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Low glycemic index and increased protein content in a novel quinoa milk

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ABSTRACT

The goal was to develop a quinoa milk with increased amount of protein and low glycemic index. The adaptation of a process of rice milk was carried out to increase the extraction of proteins from grains to beverage. The product was analyzed for proximate analysis, sodium, starch, sugar, glycemic index, and consumer acceptance in comparison with a commercial rice milk. The inclusion of soaking step and the change of cooking step by replacing water by acidified saline solution (0.03 mol/L sodium chloride, pH 5.0) resulted in about 3 times more protein. Sodium content (20.3 mg/100 g) and lipids (0.2 g/100 g) were lower in comparison with other milks. Quinoa milk presented 5 g/100 g of starch and 9.7 g/100 g of glucose, but the glycemic index was low (52). Sensory acceptance was similar to that of rice milk, but differences were found for attributes and consumers groups. The group that need to consume vegetable milks showed higher acceptance for quinoa milk. The addition of flavor may be recommended to improve odor acceptance. Quinoa milk represents a novel alternative to current milk-substitute products that cause no known adverse effects in humans and which have increased protein content and low glycemic index.

1. Introduction

Consumer demand for healthy food and the increasing prevalence of adverse reactions have created a need for special foods (Swieca, Seczyk, Gawlik-Dziki, & Dziki, 2014). Among common adverse effects of food, reaction to cow milk is the most prevalent, reaching almost 80% of the population worldwide, and includes allergies and lactose intolerance (Bailey et al., 2013; Caffarelli et al., 2010). Usually, to avoid adverse reactions to cow milk, dairy and dairy products are eliminated from the diet, especially in the case of allergies (Boyce et al., 2010).

The demand for dairy-free products has increased by around 20% per year since 1997 in the USA (Adhikari, Dooley, Chambers, & Bhumiratana, 2010). There are many milk-substitute products in the market that are based on cereals, legumes, and nuts or modified cow milk, but they still show some limitations in fully replacing milk: some products are allergenic (Fernández-Rivas & Asero, 2014; Kattan, Cocco, & Järvinen, 2011), whereas others have high glycemic index (Mendosa, 2008) or low protein content (Mäkinen, Uniacke-Lowe, O'Mahony, & Arendt, 2015; Onning et al., 1999; Tarantola & Wujastyk, 2009). Additionally, most of these milk-substitute products are not fully accepted by consumers who may reject some sensory attributes, such as odor and flavor (Mäkinen et al., 2015).

Although soy milk is the most common milk-substitute due to its high protein content, 60% of the individuals who present reaction to cow milk also have reactions against soy (Zeiger et al., 1999). On the other hand, rice and some other types of plant-based milk have low or no protein content. Therefore, it is necessary to look for new alternatives to current milk-substitute products that cause no

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adverse effects in humans and that have better nutritional, sensory, and technological characteristics.

One such potential alternative is quinoa, an Andean grain used for human food because of its good nutritional quality. The grain of quinoa has around 9–18% total protein (Nowak, Du, & Charrondière, 2015; Vidueiros et al., 2015) with few reports of allergy or intolerance (Dutau & Rancé, 2011; Fok, Hissaria, Giri, Heddle, & Smith, 2013), suggesting that quinoa may be an interesting raw material for the manufacturing of non-dairy milk. To the best of our knowledge, only one report about quinoa milk exists in the literature, from the European market (Mäkinen et al., 2015). Although the product already presented some advantages over other plant-based milks, some issues concerning quality remained, especially with regard to its higher content of lipids, and low sensory acceptance. In this study, a quinoa-based vegetable milk with increased protein content, low glycemic index and gluten, dairy, and nut free was developed. These results provide new insights into the technological requirements to improve protein content in plant-based milk substitutes and is a first step to the development of a nutritious and low-allergenic quinoa milk that is well accepted by the consumers of plant-based milks.

2. Material and methods

2.1. Processing of quinoa milk

The procedure was adapted from the process to obtain of rice milk (Mitchell & Mitchell, 1998) by substituting 100 g of rice by 100 g of quinoa, previously cleaned for removal of foreign materials. Water was added in the proportion 1:7 (quinoa: water) and the mixture was autoclaved at 112 °C for 30 min for cooking and gelatinization of starch. Cooked grains with the water were ground in a semi-industrial blender (Oster, model 6826, Owosso, MI, USA) at medium speed for 6 min. Heat-stable bacterial alpha − amylase Termamyl 120L (Novozymes, Paraná, Brazil) was added for liquefaction of starch in the mixture, calculated on the proportion of 3 mL/kg of starch and applied at 90 °C for 120 min. Subsequently, amyloglucosidase AMG 300L (Novozymes, Paraná, Brazil), at a dose of 2 mL/kg of starch (Surmely, Alvarez, Cereda, & Vilpoux, 2001), was applied to produce glucose, at 60 °C for 60 min. Enzymatic inactivation was carried out by boiling for 15 min, followed by cooling to 40 °C. The beverage was filtered with a cloth and sunflower oil (1% of the initial mass of quinoa) was added with a mixer at medium speed for 6 min. The beverage was bottled in previously sterilized glass bottles, subject to pasteurization at 65 °C for 30 min in a water bath, followed by cooling to 4 °C on ice and water bath. The processing yielded 800 mL of quinoa milk. This was considered the basic process.

2.2. Changes in quinoa-milk processing

From the basic process, adjustments were made in the flowchart in order to raise the protein content of the quinoa milk (Fig. 1). In the first experiment, a Central Composite Rotatable Design (CCRD) with two factors (pH and saline concentration, -α: pH 4 and 0.0 mol/L NaCl; α: pH 6 and 0.06 mol/L NaCl, $p < 0.05$) was applied for response surface technique with protein as response variable. In the second experiment, the effect of: a) soaking quinoa in water for six hours (1:10; grain: water) to remove saponins; and b) maceration of grains in acidified saline solution overnight (12 h) before autoclaving, were evaluated to increase protein content. Each processing assay of both experiments was carried out three times. Analyses of each bottle (experimental unit) were run in triplicate. Proximate analyses and determination of sodium, sugar, starch and glycemic index were carried out. Besides, sensory acceptance of quinoa milk in comparison with a commercial rice milk, using a 9 cm-hedonic scale, with 160 panelists (18–50 years old, 70% females), previously characterized according to socio-demographic data, report of allergies and frequency of consumption of plant-based milk, was performed to characterize quinoa milk.

2.3. Composition

Proximate composition was carried out according to AOAC (2005) methods. Moisture was determined by gravimetric method, heating in an oven at 105 °C until constant mass; total nitrogen was determined according to the Kjeldahl method and converted into protein, using factor 6.25; total lipids were extracted by the Soxhlet technique with hot solvent (hexan) and afterwards were determined by gravimetry; ash was determined by gravimetry of incinerated sample, in muffle, at 550 °C. Total carbohydrates were calculated by difference. Sodium content was determined by flame photometry from the ashes (AOAC, 1990).

2.4. Analysis of sugar and starch

Sugar extraction was performed with lyophilized samples of quinoa milk (Amaral, Gaspar, Moreira, & Buckeridge, 2007). The hydroalcoholic extract was analyzed by HPLC-RID for sugar profile (Macrae, 1998). The pellet of the extraction, after centrifugation, was dried in a vacuum concentrator and used for determining starch.

2.5. Glycemic index

For glycemic index determination of the quinoa beverage, a trapezoidal method was used through the SlideWrite 7.0® program. Curve data with mean glycemic response from healthy individuals with pre-determined times (0, 15, 30, 45, 60, 90, and 120 min) (FAO/OMS, 1998) were used, as well as results from anhydrous glucose (Vetec Química Fina®) as standard value (100).

For glycemic response, 12 volunteers were recruited from both sexes with the following inclusion criterion: aged 20–50 years; Body Mass Index (BMI) in the eutrophia zone (18.5–24.9 kg/m^2) (WHO, 2014); without family history of glucose intolerance or diabetes mellitus type 2 (DM2) (Brazilian Ministry of Health, 2006), and not showing adverse reactions to quinoa.

Volunteers were 21 ± 2.91 years old, 50% females, and BMI of 22.77 ± 2.63. For tests, volunteers were oriented to have an empty stomach for 10–12 h, not take medicines or alcoholic beverages in the past 24 h, and not practice intense physical activity in the past 12 h. Tests occurred randomly on four non-consecutive days in the morning with a minimum interval of one day and maximum of two days among them.

For glucose analysis in the pre-determined periods, capillary blood glycemia was measured through finger-stick test with disposable lancets (AccuChek Safe T Pro Uno®, Mannheim, Germany) and digital glucometer (AccuChekAdvantage®).

For curve construction, basal glycemia (time 0) was measured. After this moment (5–10 min later), volunteers consumed 50 g of glucose (anhydrous glucose) diluted in 250 mL of water or 312.5 mL of quinoa milk that contains 50 g of carbohydrates.

2.6. Sensory analyses

The acceptance test was conducted with 160 untrained assessors, aged between 18 and 50 years old, 70% females. They were classified according to socio-demographic characteristics and consumption frequency of plant-based milk (soybean, rice, oat, almond, among others), as: (i) “no intake” if the consumption