Diviner 2000 probe (Sentek, Kent Town, Australia). Irrigation was effected through a sprinkler system, when required, and the crop received a total water supply of 474 mm (inclusive of rainfall). Potatoes were harvested 2–3 weeks after shoot die-back, they were hand-washed with tap water, allowed to air-dry and stored in a dark room for two months at 8–12 °C. Potatoes from the three replicates were then combined into one batch and assessed after the 2-month storage period. Potatoes used for analysis were randomly selected from the respective batch. Three potatoes were cut, with their skins left intact, to acquire 100 g samples, which were then homogenised separately with a food blender. The samples were weighed before and after oven-drying at 105 °C, to a constant weight, to determine the dry mass content (Puri et al., 2015). Eight medium-sized (100–250 g) potatoes per cultivar were then frozen (−20 °C) until required for further processing within three months. Five of these potatoes were retrieved, lyophilised (−56 °C, 4.0 mbar) for 72 h (whole potatoes with skins intact), milled with a Laboratory Mill 120 (Perten instruments, Hamburg, Germany) and the powder was stored in zip-seal plastic bags at ambient temperature (±25 °C) until required for different analyses i.e. starch and sugar content and starch physicochemical properties.

2.3. Starch content

The starch content of each potato cultivar was determined in quadruplicate. For each analytical sample, a 0.2 g portion of potato powder was moistened with a few drops of 80% ethanol and mixed with 5 mL of deionised water, as suggested by Raigond et al. (2015), who modified the method used by McCready et al. (1950). Twenty-five millilitre of 80% ethanol was added, the mixture was stirred with a stainless steel spatula and allowed to stand overnight and then centrifuged at $200 \times g$ (at 37 °C) for 5 min. The supernatant, containing free sugars, was discarded and the procedure was repeated twice more, using 30 mL of 80% ethanol to rid the residue of free sugars. Five millilitre of deionised water and 6.5 mL of 52% perchloric acid were added to the residue and the mixture was continuously swirled for 20 min. Twenty millilitre of deionised water was added and the sample was centrifuged. The resulting supernatant was transferred to a 100 mL volumetric flask. The residue was treated with 5 mL of deionised water and 6.5 mL of 52% perchloric acid again, and allowed to solubilise, as before, for 30 min. The two mixtures were combined with 100 mL deionised water and filtered, using Whatman's No. 1 filter paper. A 0.5 mL aliquot of the filtrate was taken from this solution and made up to 50 mL with deionised water. Of the 50 mL, 100 μL was diluted with 900 μL deionised water and mixed with 2 mL of a freshly prepared anthrone sulphuric acid reagent (200 mg anthrone in 100 mL chilled concentrated sulphuric acid). For a blank reading, deionised water was mixed with anthrone sulphuric acid reagent. The sample was heated for 8 min in a water bath (100 °C), then cooled to ambient temperature and absorbance was recorded at 620 nm. The starch content was calculated by using an equation from a glucose standard curve (prepared from reading 0.1, 0.2, 0.3, 0.4 and 0.5 mg mL^{-1} solutions). The starch content was determined relative to the dw and converted to fw, using dry mass content data.

2.4. Total and reducing sugar content

A 2 g powder sample was mixed with boiling deionised water (1:4, w/v), stirred with a stainless steel spatula and made up to 40 mL with deionised water at ambient temperature. The sample