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Effect of Different Heat-moisture Treatments on the Physicochemical Properties of African Locust Bean (*Parkia biglobosa*) Starches

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ABSTRACT

***Parkia biglobosa* starch was subjected to different heat-moisture treatment (HMT) at different moisture contents (15, 20, 25, and 30%) at 110°C for 16 hours. The content of resistant starch (RS) was the lowest (33.38%) in the untreated native Parkia and increased in the samples with HMT-15 (37.79%), HMT-30 (39.64%), HMT-25 (46.63%), and HMT-20 (50.14%), showing significant increase ($P < 0.05$) in RS following the HMT. There was a reduction in the swelling power and pasting properties of HMT starches, but the solubility of the HMT starches was higher than that of untreated native starch. Differential scanning calorimetry and the changes in the X-ray diffraction (XRD) patterns confirmed the effect of HMT on Parkia starch. Therefore, replacing native Parkia with heat-moisture treated Parkia starch leads to the development of new products from RS-rich powder with high RS levels and functional properties.**

Keywords: African locust bean, Differential scanning calorimetry, Digestibility, Physical treatment, Starch solubility, X-ray diffraction pattern.

INTRODUCTION

African locust bean (*Parkia biglobosa*) is a perennial tree legume that belongs to the sub-family Mimosoideae and family Leguminosae. It grows in the savannah region of West Africa (Pelig-Ba, 2009; Ihegwuagu *et al*., 2009). African locust bean tree is an important food tree for both man and livestock such as husks and pods, and plays a very vital role in the rural economics of West African countries; virtually every part of the species is of value as food or fodder (Tee *et al*., 2009). The yellow pulp surrounding the seed is edible in many forms and the seeds are made into condiments extensively as flavoring and additives to soups and stews; the seeds are good source of protein, lipids, carbohydrates, and phosphorous, while the fruit pulp is high in carbohydrates and vitamin C (Tee *et al*., 2009; Ergun, 2012; Ahmadi and Baker, 2001). Qualitative determination of the chemical and nutritional composition of Parkia seeds has revealed that it is rich in starch, lipids, protein, carbohydrates, soluble sugars, and ascorbic acid (Ihegwuagu *et al*., 2009).

Starch is of considerable commercial importance because of its numerous desirable functional properties, thus, needed in various industries. Functionality of starch includes the ability to absorb water, gel formation, and granular organization (Blazek and Copeland, 2008; Majzoobi *et al*., 2011). The peculiar physicochemical characteristics of starch have significant impact on their functional and rheological behavior, affecting their suitability for specific uses. Starch is not completely digested and absorbed in the small intestine, as it was previously thought before the early 1980s. Englyst *et al*. (1992) first recognized

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the presence of starch fraction resistant to enzyme hydrolysis during their research on measurement of non-starch polysaccharides. Usually, starch products contain a portion that digests rapidly i.e. rapidly digesting starch (RDS), a portion that digests slowly i.e. slowly digesting starch (SDS), and a fraction that is resistant to digestion i.e. resistant starch (RS) (Englyst *et al*., (1992). RS has potential physiological benefits similar to dietary fiber and unique functional properties. Heat-moisture treatment (HMT) modification has been used to produce RS by holding high amylose starch with 30–40% moisture content at 90–120°C for 1–4 hours (Brumovsky and Thompson, 2001). HMT may increase RS levels in starch by (1) growth or perfection of existing crystals (Hoover and Vasanthan, 1994), (2) increased interaction between amylose and amylopectin (Kawabata *et al*., 1994), and/or (3) transformation of single-chain amylose into its double helical crystals (Lorenz and Kulp, 1982). In general, however, RS content of granular starches is positively correlated with the level of amylose (Themeier *et al*., 2005). Chung *et al*. (2009) reported that the RS levels of corn, peas, and lentil starches increased from 4.6, 10.0, and 9.1% to 12.3, 14.5, and 14.7%, respectively, after HMT. Similarly, Lin *et al*. (2011) reported that resistant starch (RS) content of normal corn starch was increased from 23.3% for native starch to 47.7 to 83.8% for starch modified by HMT. Consequently, it is considered worthwhile to investigate appropriately modified Parkia starch and, perhaps, develop an alternative way to avoid excessive utilization of common starches in the long term.

In our previous work, we showed the yield improvement of resistant starches from African locust beans as influences by different treatments (Sankhon *et al*., 2012). Thus, physical properties of Africa locust bean seeds starch fractions are yet to be determined. Therefore, the objective of the present study was to evaluate the influence of HMT on the formation and properties of resistant starches from the African locust bean starch fractions. This could be of great importance not only to the development of novel starches for food applications but also to advance the understanding of the influence of moisture content on the properties of Parkia resistant starch.

MATERIALS AND METHODS

Materials

African locust bean (*Parkia biglobosa*) seeds were purchased from the local market in Madinah (Conakry, Guinea) in August, 2011, and shipped to Wuxi, China. Porcine pancreatic α-amylase and amyloglucosidase were purchased from Sigma-Aldrich (Shanghai, China) and were used for analyzing the content of the RS. Chemicals and solvents in this work were of analytical grade.

Isolation of Starch

Isolation of starch from Parkia seeds were performed according to the method of Perez-Sira and Amaiz (2004) with slight modification. Visible dirt and contaminants were removed from the dark-colored Parkia seeds (1 kg), which were then steeped in a solution of sodium hypochlorite (35 g) and potassium hydroxide (50 g) in water (2 L) at room temperature (28°C) for 3 hours. The pH of the steeping solution was adjusted to 9 using 1M HCl solution and the mixture was maintained at 100°C in a thermostat water bath for 3 hours. The solution was then drained and the seeds were immersed in water and left overnight at ambient temperature. Finally, the seeds were thoroughly washed, manually de-hulled, and the cotyledon was washed repeatedly until the wash pH was neutral. The cotyledon was blended with water for 24 hours using a domestic blender. The homogenate was filtered through muslin cloth and the filtrate was allowed to settle overnight. The supernatant was decanted, and the sediment was centrifuged at 4500 rpm for 10 minutes using a ZOPR-52D refrigerated centrifuge (Hitachi Koki Co. Ltd., Tokyo, Japan). The

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sediment of starch was re-suspended in water, and the process was repeated six times. The resultant starch was dried at 60°C in a hot air oven, then, ground into powder using a mortar and pestle and stored in cellophane.

Production of Heat Moisture Treated Starch (HMT)

Heat-moisture-treated Parkia starch was produced according to the method of Hoover and Manuel (1996) with slight modification. The moisture levels of the starch samples were adjusted to 15, 20, 25%, and 30% (the moisture level of the raw starch was predetermined) by dispersing the samples in appropriate amounts of distilled water. The samples were sealed in different stainless steel containers and equilibrated at 4°C overnight. The sealed samples were heated in a thermostatically controlled convection oven at 110°C for 16 hours. The samples were cooled at room temperature (28°C). The contents were removed from the containers and dried at 30°C to uniform moisture content (~8%). All samples were ground and screened through a 70 mesh sieve. Based on the treatment moisture content, the resulting HMT starches were referred to as: HMT-15, HMT-20, HMT-25, and HMT-30.

Resistant Starch Determination

Resistant starch content was determined according to the method of Goñia *et al*. (1996) with some modifications. One hundred mg of the prepared sample on dry basis was dispersed in 9 mL of water, incubated with 1 mL α-amylase solution ("EC 3.2.1.1"enzyme activity 2,500 U mL^{-1}) at 37ºC for 24 hours under constant shaking to hydrolyze digestible starch, then, deposited with 95% ethanol (ethanol volume was four times of the residue) for 12 hours. The residue obtained was washed with 95% ethanol twice, air-dried and treated with KOH solution (4 mol L^{-1}, 3 mL) to solubilize resistant starch. Resistant starch solution obtained was adjusted to pH 4.75 with 2 mol/L hydrochloric acid and 0.4 mol L^{-1} sodium acetate buffer, incubated with 1 mL amyloglucosidase solution (enzyme activity 1,500 U mL^{-1}) at 60ºC for 45 minutes under constant shaking, and then heat treated at a water bath of 95ºC for 5 minutes to inactivate the enzymes. Glucose content formed in the solution was determined by titration with Fehling reagent. Resistant starch was calculated as glucose (g)×0.9 and the content expressed as percentage of RS in the analyzed sample.

Apparent Amylose Content

The starch was defatted with refluxing 85% methanol for 16 hours at 65°C in a Soxhlet extractor, the product was dried and analyzed for apparent amylose content, which was determined following the method of Mohana *et al*. (2007) based on the reaction between amylose and iodine. Starch (100 mg) was weighed accurately and dissolved in ethanol (1 mL, 95%) and NaOH (1N, 9.2 mL) and left overnight and made up to 100 mL in a volumetric flask. An aliquot (5 mL) of this solution was then added with acetic acid (1N, 1 mL) and iodine solution (2 mL, 0.2% I_2 in 2% KI) and the volume made up to 100 mL with distilled water and mixed. After 20 minutes, the absorbance was measured at 620 nm (Shimadzu spectrophotometer UV-2401 Kyoto, Japan), using a blank with 5 mL 0.09N NaOH, 1 mL acetic acid and 2 mL iodine solution and made up to 100 mL in total volume. The above analysis was carried out in 2 replicates.

Swelling Power and Starch Solubility

The method of Adebowale *et al*. (2002) was employed for the determination of the effect of temperature on the starch solubility and swelling. A starch sample (1.0 g) was accurately weighed and quantitatively

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transferred into a clear dried test tube and re-weighed (W1). The starch was then dispersed in 50 cm^3 of distilled water using a blender. The resultant slurry was heated to the desired temperature (95°C) for 30 minutes in a water bath. The mixture was cooled to 28°C and centrifuged (3000×g for 15 minutes). Aliquots (5 mL) of the supernatant were dried to a constant weight at 110°C. The residue obtained after drying the supernatant represented the amount of starch solubilized in water. Solubility was calculated as grams per 100 g of starch on a dry weight basis. The residue obtained from the above experiment (after centrifugation) with the water it retained was quantitatively transferred to the clean dried test tube used earlier and weighed (W2).

Swelling of starch=W_2-W_1/Weight of starch (1)

Scanning Electron Microscopy (SEM)

Examination by SEM was carried out using at 20kV accelerating voltage and the samples were dried at 30°C to uniform moisture content (~8%). Samples were gold coated and scanned using an Electroscan Quanta 200 environmental scanning microscope (FEI Company, Netherlands).

X-ray Powder Diffraction of Starch

X-ray powder diffraction analysis (XRD) (Shimadzu Lab XRD-6000) was used to examine the crystalline properties of starch samples (both native starches and modified starches). The scanning region of the 2θ angles was from 2° to 40°, which covered all the significant diffraction peaks of the starch crystallites.

Pasting Properties

The pasting properties of the starch samples at different moisture contents were evaluated using a rapid visco-analyzer (RVA) (Newport Scientific Pty Ltd, Warriewood, Australia) where peak viscosity, trough, breakdown, final viscosity, set back, and pasting temperature were read from the pasting profile. Briefly, 3 g of each sample was mixed with 25 mL of distilled water. Each sample then underwent a controlled heating and cooling cycle with constant shear, where it was held at 50°C for 1 minute, heated from 50 to 95°C at a rate of 6 °C min^{-1}, then held at 50°C for 5 minutes.

Differential Scanning Calorimetry (DSC)

Calorimetric measurements (gelatinization temperature and enthalpy) of the processed Parkia starch product were analyzed with the Pyris-1 differential scanning calorimeter (DSC) (PE, USA). Starches (2.6 mg, dry weight) was loaded into a 40 μL, capacity aluminum pan (Mettler, ME-27331) and distilled water was added with the help of a Hamilton microsyringe to achieve a starch–water suspension containing 70% water. Samples were hermetic ally sealed and allowed to stand for 24 hours at room temperature 28°C before heating in the DSC. The samples were then heated from 65 to 120°C at a rate of 10 °C min^{-1}. An empty pan was used as reference. Onset (T_o), peak (T_p), and conclusion (T_c) temperatures of gelatinization as well as gelatinization enthalpy changes (DH) were determined.

Statistical Analysis

All measurements were done in triplicate, and the results were averaged. The results were processed by one-way variance analysis test (ANOVA) using SAS (version 8.1) analytical software. Differences at $P \leq 0.05$ were considered to be significant.

RESULTS AND DISCUSSION

Influence of HMT on Parkia Starch

The resistant starch (RS) contents of the untreated and treated Parkia starches are

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presented in Table 1. The enzyme-resistant portion of native starch was the lowest (33.38%), while the RS values with HMT starches increased significantly ($P \leq 0.05$), 37.79% for HMT-15, 50.14% for HMT-20, 46.63% for HMT-25, and 39.64% for HMT-30. This corroborates with the work of Lin *et al*. (2011) where native corn starch increased significantly after HMT. These results are similar to those of corn, pea, and lentil starches modified by HMT to yield products with increased amounts of resistant starch, as reported by Chung *et al*. (2009). Their report pointed out that the rearrangement of the starch molecule into an enzyme-resistant structure was caused by increasing RS during HMT under non-gelatinized conditions. Moisture content is the key factor in RS formation during HMT. It has been shown that water creates hydrogen bonds between molecular chains within the starch granule (Kurakake *et al*., 1997), therefore, it is reasonable to suggest that the moisture content of the starch prior to HMT can be optimized to maximize the resistant starch content during HMT. As a result, controlling the water content during HMT may help increase the resistant starch content.

The apparent amylose content of Parkia starch with HMT increased compared to that of untreated starch, as shown in Table 1. The amylose content of Parkia starch was in the range of 39.64–46.63% Table 1. This value is comparable to amylose contents reported by Su *et al*. (1997) and Biliaderis *et al*. (1979), who found amylose contents of 41.4–41.5 and 36.0–35.0% for navy and red kidney bean starches, respectively. Perera and Hoover (1999) also reported higher amylose content in large-size *A*-type granules in six wheat cultivars. However, our results on RS content corroborate with the general amylose level reported. It is likely that augmentation in amylose formation is susceptible to the formation of longer or more ordered helical segments by amylose–amylose and/or amylose–amylopectin interactions formed with HMT. The apparent amylose content of HMT-20 was the highest of all the samples, and its RS level was also the highest of all the samples, at 50.14%. Amylose content has a significant effect on functional and physicochemical properties, including pasting, gelatinization, retrogradation and swelling of starch.

Influence of Temperature on Swelling

The influence of temperature on the swelling power of all the starches (Table 2) revealed that all the starches swelled as the temperature increased in the following order: native, HMT-30, HMT-25, HMT-15, and HMT-20. The lower swelling power of HMT (15, 20, 25, and 30 min) compared to native starch (Table 2) could be attributed to a restriction in the percolation of water within the starch matrices as a result of increased starch crystallinity after modifications. The swelling power of HMT starch was less than that of native starch. During starch gelatinization in the presence of water, the granules absorb water and swell. Our results are in accordance with the work of Adebowale *et al*. (2005) and many

Table1. Resistant starch and the thermal properties of native starch (control) with HMT Parkia starch.[a]

Samples	RS contents	ApA contents	T_o (°C)	T_p (°C)	T_c (°C)	ΔH (J g^{-1})
Untreated	33.38 ±0.32^{e}	39.64±1.2^{e}	66.38^{e}	70.59^{e}	64.56^{e}	9.69^{a}
HMT-15	37.79 ±0.11^{d}	40.59±o.32^{d}	74.24^{d}	76.89^{d}	79.95d	4.74^{c}
HMT-20	50.14 ±0.14^{a}	46.63±0.61^{a}	76.54^{c}	82.79^{c}	86.29^{c}	3.09^{e}
HMT-25	46.63 ± 0.42^{b}	43.05±0.45^{b}	81.64^{a}	86.44^{b}	89.57^{b}	4.42^{d}
HMT-30	39.64 ±0.23^{c}	41.91±1.42^{c}	80.69^{b}	87.14^{a}	98.31^{a}	6.59^{b}

[a] RS: The resistant starch, ApA: Apparent amylase contents and the thermal properties of untreated and HMT Parkia starch. Means values with different letters within each column are significantly different ($P \leq 0.05$).

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Table 2. Swelling power and solubility of Parkia starch with the modified derivative as functions of temperature.

Property	65 °C	75 °C	85 °C	95 °C
Swelling power				
Untreated starch	4.94±0.3[a]*	6.38±0.4a	7.96±0.6[a]	13.05±0.4[a]
HMT-15	2.73±0.2[d]	4.56±0.3[d]	5.44±0.5[d]	6.83±0.6[d]
HMT-20	2.54±0.6[e]	3.02±1.2[e]	3.47±0.9[e]	4.07±0.4[e]
HMT-25	2.96±0.3[c]	5.44±0.5[c]	6.54±0.4[c]	8.28±0.3[c]
HMT-30	3.04±0.5[b]	5.63±1.1[b]	6.96±0.9[b]	10.21±0.7[b]
Solubility	65 °C	75 °C	85 °C	95 °C
Untreated starch	6.41±0.5[e]	9.34±0.7[e]	13.36±0.5[e]	16.33±0.3[e]
HMT-15	16.96±0.4[c]	26.51±0.6[c]	31.76±0.6[c]	42.87±0.4[c]
HMT-20	19.41±0.3[b]	30.22±0.5[b]	41.69±0.4[b]	52.57±0.5[b]
HMT-25	15.31±0.3[d]	21.04±0.4[d]	29.43±0.3[d]	38.76±0.3[d]
HMT-30	22.29±0.5[a]	31.53±0.7[a]	43.68±0.6[a]	54.87±0.4a

* Means values with different letters within each column are significantly different ($P \leq 0.05$).

other millet base foods (Amadou *et al*., 2011). They reported that the swelling capacity of starch was diminished by HMT, accounting for the orderly rearrangement of starch molecules and restriction of starch hydration. It is also presumed that strong interactions may have been formed between AM and AM chains during HMT. The swelling capacity of HMT-15, HMT-20, HMT-25, and HMT-30 had increased slightly and exerted a negative effect on RS compared to that of HMT-20.

Influence of Temperature on Solubility

Table 2 shows that all the Parkia starches solubilized at different rates as a function of temperature. The orders for the solubility were HMT-30, HMT-20, HMT-15, HMT-25, and native. The solubility profile of the native and HMT starches at different temperatures is shown in (Table 2) compared to the native starch, the solubility of heat-moisture treated starch increased as the temperature increased (65–95°C). The solubility of HMT starches increased significantly when the temperature was increased above 70°C. Similar results for increased solubility after HMT were confirmed by studies involving maize starch (Kurakake *et al*., 1997), finger millet starch (Adebowale *et al*., 2005), indicating that HMT starches had a higher solubility than native starch. The solubility increased as the temperature increased because of an increase in the mobility of the starch molecules, which facilitated dispersion of the starch molecules in water.

Scanning Electron Microscopy

Scanning electron micrographs of Parkia native starch and HMT samples were obtained and compared with that of untreated Parkia starch. Figure 1 clearly illustrates the modification of native Parkia starch structure by HMT. While native starch exhibited a small granular appearance (Figure 1a), the granular structure disappeared and a continuous network with irregular shape was formed in the HMT-15 and HMT-20% modified starch (Figure 1, b-c). On the other hand, the treatment of HMT-25 and HMT-30% appeared to make the starch structure more compact and dense (Figure 1, d-e). These changes are attributed to the interplay of factors such as (1) amylose content, (2) interactions between starch chains, (3) arrangement of amylose chains within the amorphous domains, and (4) lipid–amylose complexes (Hoover and Manuel, 1996).

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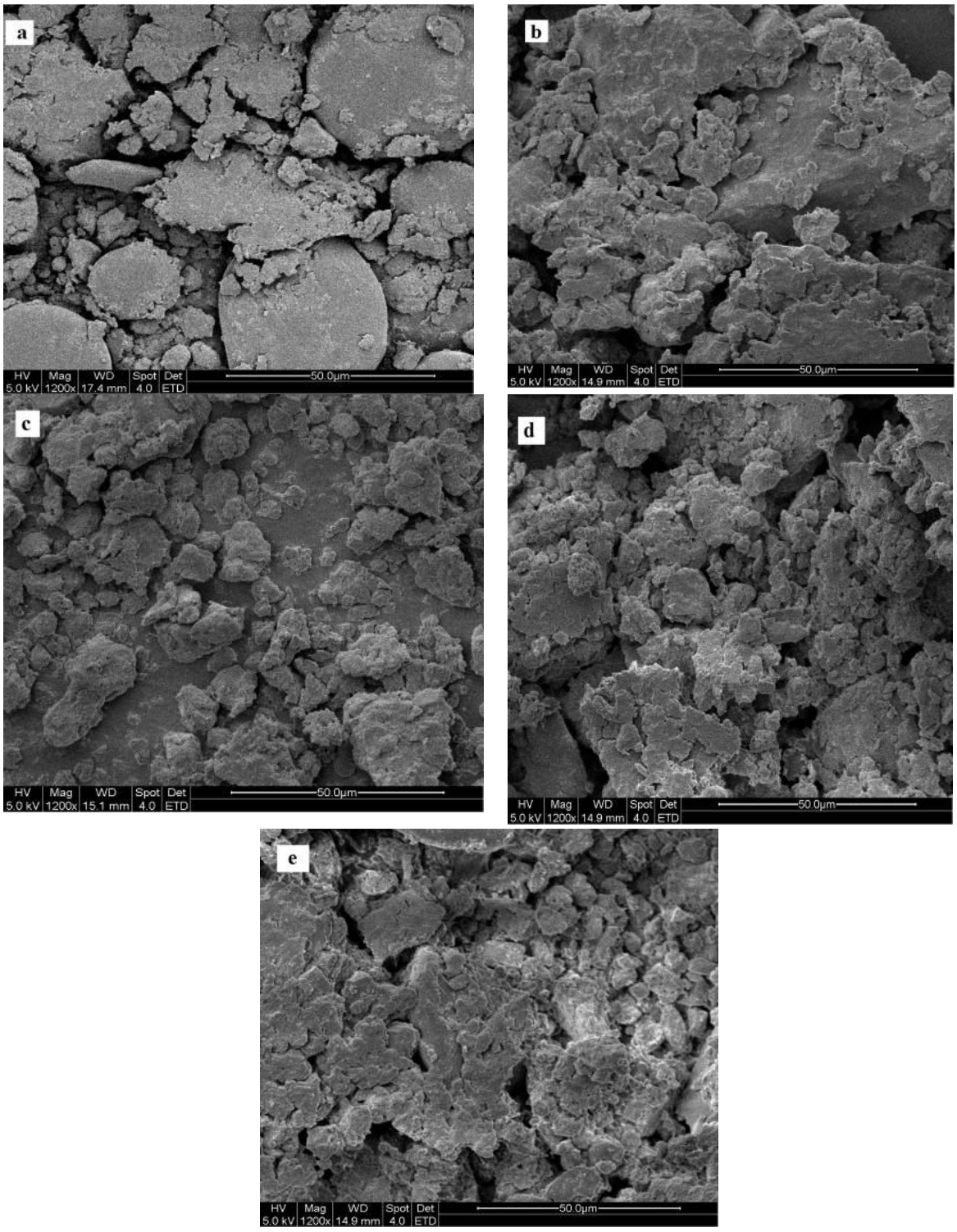

Figure 1. Scanning electron micrographs of untreated (native) starch and the influence of HMT: **(a)** Native starch Parkia starch; **(b)** HMT-15: Heat-moisture-(15%) treated Parkia starch; **(c)** HMT-20: Heat-moisture-(20%) treated Parkia starch; **(d)** HMT-25: Heat-moisture-(25%) treated Parkia starch, **(e)** HMT-30: Heat-moisture-(30%) treated Parkia starch.

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However, this change was also observed in the case of Parkia starch. Similar results were reported by Pereira and Hoover (1999) on potato starch. The role of anomalous amylopectin contributions in the control of enzyme resistance explains the value of Parkia starches as raw materials used on the study of the effect of HMT on RS processing. In this study, crystalline perfection, seen in Figure 1 (b–e), and amylose–amylose and/or amylose–amylopectine interactions might have influence the RS level.

X-ray Powder Diffraction of Starch

The X-ray diffraction pattern and intensities are demonstrated in Figure 2. All the Parkia starches obtained showed the characteristic C-type pattern of legume starches, however, it is a mixture of *A*- and *B*-type starches as described by Buleon (1998). Moreover, the type '*A*' X-ray pattern (shown mainly by cereal starches) and '*B*' patterns represent the true crystalline forms of starch. This is in agreement with the results of Mun and Shin (2006), who also obtained a B-type crystallinity pattern for RS from sources such as wheat and corn. The native Parkia starch has a characteristic "*A*" pattern, which shows strong intensity at peaks of 5.75, 17.5, and 23.4 Å. Differences in X-ray intensity were linked to the manner in which the double helices were arranged within the crystalline domains of the granules. After treatment, the HMT starches (HMT-15, HMT-20, HMT-25, and HMT-30) displayed relatively strong diffraction intensities at peaks of 5.75, 15.0, 17.5, 22.3, and 30.5 Å. The intensity of the peaks of HMT Parkia starch was higher than that of native starch at peaks of 22.3 and 30.5 Å. This result indicated that moisture content played an important role in starch crystalline formation. Appropriate moisture content results in structural rearrangement especially realignment of bonding forces in starch granules and the formation of ordered double helical amylopectin side-chain clusters. This result further demonstrated the outcome of the limitation of starch swelling (Table 2). An A-type XRD pattern for rice starch remained unchanged after HMT at

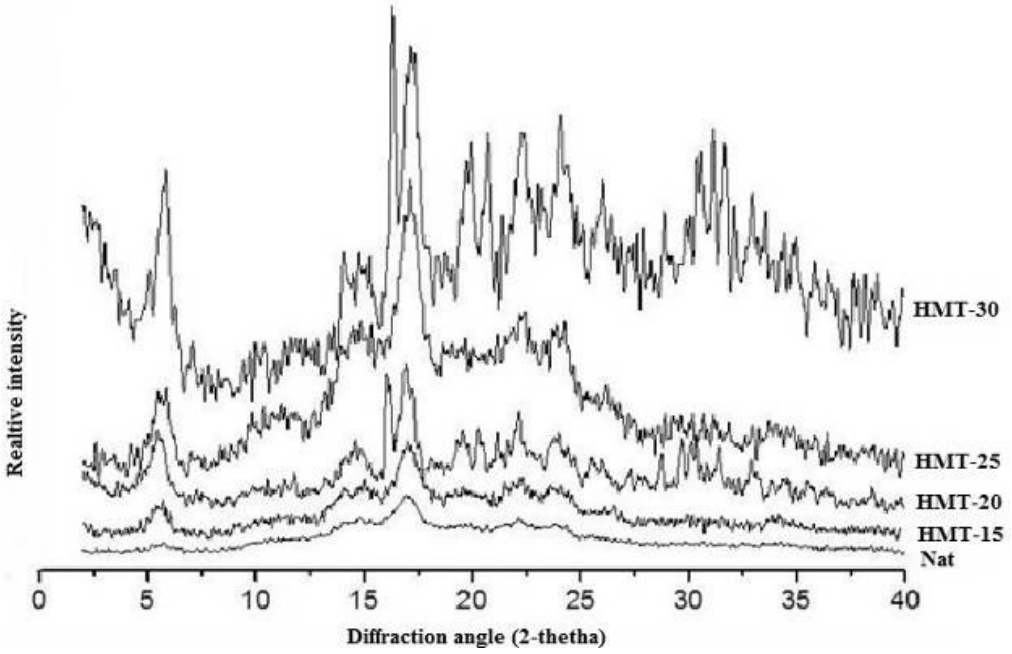

Figure 2. X-ray diffraction pattern of native starch and influence of HMT-modified (HMT-15, HMT-20, HMT-25, and HMT-30) Parkia starches.

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low moisture contents, and the amorphous content increased after HMT at 40% moisture content (Shih *et al*., 2007).

Pasting Properties

Pasting properties included the index of peak viscosity, trough viscosity, final viscosity, and they related to the starch properties of crystallinity region and amorphous region. However, crystallinity region is known as peak viscosity and amorphous region is trough viscosity. There was a relationship among the starch and pasting properties with low crystallinity and viscosity of HMT compared to native starch.

This is an advantage in food products like bread, which undergoes staling easily, and in soups and sauces, which undergo loss of viscosity and precipitation as a result of retrogradation. These defects could be minimized with hydrothermal modifications. The pasting properties of the native and HMT Parkia starches are presented in Table 3 and the pasting profiles in Figure 3. There was a decrease in the peak viscosity, trough viscosity, final viscosity, and break down, and setback after HMT, while the pasting temperature increased when compared with the native starch. These results indicated that heat moisture treatment had maximal effect on the granular arrangement of the starch with resultant lower swelling power when compared with the native starch. This observation concurred with the reported review by Abbas *et al*. (2010) for different starches. The reduction in the viscosity value as a result of HMT is a thinning effect which might be due to the weakening of bonding forces within the granules and their breakdown. Peak viscosity of HMT starches was significantly lower than native starch. Peak viscosity decreased from 502 cP for native starch to 441 cP for HMT15 and 292 cP for HMT30 starches. The decrease in peak viscosity, of HMT starches was moisture content dependent (Khamthong and Lumdubwong, 2012).

Kaur and Singh (2005) also reported that flour from different chickpea cultivars showed higher pasting temperatures and lower peak viscosities, setback, and final viscosities than Kabuli chickpea cultivars. With hydrothermal treatment, whether done in excess water (starch suspension) or below 30% (no free water), the general effect on pasting properties is lower peak viscosities, less breakdown, and higher cold paste viscosities for potato starch (Stute, 1992).

Thermal Properties

The influence of HMT on gelatinization temperatures [onset (T_o), peak (T_p), and conclusion (T_c)] are presented in Table 1. The gelatinization temperatures increased with HMT at all moisture levels (HMT-15, HMT-20, HMT-25, and HMT-30). This result is comparable to those obtained for cereal, legume and tuber (Hoover and Vasanthan, 1994). Adebowale and Lawal (2003) also observed only a slight increase in T_o after HMT of mucuna bean (*Mucuna pruriens*) starch. The increase in T_o of HMT Parkia starches has been attributed to structural changes within the starch

Table 3. Pasting characteristics of Native and the influence of Heat-moisture (HMT) treatments of Parkia starch.

Starch samples	Peak	Trough	Break down	Final viscosity	Setback	Peak time	Pasting temperature
Native	502[a]*	296[a]	215[a]	525[a]	238[a]	4.65[b]	82[c]
HMT-15	441[b]	263[b]	191[b]	484[b]	198[b]	4.65[b]	82[c]
HMT-20	432[b]	264[b]	180[b]	467[c]	188[c]	4.73[b]	82[c]
HMT-25	348[c]	218[c]	130[c]	396[d]	177[d]	4.77[b]	85.60[a]
HMT-30	292[d]	196[d]	93[d]	352[e]	177[d]	4.94[a]	84.45[b]

*Means values with different letters within each column are significantly different (P≤ 0.05).

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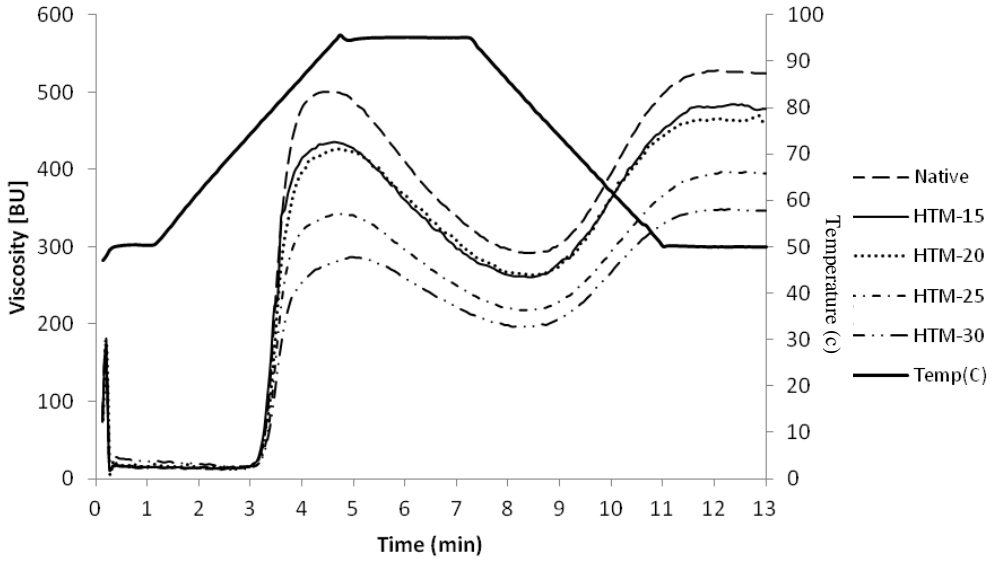

Figure 3. The RVA profiles of native starch and HMT (HMT-15, HMT-20, HMT-25, and HMT-30) Parkia starches.

granules, which involves mainly amylose–amylose (AM–AM) and amylose–lipid interactions (AM–lipid). These interactions consequently reduced the mobility of the amylopectin chains, leading to increases in T_o, T_p and T_c. Lim *et al*. (2002) proposed that the increase in T_o of HMT starches was caused by the transformation of the inter-crystalline parts into amorphous phases. The gelatinization enthalpies (DH) values of all Parkia starches decreased with increasing moisture level of the treatments. This may be associated with the differences in their granular structure and amylose content and the presence of lipids. This suggests that some of the double helices present in the crystalline and in non-crystalline regions of the granules may have been disrupted under the conditions prevailing during HMT.

CONCLUSIONS

This study concluded that HMT-20 had the highest resistant starch (50.14%) and the lowest resistant starch was from HMT-15 (37.79%), with a reduction in the swelling power and pasting properties of HMT starches. Moreover, the solubility of HMT starches was higher than that of native starch.

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اثر تیمارهای مختلف گرما-رطوبت روی خواص فیزیکوشیمیایی نشاسته لوبیای آفریقایی (*Parkia biglobosa*)

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چکیده

در این پژوهش، نشاسته لوبیای آفریقایی Parkia biglobosa یا پارکیا برای مدت ۱۶ ساعت تحت اثر تیمارهای مختلف گرما-رطوبت (HMT)، شامل رطوبت های ۱۵٪، ۲۰٪، ۲۵٪، و ۳۰٪ در حرارت ۱۱۰ درجه سلسیوس قرار داده شد. نشاسته مقاوم به هیدرولیز(RS) در پارکیای تیمارنشده از همه کمتر (۳۳/۳۸ ٪) بود ومقادیر آن در تیمارهای HMT به ترتیب افزایشی چنین بود:(%37/79)HTM-15، HTM-30(%39/64)، HTM-25(%46/63)، و HTM-20(%50/14) که این نتایج حاکی از افزایش معنی دار ($p\leq0.05$)مقدار RS بعد از تیمارهای HTM بود. هر چند توان انبساط و خواص چسبندگی نشاسته های تیمار شده کاهش داشت ولی حلالیت آنها بیشتر از نشاسته تیمار نشده بود. اثر تیمارهای HMT روی نشاسته پارکیا با استفاده از حرارت سنجی افتراقی و تغییرات افتراق اشعه ایکس (XRD) تایید شد. بنا براین، جانشین کردن نشاسته معمولی پارکیا با نشاسته تیمارشده با گرما- رطوبت منجر به ایجاد محصولات جدیدی از پودر نشاسته سرشار از RS با خواص عملیاتی بالا می شود.

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