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Critical Review

Nutrients, bioactive non-nutrients and anti-nutrients in potatoes

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ABSTRACT

Globally, potatoes account for only about 2% of the food energy supply, yet they are the predominant staple for many countries. In developed countries, potatoes account for 540 kJ (130 kcal) per person per day, while in developing countries, it is only 170 kJ (42 kcal) per person per day. In addition to energy, which is derived almost entirely from their carbohydrate content, many varieties of potatoes contribute nutritionally important amounts of dietary fibre (up to 3.3%), ascorbic acid (up to 42 mg/100 g), potassium (up to 693.8 mg/100 g), total carotenoids (up to 2700 mcg/100 g), and antioxidant phenols such as chlorogenic acid (up to 1570 mcg/100 g) and its polymers, and anti-nutrients such as α-solanine (0.001–47.2 mg/100 g); and lesser amounts of protein (0.85–4.2%), amino acids, other minerals and vitamins, and other beneficial and harmful bioactive components. Nutrient content depends on a number of factors, with variety being among the most important. Potato biodiversity is vast, with more than 4000 known varieties. Most belong to the species *Solanum tuberosum*, but another 10 species are cultivated and 200 wild species have been identified. Modern agricultural practices and climate change are contributing to the loss of potato biodiversity, and thus the loss of the genes coding for nutrient biosynthetic pathways. Knowledge of differences in nutrient composition of potatoes related to their genetic diversity will help guide strategies that may contribute to reducing biodiversity loss and improving food and nutrition security.

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1. Introduction

Potato biodiversity is vast: approximately 5000 varieties of potatoes are known. Most cultivated varieties belong to the species *Solanum tuberosum*. However, about 10 other *Solanum* species are cultivated, and 200 wild species have been recorded. Conventional agriculture and climate change may threaten the survival of these wild relatives: it is forecast that as many as 12% will become extinct as their growing conditions deteriorate. If climate changes drastically, the area where wild potatoes grow naturally could be reduced by as much as 70% (FAO, 2008).

According to the latest FAOSTAT statistics (FAO, 2009a), potatoes account for only about 2% of the world's dietary energy supply. As a staple food, potatoes are less important globally than rice, wheat and maize, which account for 20%, 18% and 5%, respectively. During the past 50 years, potato production and consumption has been rather steady. FAOSTAT reports continue to increase around the world. Potatoes have a more dominant place in the diets of people in developed countries than those in developing countries. Averaged across the world, potatoes account for only 170 kJ (41 kcal) per person per day for the developing world, yet the number is 540 kJ (130 kcal) for developed world. Countries in the Commonwealth of Independent States (CIS) rely most heavily on potatoes for their energy intakes, with Belarus topping the list at 1250 kJ (300 kcal) per person per day. Seven other CIS (Commonwealth of Independent States) countries and Portugal follow closely behind, each averaging more than 840 kJ (200 kcal) per person per day from potatoes.

Potatoes are the subject of many popular culture conceptions and misconceptions. At various times in recent history, they have had the reputation of being nutritionally both "bad" and "good". During its phase of having a nutritionally bad reputation, potatoes were marked as being "fattening" and contributing to diabetes, obesity and its co-morbidities. Many more campaigns have promoted potatoes as good, including the famous, "Potatoes are not fattening" campaign of the United Kingdom, "Goodness Unearthed" and "Healthy MR. POTATO HEAD" campaign of the US potato industry (US Potato Board, 2009a, 2009b), the "Spudtacular Show" and "Baked Potato Campaign" of New Zealand (HEHA, 2009).

The food components most frequently highlighted in nutrient content claims are energy, e.g. "one medium-sized potato has 110 calories"; fat, e.g. "100% fat free; saturated fat, trans fatty acids, and cholesterol, e.g. "fat free"', "0 grams trans fat", no cholesterol; sodium, e.g. "salt free". Other nutrients frequently declared are potassium, fibre, Vitamin C, B6 and various antioxidants (US Potato Board, 2009c).

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Rarely are varieties differentiated in nutrient declarations or content claims, yet there are well-known content differences. Under the Codex Alimentarius food labelling guidelines for "source" and "good source" of nutrients (Codex Alimentarius, 2007), some varieties would qualify for the claims, while others would not. The purpose of this review is to examine the literature on potato composition at the level of the genetic resource and compile the data illustrating that the vast existing biodiversity of potatoes also reflects vast differences in nutrient content.

2. Methods

2.1. Compilation of nutrient composition data of potatoes by variety

A thorough literature search was performed to gather existing information on nutrient composition of potatoes by variety. While many environmental, agricultural and post-harvest factors such as climate, fertilizer use, maturity at harvest, storage, processing and preparation influence the nutrient content, this review focuses mainly on the measured differences among varieties. However, the influence of variety cannot be assured for many of the data. National Food Composition tables were searched, as were nutrition and agriculture journals. In most food composition data resources, part (flesh, flesh + peel) and state (e.g. cooked or raw) are generally reported, but varietal name is often missing.

Differences in water content will likely account for many of the differences in nutrient content, because values are present on a per 100 g basis, fresh weight, unless otherwise noted.

2.2. Nutrient identification—methods and expressions

Among the different data sources, significant differences were encountered in the data expressions and conversion factors. Therefore it was necessary to standardize these data for making comparisons. For example, nitrogen to protein conversion factors are mostly standardized as 6.25 for potatoes, some researchers have suggested numbers as low as 5.7 and as high as 7.5 (Vigue and Li, 1975; Desborough and Weiser, 1974). The variation in units used to calculate micronutrient composition was extensive. Some of the units encountered were mg/g, g and mg/100 g, mg/kg, mg/100 kg, % dmb, ppm and %. All nutrients were standardized to g, mg, or mcg per 100 g fresh weight, unless otherwise noted. Differences in the data reported in this paper and those found in the source materials result from these recalculations.

3. Results and discussion

Tables 1–4 provide summary data on the varietal differences found in potatoes. The full data set is to be published as an on-line database (FAO, 2009b).

In addition to energy, which is derived almost entirely from their carbohydrate content, many varieties of potatoes contribute nutritionally important amounts of other nutrients and bioactive non-nutrients. Although nutrient content depends on a number of factors, variety is thought to be among the most significant factors (Toledo and Burlingame, 2006). Important nutrients in different varieties of potatoes include dietary fibre, up to 3.7% found in the skin of Red Pontiac variety (Mullin et al., 1993), the highest value found in flesh is for the variety Runa, grown in Argentina, which has a value of 3.3 g/100 g (Jiménez et al., 2009), ascorbic acid, up to 42 mg/100 g in the Korean grown Chaju (Han et al., 2004), potassium, with up to 693.8 mg/100 g found in Azucena of Spain (Casañas Rivero et al., 2003b), total carotenoids, with high-end values exceeding 2000 mcg/100 g for several varieties including *Phureja* group 1 of Peru (Bonierbale et al., 2009).

3.1. Water

The water content of fresh weight potatoes varies for a number of reasons, variety being one. Values reported in the literature for moisture content of fresh weight potatoes, raw, range from 63 to 87%. The lowest values was reported for the variety Chandramukhi, grown in India (Chatterjee et al., 2006); the highest for the Puca Quitish variety grown in Peru (Ritter et al., 2008). It is likely that some of the differences in nutrient composition are related to the differences in water content.

3.2. Carbohydrates

More than 95% of the energy in uncooked/unprocessed potato comes from its carbohydrate content. Data from studies on 53 different varieties of potato show starch contents as low as 9.1% for an Indian cultivar Kufri Bahar (Negi and Nath, 2002), and as high as 22.6% for another Argentine variety, Imilla Negra *S. tuberosum* ssp. Andigena (Jiménez et al., 2009).

3.3. Protein

Protein content showed a wide range of values, from a low of less than 1% for the Argentine cultivar Revolución (Jiménez et al., 2009), to a high of 4.2% for the Spanish Roja Riñon (Ritter et al., 2008).

4. Special issue of JFCA on potato

This special issue covers a range of topics, from new data on nutrition and biodiversity issues to topics relevant to food safety. The importance of the potato as one of the world's major staple crops is reflected in the geographic origin of the research contributions which include Algeria, Argentina, Brazil, Denmark, France, Holland, India, Italy, New Zealand, Philippines, Poland, Turkey and U.S.A.

Several articles quantify the nutrients and antioxidants. Burgos et al. (2009b) determined the total and individual carotenoid profiles in raw tubers of a sample of 23 accessions of *Solanum phureja* cultivated potatoes in two papers in this issue, first by spectrophotometry and HPLC. The authors identify two accessions which contains the highest concentration of zeaxanthin (1290 mg 100 g^{-1} FW) reported thus far for potatoes, including genetically modified potatoes; see Fig. 1 (p. 500). The companion paper by Bonierbale et al. (2009) presents a new method to estimate total and individual carotenoid concentrations by near-infrared reflectance spectroscopy (NIRS), and shows that this method is useful for characterizing a large germplasm collection at low cost and in reduced time compared to HPLC. Burgos et al. (2009a) look at how the ascorbic acid concentration of native Andean potato varieties is affected by environment, cooking and storage; in another paper by a slightly different team of researchers, Burgos et al. (2009c) study the protein, iron, zinc and calcium concentrations of potatoes following traditional processing as "chuño", and they conclude that the addition of water used in the preparation of this traditionally freeze–dried potato in the Peruvian highlands contributes to higher calcium levels.

In another paper from the International Potato Center in Peru, André et al. (2009) present their data on the influence of environment and genotype on polyphenol compounds and *in vitro* antioxidant capacity of native Andean potatoes (*S. tuberosum* L.). They conclude that the hydrophilic antioxidant capacity observed in potato extracts is the result of various and complex interactions that could be attributed to phenolic compounds, to other non-identified molecules, and to synergistic as well as

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