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Crystallinity, thermal and pasting properties of starches from different potato cultivars grown in Brazil

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ABSTRACT

Starches from different potato cultivars were characterized as amylose and phosphorus content, crystallinity, thermal and paste properties. Statistical analysis of amylose content showed difference between starches samples and the cultivars Asterix and BRS Clara showed higher contents than others. Phosphorus content ranged from 633 to 966.7 mg kg^{-1}. The X-ray diffraction analysis showed that the crystallization of potato starches can be classified as B-type X-ray pattern, presenting crystallinity index ranging from 20.02% to 21.59%. Regarding thermal properties, the onset temperature did not show statistical difference between starch samples, in gelatinization and retrogradation analysis. As expected there was a significant decrease in peak temperature and enthalpy after the retrogradation of starches. For the pasting properties results showed significant difference in all cultivars. Pearson correlation coefficients showed that amylose content was negatively correlated to the onset, peak and final temperature of gelatinization, final temperature of retrogradation and pasting temperature. Phosphorus content was positively correlated to crystallinity index, peak viscosity and breakdown. Starches extracted from potato varieties showed different characteristics which can be useful to food and related industries that make use of potato starch, allowing wide options of use in various sectors of industrial application in Brazil.

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1. Introduction

Potato (*Solanum tuberosum*) is one of the most important crops in the feeding the world population. It is in fourth in world production, after rice, wheat and maize, presenting nearly 36.7 million tons harvested in 2013. In the same year was harvest in Brazil 3.57 million tons of potatoes [1]. However, it is estimated that less than 50% of potatoes grown worldwide are consumed fresh. Industrial uses of potatoes include products like frozen fries, flakes, snacks, flour and starch [2].

Potatoes are planted in almost all Brazilian states although commercial cultivation is practiced predominantly in the South and Southeast where soil and climatic conditions are more favorable and the cultivation is strongest. More recently, the commercial cultivation has advanced to the states of Goiás and Bahia, Midwest and Northeast regions of Brazil respectively, which have plateaus with soil and climate conditions highly favorable to culture [3].

The potato stands out as tuber culture of greater economic importance to Brazil, being the country self-sufficient in the production of the same, though the consumption being only of the tuber *in nature*. Due to it, the country depends on the import of potato starch, because although there are great areas of cultivation, there is no processing of these tubers for extraction and marketing of starch. Starch is composed exclusively of glucose residues linked by only two types of bonds: α-1,4 and α-1,6 glycoside linkages. Amylose and amylopectin make up 98–99% of the dry weight of native granules, with the remainder comprising small amounts of lipids, minerals, and phosphorus in the form of phosphate esters. Amylopectin in the granule is present in the semi-crystalline structure, while amylose is located in amorphous. Starch granules possess different X-ray patterns, displaying A, B and C-type, depending on their amylopectin branch chain-length [4,5].

Starch varies greatly in form and functionality between and within botanical species, and even from the same plant cultivar grown under different conditions. This variability provides starches of diverse properties [6]. Starch contributes greatly to the textural properties of many foods and has many industrial applications as a thickener, colloidal stabilizer, gelling agent, bulking agent, water retention agent and adhesive [6].

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Most starch consumed by humans has undergone some form of processing, which usually involves heating in the presence of moisture under shear, and then cooling. During heat treatment, the starch granules are gelatinized, losing their crystallinity and structural organization. On cooling, the disaggregated starch molecules firstly form a gel and then retrograde gradually into semi crystalline aggregates that differ in form from the native granules. Understanding the steps that occur during gelatinization and retrogradation of a particular starch are key steps to better predict the functional properties of processed starch from knowledge of the structure of native granules [5].

The different pasting properties of starch from different cultivars may be due to the difference in granular size, phosphorous content and amylose content of starch granules. Considering pasting properties potato starches has the highest pasting viscosity, this characteristics is largely attributed to starch-bound phosphate [7]. The presence of phosphate groups in starch increases the hydration capacity of starch pastes after gelatinization, resulting in a correlation between the starch phosphate content and the starch viscosity changes and the gel-forming capacity [8]. Potato starches has higher concentration of phosphate than the starches from others botanical sources [9].

The relationship between the structural characteristics and functional properties of starches has received much attention, since it is important to understanding how the functional properties of starch are affected by its structural features. This information could provide the basis for further manipulation of appropriate quality attributes [10] and understand starch behavior and utilization [7]. The cooking, textural and rheological properties of potatoes are related to the physicochemical, morphological, thermal and rheological properties of their starches [11].

Considering the importance of the potato as a world source of starch, the fact that Brazil is the second largest producer of cassava starch with large companies involved with this process, and the yield potential of potato starch in the country, this study aimed to determine the crystallinity, thermal and pasting properties of starches which were isolated from six potato cultivars grown in Brazil in order to obtain information about their properties targeting future applications.

2. Material and methods

2.1. Raw materials used

The potato cultivars were grown in the Pouso Alegre city, Minas Gerais state, Brazil. The cultivars used were: Asterix, Atlantic, BRS Clara, Ágata, Mustang and Fontane. The extractions were performed by physical method with three repetitions by cultivar [12]. The moisture, lipids and protein content of the starches were determined following the AOAC [13].

2.2. Amylose content

Amylose content was determined according to ISO-6674 method [14]. The amylose content was calculated from standard curves of amylose and the results were expressed as percentage of amylose.

2.3. Phosphorus content

Phosphorus content was determined according to Malavolta et al. [15]. The phosphorus content in the digestion was measured as inorganic phosphorus, using the vanado-molybdate method to calculate the phosphorus content of starch (absorbance read at 420 nm).

2.4. X-ray analysis

Crystallinity were determined as follows, the starches were kept in a desiccator containing saturated solution of $BaCl_2$ (25 °C, aw = 0.9) for 10 days for moisture balance. The X-ray diffraction patterns of the starches were then determined using a Wide Angle Goniometer unit (RINT2000, Rigaku, Tokyo, Japan), with Cu Kα radiation (λ = 0.1542 nm). The scanning speed was 1°/min at 50 kV and 100 mA. The relative crystallinity was quantitatively estimated based on the relationship between the peak and total areas following the method of Nara and Komiya [16] using the Origin software (version 7.5, Microcal Inc., Northampton, MA, USA).

2.5. Thermal properties (DSC)

The thermal properties of potato starches were analyzed using a differential scanning calorimeter (DSC) Pyris 1 (Perkin Elmer, USA). Starch samples (about 2.5 mg, dry basis) were weighed into aluminum pans, mixed with distilled water (7.5 µL) and sealed. The sealed pans were kept at room temperature for 2 h for balance and heated at a rate of 10 °C min^{-1} from 25 °C to 100 °C. An empty pan was used as reference. After running the samples in DSC, they were refrigerated at 4 °C for 14 days and analyzed again under the same conditions to determine the thermal properties of retrograded starches. Gelatinization temperature (onset, peak and final) and enthalpy change of native and retrograded starches were determined using the Pyris 1 software from Perkin Elmer, USA [17].

2.6. Pasting properties

Pasting properties of potato starches were determined using a Rapid Visco Analyzer (Model RVA 4, Newport Scientific Pty. Ltd., Warriewood, Australia), using starch suspensions (2.5 g of starch in 25 mL of water), corrected for the basis of 14% of moisture. The program used was Standard 1 and viscosity was expressed as RVU. Obtaining results for peak viscosity, breakdown, final viscosity, retrogradation and pasting temperature.

2.7. Statistical analysis

Analysis of variance (ANOVA) and Tukey's test were used to conduct the statistical analysis of results. Significant differences were reported for $p < 0.05$. Pearson correlation coefficients were determined to evaluate relationship between variables.

3. Results and discussion

Table 1 shows the chemical composition of potato starches. Protein content ranged from 0.19 to 0.31%. Lipids content of potato starches showed low values ranging from 0.04% (Atlantic) to 0.14% (Mustang). The amylose content of potato starches presented low variation. Asterix cultivar had the highest amylose content (23.43%) while Mustang cultivar had the lowest value (16.10%). Amylose and amylopectin contents affect starch granule architecture in pasting properties, textural attributes and application for processed food. Similar results were found by Buléon et al. [18] and Noda et al. [19]. Results from Asterix cultivar confirmed previous reported results in which the phosphorus content was negatively correlated with the amylose content in potato starch [7,20]. Phosphorus content of potato starches ranged from 633 mg kg^{-1} (Asterix) to 966.7 mg kg^{-1} (Atlantic). The range of the phosphorus content was similar to that reported by Noda et al. [7], Noda et al. [19], Veselovsky [21], Wiesenborn et al. [22] and Kim et al. [23].

X-ray patterns of potato starches from different potato cultivars are presented in Fig. 1. All samples showed a typical B-type X-ray pattern, with major peaks at 5.6, 15, 17, 18 and 23 in 2θ.

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