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Effect of single and dual heat–moisture treatments on properties of rice, cassava, and pinhao starches

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ABSTRACT

The effects of single and dual heat–moisture treatment (HMT) of rice, cassava and pinhão starches at 100 °C and 120 °C were investigated. The starches were adjusted to 22% w.b. moisture content and subjected to single HMT (autoclaved for 2 h) or dual HMT (after being autoclaved for 1 h, the material was allowed to stand for 24 h and was autoclaved again for more 1 h). Starch crystallinity, solubility, swelling power, thermal properties, pasting properties, and gel hardness were evaluated. The temperature variation affected more the starch properties than the single or dual HMT. The starch subjected to single HMT at 120 °C was the most applicable to food applications, where low swelling power, low viscosity and high thermal stability are necessary.

1. Introduction

Starch is a semi-crystalline biopolymer that serves as a reserve carbohydrate in many plants, including seeds, roots, tubers and cereals. Starch is composed of amylose and amylopectin, and the ratio between these two macromolecules varies with the starch source analysed. Variations in the properties of starches from roots, tubers, seeds, cereals, and between varieties of a particular source of starch may be the result of differences in composition, morphology, molecular structure and arrangement of amylose and amylopectin within the starch granule (Hoover, 2010).

Starch, in its native form, has limited application in the industry. Therefore, starches are often modified by physical, chemical or enzymatic processes to provide specific functional properties. Physically modified starch can be considered as a natural material and a highly safe ingredient; therefore, the presence and quantity of the starch in food is not limited by legislation, which is considered a great advantage compared to chemical and enzymatic modified starches. Heat–moisture treatment (HMT) is defined as a physical modification that involves the treatment of the granules at a low moisture content (<35%) for a specific period of time (15 min–16 h) at temperatures (84–120 °C) above the glass transition and gelatinisation temperatures, in which the gelatinisation does not occur because of the poor moisture content of the HMT (Hoover, 2010). The HMT allows for the control of the molecular mobility at high temperatures by limiting the amount of water (Chung, Liu, & Hoover, 2009; Maache-Rezzoug, Zarguili, Loisel, Queveau, & Buléon, 2008). The HMT promotes a change in the structural arrangement of starch chains within the amorphous and crystalline areas of the granules, resulting in changes in granular swelling, crystallinity, amylose leaching parameters, gelatinisation, retrogradation, thermal stability and paste properties (Hoover, 2010).

Numerous studies have demonstrated the effects of HMT in starches from different sources, including rice (Hormdok & Noomhorm, 2007; Zavareze, Storck, Castro, Schirmer, & Dias, 2010), potato (Varatharajan et al., 2011; Vermeylen, Goderis, & Delcour, 2006), cassava (Gunaratne & Hoover, 2002), maize (Miyazaki & Morita, 2005; Pukkahuta, Suwannawat, Shobsngob, & Varavinit, 2008), canna (Watcharatewinkul, Puttanlek, Rungsardthong, & Uttapap, 2009) and pinhão (Pinto et al., 2012). Starches from different botanical sources have different responses to the conditions of HMT. Starches with standard X-ray type B crystalline structure have been shown to be more susceptible to treatment than starches with standard X-ray type A crystalline structure (Gunaratne & Hoover, 2002).

The effects of a single or dual hydrothermal treatment, using both the heat–moisture treatment followed by annealing (ANN) and the annealing followed by heat–moisture treatment, on the molecular structure and physicochemical properties of corn, pea, lentil, and navy bean starches have been reported (Chung et al.,

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2009; Chung, Liu, & Hoover, 2010). These authors reported that HMT, ANN–HMT and HMT–ANN were more effective than ANN in increasing thermal stability and decreasing the extent of setback.

The HMT promotes a pronounced effect on starch properties, and the treatment of dual HMT with a time interval between the treatments can provide a differentiated rearrangement in the molecular structure of the starch. However, there are no reports in the literature regarding the effect of dual HMT with combinations of different temperatures for rice, cassava and pinhão starches. The objective of this study was to evaluate the impact of single and dual HMT at different temperatures on the physicochemical properties of these starches.

2. Materials and methods

2.1. Materials

Rice grains of cultivars IRGA 417, provided by the Instituto Rio-Grandense do Arroz (IRGA), pinhão seeds (*Araucaria angustifolia* Bert O. Ktze) and cassava starch purchased in a local market in the city of Pelotas, Brazil, were used. The amylose content of rice, pinhão and cassava starches were 36.6, 26.9, 18.5% d.b., respectively. All reagents used were analytical grade.

2.2. Isolation of rice starch

Rice grains were dehulled, polished using a laboratory mill (model PAZ-1-DTA, Zaccaria, Limeira, Brazil) and ground using laboratory mill (Model 3100, Perten Instruments, Hägersten, Sweden) to obtain rice flour. Rice starch was isolated with 0.1% NaOH, as described by Wang and Wang (2004). Briefly, the rice flour was soaked in 0.1% NaOH in a 1:2 (w/v) ratio for 18 h. Then, the rice flour was blended, passed through a 63 μm screen and centrifuged at 1200 × *g* for 5 min. The soft top layer was carefully removed, and the underlying starch layer was re-slurried. The starch layer was then washed twice with 0.1% NaOH and centrifuged. The starch layer was washed with distilled water and centrifuged. The starch was then re-slurried and neutralised with 1.0 mol/L HCl to a pH of 6.5 and centrifuged. The neutralised starch was washed with distilled water three times and dried at 40 °C.

2.3. Isolation of Pinhão starch

The starch was isolated according to the method described by Bello-Pérez, García-Soarez, Méndez-Montealvo, Nascimento, and Cordenusi (2006) with some modifications. The pinhão seeds were dehulled and embedded in distilled water in a ratio of 1:2 (w/v). The material was ground in a laboratory blender for 5 min. The ground slurry was screened through a cotton cloth, and the filtered slurry was then passed through a 200-mesh sieve. The material remaining on the cloth and sieve was washed five times with distilled water. The filtrated slurry was allowed to stand for 5 h. Then, the starch was decanted and dried in an oven at 40 °C until the moisture content reached approximately 11%. The dried starch was ground using a laboratory mill (Model 3100, Perten Instruments, Hägersten, Sweden).

2.4. Heat–moisture treatment (HMT)

The heat–moisture treatment (HMT) of starches was performed according to the method described by Hormdok and Noomhorm (2007). The rice, cassava and pinhão starches were conditioned to 22% moisture for subsequent heat–moisture treatment. The amount of water needed to achieve the desired moisture content of the starch was added slowly with a burette and was mixed in a planetary mixer (Model K5SS, KitchenAid, St. Joseph, USA) for 15 min at low speed and equilibrated at 4 °C for 24 h. The samples were autoclaved at 100 °C or 120 °C for 2 h in the single step treatments (HMT 100 °C or 120 °C). In the dual treatments, the samples were autoclaved at 100 °C or 120 °C for 1 h, allowed to stand within the glass container for 24 h at 20° and again autoclaved at 100 °C or 120 °C for more 1 h (HMT-HMT 100 °C or 120 °C). The treated samples were subsequently dried at 40 °C in an oven and were then ground.

2.5. X-ray diffraction

X-ray diffractograms of the starches were obtained with a XRD-6000 (Shimadzu, Kyoto, Japan) diffractometer. The scanning region of the diffraction ranged from 5 to 45°, with a target voltage of 30 kV, a current of 30 mA and a scan speed of 1°/min. The relative crystallinity (RC) of the starch granules was calculated as described by Rabek (1980) using the equation $RC(\%) = (Ac/(Ac + Aa)) \times 100$, where *Ac* and *Aa* are the crystalline and amorphous areas, respectively.

2.6. Swelling power and solubility

The swelling power and solubility of the starches were determined as described by Leach, McCowen, and Schoch (1959). Samples (1.0 g) were mixed with 50 ml of distilled water in centrifuge tubes. The suspensions were heated at 90 °C for 30 min. The gelatinised samples were then cooled to room temperature and centrifuged at 1000 × *g* for 20 min. The supernatant was dried at 110 °C to constant weight to quantify the soluble fraction. The solubility was expressed as the percentage of dried solid weight based on the weight of the dry sample. The swelling power was represented as the ratio of the weight of the wet sediment to the weight of the initial dry sample less the amount of soluble starch.

2.7. Gel hardness

The gel texture profile was analysed with Texture Analyser (TA.XTplus, Stable Micro Systems Ltd., Godalming, UK) according to the method described by Hormdok and Noomhorm (2007) with some modifications. After taking the RVA measurement, the gelatinised mixture in the canister was stored at room temperature (20 °C) for 48 h, allowing the formation of a solid gel (3.0 g, 14% moisture content (wet basis)). The canister was sealed with parafilm to prevent moisture loss during storage. The gels were punctured at 1.0 mm/s to a distance of 10.0 mm using a stainless steel cylindrical probe (P/20, 20 mm diameter). The peak force measured was reported as the gel hardness (height of the first peak).

2.8. Pasting properties

The pasting properties of the starch samples (3.0 g for rice and pinhão starches and 2.5 g for cassava starch, 14% moisture basis) were determined by using a Rapid Visco Analyser (model RVA – 4, Newport Scientific, Australia) and profile Standard Analysis 1. Starch was weighed directly in the RVA-4 canister, and 25 mL of distilled water was then added. The sample was held at 50 °C for 1 min, heated to 95 °C in 3.5 min, and then held at 95 °C for 2.5 min. The sample was then cooled to 50 °C in 4 min and was held at 50 °C for 2 min. The rotating speed was held at 960 rpm for 10 s, and the speed was then maintained at 160 rpm during the process. Parameters including pasting temperature, peak viscosity, breakdown, final viscosity and setback were recorded.

2.9. Thermal properties

The gelatinisation characteristics of starches were determined using differential scanning calorimetry (DSC model 2010, TA