Journal of Root Crops, 2013, Vol. 39 No. 1, pp. 78-83
Indian Society for Root Crops
ISSN 0378-2409

Effect of Autoclaving on Functional, Chemical, Pasting and Morphological Properties of Sweet Potato Starch

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Received: 3 March 2013; Accepted: 24 June 2013

Abstract

Starch is a major carbohydrate of sweet potato. Various attempts have been made to modify this highly flexible polymer with an aim to enhance the positive attributes of native starch. Hence in the present study, sweet potato starch was subjected to physical modification by autoclaving-cooling cycles. The effect of autoclaving on functional (water absorption capacity (WAC), oil absorption capacity (OAC), solubility, swelling power), chemical properties (amylose, protein, ash, pH, moisture and dry matter), pasting properties and morphological properties of sweet potato starch was evaluated. The results of functional properties showed that the WAC of autoclaved starch (AS) (3.95 g g^{-1}) was higher than native starch (NS) (0.62 g g^{-1}). The OAC was similar in native starch (0.73 ml g^{-1}) and autoclaved starch (0.80 ml g^{-1}). The swelling power of native and autoclaved starches from 50°C to 90°C ranged between 3.55-14.30 g g^{-1} and 4.56-6.26 g g^{-1} respectively. Solubility was in the range of 0.94-6.35 g g^{-1} for native starch and 0.68-1.47 g g^{-1} for autoclaved starch. A significant difference was noticed in functional properties between the starches. Amylose content increased by autoclaving from 18.56% (NS) to 24.98% (AS). Autoclaving increased protein (NS-0.20 g, AS-0.43 g), pH (NS-4.75, AS-5.95), while ash content decreased from 0.20% (NS) to 0.12% (AS). Significant difference was observed in chemical properties between starches. Autoclaving changed the pasting properties of starch. The peak viscosity of NS and AS was 4906 cP and 381 cP respectively and final viscosity was 3558.33 cP and 581.50 cP for NS and AS respectively. Significant difference was noticed in all the pasting properties of starches. Scanning Electron Microscopy (SEM) analysis revealed that autoclaving altered the native granular structure of sweet potato starch. The study showed that native sweet potato starch could be modified by autoclaving to obtain unique properties in food products.

Key words: Sweet potato starch, autoclaving, pasting properties, morphological properties, swelling power, solubility

Introduction

Carbohydrates are the major constituents of cereals, legumes, tubers and unripe fruits, accounting for up to 40–80% of the dry matter (Skrabanja et al., 1999). Starch is the principal carbohydrate in these vegetable sources. The unmodified starches have limited use in the food industry. Hence the food manufacturers usually desire starches with better behavioral characteristics than those provided by native starches (Adzahan, 2002). Starch modification will improve its properties particularly water holding capacity, heat resistant behavior, reinforce its binding capacity, minimize syneresis of starch and improve thickening (Adzahan, 2002; Miyazaki et al., 2006). There is a huge market for the many new functional and value added properties resulting from these modifications. Sweet potato (*Ipomoea batatas* (L.) Lam) is a tuberous rooted perennial plant belonging to the family Convolvulaceae (morning glory) (CIP, 2010).

The value of sweet potato starch is primarily determined by its physico-chemical properties, which are affected by amylose content, pasting properties, molecular structure, granule size and shape (Jacobs and Delcour, 1998). Sweet potato starch is characterised by a high pasting peak viscosity followed by rapid and major thinning on cooling (Collado et al., 2001). These characteristics limit the exploitation of sweet potato starch in food industry principally in products that require starches with quicker retrogradation rates like starch noodles. These requirements could be achieved by modifying native starch. The techniques for starch modification have been broadly classified into four categories; physical, chemical, enzymatic and genetic modifications (Neelam et al., 2012). Currently, there is substantial interest in physical modification, as it is considered to be more natural and safe as compared to chemical modification (Maache-Rezzoug et al., 2008). The physical method of autoclaving is particularly favourable for the food applications with novel functional properties. Hence the present study was undertaken to understand the effect of autoclaving on modification of native sweet potato starch properties.

Materials and Methods

Sample preparation

Pink skin sweet potatoes were purchased from local market in Salem, Tamil Nadu. The tubers were placed in a polyethylene bag to prevent loss of moisture during transportation to the laboratory of Department of Food Science, Periyar University, where analysis was conducted. Non edible portion (peel) was eliminated before the samples were washed with running cold water to remove impurities and edible portion of the sweet potato was cut into small pieces. Starch was isolated from the edible portion.

Method of isolation of starch

The edible portion of sweet potato was cut into small pieces and homogenized with 1 M NaCl solution using a blender (Riley et al., 2006). The mixture was filtered through triple layered cheesecloth; starch was washed with distilled water. The granules were allowed to settle and water was decanted. The sediment was centrifuged at 3000 x g for 10 min. Starch was removed, allowed to air dry overnight at room temperature and the dried starch was ground with mortar and pestle into fine powder.

Preparation of autoclaved sweet potato starch

Autoclaved sweet potato starch (AS) was prepared by the method suggested by Berry (1986). Native starch (NS) (60 g) was mixed with 210 ml of water and the mixture was pressure-cooked at 121^{o}C for 1 h in an autoclave. The mixture was cooled to room temperature and stored at 4^{o}C for 24 h. After three repetitions of the autoclaving and cooling cycles, the sample was freeze-dried and ground into fine particles.

Functional properties of native and autoclaved starches

Swelling power and solubility

Swelling power and solubility profiles of native and autoclaved sweet potato starches were studied by the method of Leach et al. (1959).

Water absorption capacity (WAC) and oil absorption capacity (OAC)

Water/Oil absorption capacity of native and autoclaved sweet potato starches were analyzed according to the method described by Abbey and Ibeh (1988). Ten millilitre of water/oil was added to 1 g of the starch sample in a centrifuge tube of known weight. The mixture was allowed to stand for 30 min; centrifuged (3500 g, 15 min) and the supernatant was discarded. The tube and the residue were weighed and the gain in weight was regarded as the water/oil absorption capacity.

Chemical analysis of native and autoclaved sweet potato starches

Moisture (MC) and dry matter (DM) contents were determined by the method of Adebayo et al. (2010). Ash, crude protein and crude fat contents were determined according to AOAC (AOAC, 1990; 2000). The pH was determined according to the method of Benesi (2005). Amylose and total starch were measured as per the method described by Williams et al. (1958) and Dubois et al. (1956) respectively.

Pasting properties

Pasting properties of sweet potato starches were evaluated with a Rapid Visco Analyzer (RVA) (RVA Tech Master, Perten Instruments, Japan) according to the method described by Noda et al. (2004).

Morphological properties

Granular morphology of the sweet potato starch samples was examined by a Scanning Electron Microscopy (SEM). Prior to the examination, starch and autoclaved starch were dried in hot air oven at 80°C and mounted on a stub with double sticky tape. The stub was then coated with a thin layer of gold in order to improve conductivity and prevent electron charging on the surface. The SEM was operated at 15 kV to image the samples.

Statistical analysis

The data reported in all the tables are average values of triplicate observations. Students t-test was used to determine the significant difference between groups using Microsoft Excel 2007 version.

Results and Discussion

The swelling power and solubility of native and autoclaved sweet potato starches were measured from a temperature range of 50°C to 90°C.The results of swelling and solubility are represented in the Figs. 1 and 2. Swelling capacity of native starch (3.55 to 14.30 g g^{-1}) was greater than autoclaved starch (4.56 to 7.45 g g^{-1}). Native and autoclaved starch presented a low swelling value in the initial stage (50°C), which indicated that this temperature was not high enough to induce water flux into starch granules. Further increase in temperatures was accompanied by enhanced swelling, specifying that gelatinization occurred gradually with temperature. Autoclaving treatments would have resulted in disruption of the granular structure, leading to partial water adsorption and hence autoclaved starch displayed low swelling. Swelling power is associated with amylose content. High amylose in AS showed the presence of a strong structural network and since the crystalline structure had strong linkage, it restricted swelling. Solubility of autoclaved starch was lower than native starch, this behaviour might be due to the production of resistant starch in the autoclaved samples, that accounted for insoluble material and thereby decreased solubility (Aparcio-Saguilan et al., 2005). In general, autoclaved samples presented lower swelling power and solubility than the corresponding native starch sample similar to the report of Aparcio-Saguilan et al. (2005). The WAC of native and autoclaved starches was 0.62 and 3.95 ml g^{-1} respectively. Higher WAC of autoclaved starch might have resulted from the linear chains produced by breakage of

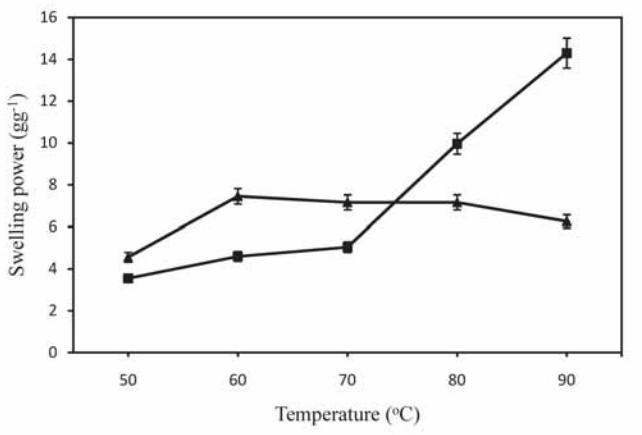

Fig. 1. Swelling power profiles of sweet potato starch samples ■ Native starch; ▲ Autoclaved starch

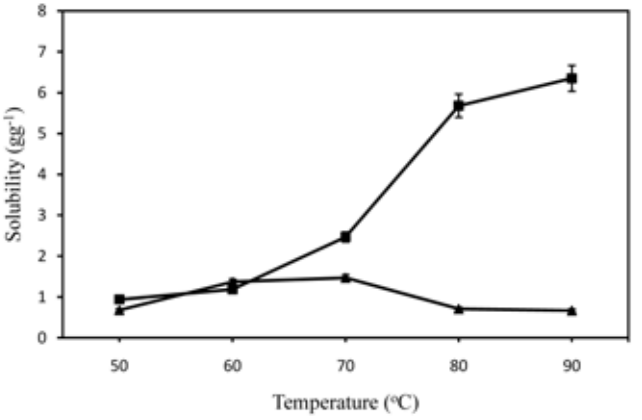

Fig. 2. Solubility profiles of sweet potato starch samples ■ Native starch; ▲ Autoclaved starch

amylopectin branches, which increased the water binding capacity (Shin et al., 2003). The OAC ranged from 0.73-0.80 ml g^{-1} for native and autoclaved starch. Autoclaving had no effect on the OAC.

Neither moisture content nor dry matter was changed (Table 1) after series of autoclaving treatment of native starch. Ash content was not changed after autoclaving which indicated that heating and cooling cycles had no effect on the mineral concentration. The pH of native starch was 4.75 while that of autoclaved starch was 5.95. Surprisingly autoclaved starch was found to have elevated levels of protein in contrast to the results of Aparicio-Saguilan et al. (2005). This could be due to the fact that the bound protein in the starch granule might have been released as a result of autoclaving. Autoclaving of starch reduced lipid contents (0.03%) slightly. Similar pattern of change was observed by Aparicio-Saguilan et al. (2005) regarding native and autoclaved banana starch. High

Table 1. Chemical composition of native and autoclaved sweet potato starches

Chemical compositon	Native sweet potato starch	Autoclaved sweet potato starch
Moisture (%)	14.44 ± 2.69[a]	14.97 ± 0.07[a]
Dry matter (%)	85.55 ± 2.69[a]	85.03 ± 0.07[a]
Ash (%)	0.20 ± 3.39[a]	0.22 ± 0.02[a]
pH	4.75 ± 0.09[a]	5.95 ± 0.12[b]
Protein (%)	0.13 ± 0.04[a]	0.43 ± 0.08[b]
Fat (%)	0.07 ± 0.01[a]	0.03 ± 0.01[a]
Amylose (%)	18.17 ± 1.54[a]	24.98 ± 0.46[b]

Mean values followed by different letters within the row are significantly different ($P < 0.05$)

temperature treatment may release some of the starch bound lipids, which might then become solubilised. Native starch exhibited lower amylose content (18.17%) than the autoclaved starch (24.98%) (Table 2), which might have occurred from the partial debranching of amylopectin due to the drastic pressure-heating, as reported by Aparcio-Saguilan et al. (2005).

RVA profile of native and autoclaved starch samples is given in Table 2. Pasting properties of native sweet potato starch in the present study are comparable with the previous reports of Tsakama et al. (2011). Peak viscosity of native starch (4906.66 cP) was greater than autoclaved starch (381 cP). Proteins determine the pasting characteristics of the starch showing a negative correlation to the peak viscosity of the starch paste (Seoul et al., 1999). This relation is supported by our results as autoclaved starch which is high in protein content showed a low peak viscosity. In addition, the lowest peak viscosity might have resulted from the gelatinization of starch sample, as lower peak viscosity has been reported for pregelatinized starch as compared to native starch (Ozturk et al., 2011).

Table 2. RVA profile of native and autoclaved sweet potato starches

Parameters	Native sweet potato starch	Autoclaved sweet potato starch
Peak viscosity (cP)	4906.66 ± 505.02[a]	381.00 ± 22.00[b]
Trough viscosity (cP)	2385.00 ± 175.76[a]	370.66 ± 20.50[b]
Break down (cP)	2392.66 ± 370.93[a]	10.66 ± 1.52[b]
Final viscosity (cP)	3558.33 ± 213.35[a]	581.50 ± 43.50[b]
Set back (cP)	1102.66 ± 49.70[a]	211.00 ± 23.00[b]
Peak time (min)	04.87 ± 0.00[a]	06.90 ± 0.03[b]
Pasting temperature (°C)	70.68 ± 17.46[a]	50.07 ± 0.02[b]

Mean values followed by different letters within the row are significantly different ($P < 0.05$)

Kaur et al. (2007) observed a negative correlation between break down viscosity and amylose. This relation holds true in our observations as autoclaved starch had the lowest break down viscosity. A significant difference was observed in trough and break down viscosities among the starch and autoclaved starch. Final viscosity of native starch and autoclaved starch was 3558.33 cP and 581.50 cP respectively. Set back viscosity of native starch was significantly higher than autoclaved starch (Table 2). The difference in set back among samples may be due to the amount and the molecular weight of amylose leached from the granules and the remnant of the gelatinized starch (Loh, 1992). Pasting temperature provides an indication of the minimum temperature required for cooking the sample. Autoclaving reduced the pasting temperature of starch. These results showed that the autoclaved starch will be cooked faster possibly because it is already in a pregelatinized form and indeed with less energy thereby saving cost and time compared to the native starch.

Scanning Electron Micrographs (SEM) of native and autoclaved sweet potato starches are illustrated in Fig.3. Illustrations of native starch samples showed the presence of starch granules from small to large sizes.The surface of the native starch granules appeared to be smooth with no indication of any fissures. Zhu et al. (2011) also observed smooth granule surface of sweet potato starches without cracks. In our study also most of the sweet potato starch granules were polygonal in shape, however round and irregular shapes were also noticed. Polygonal shape for sweet potato starch granules has also been reported by Huang (2008). Single individual granules as well as compound granules were observed in the illustrations. According to Newman et al. (2007) compound granules were ascribed to the presence of residual protein that

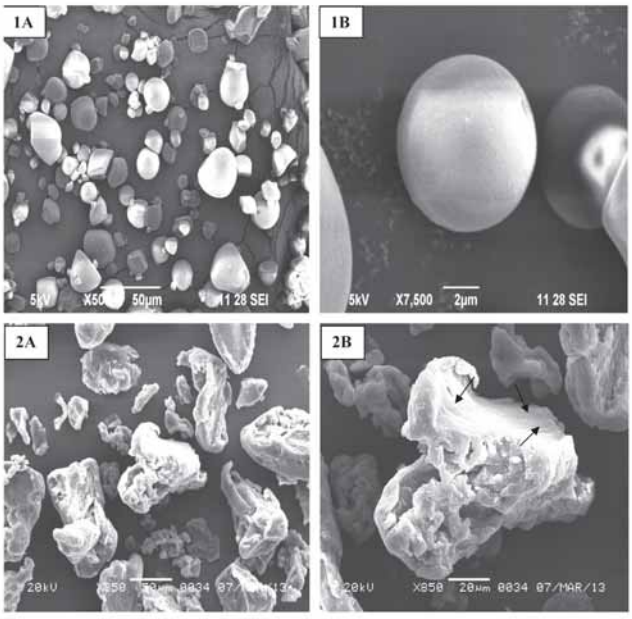

Fig. 3. Scanning electron micrographs of sweet potato starch samples. 1-Native starch (A-500X and B-7500X magnification); 2-Autoclaved starch (A-350X and B-850 X magnification)

generated slight gelatinization on the surface of granules and caused the granules to adhere together to form aggregates. On the other hand, autoclaving and cooling cycles has been shown to influence the granule morphology of native sweet potato starch. After autoclaving and cooling cycles, the granular structure disappeared and some granules with little holes on the surface appeared. The outer surface of the starch in photo micrograph (2B), granules with numerous fissure and concentric layers were visible, these layers correspond to a sequence of organized and disorganized material, often refered to as crystalline and amorphous zones by some authors (French, 1984) or "crystalline hard" and "semicrystalline soft" by others (Gallant et al., 1997).

Conclusion

Autoclaving decreased the swelling and solubility of native sweet potato starch. Water absorption capacity increased after autoclaving sweet potato starch. Significant changes in granule morphology, amylose content and pH were obtained after hydrothermal treatment. A dramatic influence on all the pasting properties was noticed, showing significant differences after modification. The low pasting profile of autoclaved starch might be due to the breakdown of the starch granule structure. Generally sweet potato starch exhibits high peak viscosity and more free swelling. These characteristics limit the utilisation of sweet potato starch in food industry especially in the preparation of starch noodles. The use of autoclaving processes has the potential of giving sweet potato starch low pasting viscosity and low swelling, thus over coming the limitation of sweet potato starch in the preparation of starch noodles. High water absorption capacity of autoclaved starch can also be made use of in the preparation of confectionary products.

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