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Effect of hydrothermal modifications on the functional, pasting and morphological properties of South African cooking banana and plantain

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ABSTRACT

The effects of annealing and heat-moisture treatment (HMT) on the properties of South African cooking banana (*Musa sapietum*) starch (CBS) and plantain (*Musa paradisiaca*) starch (PS) were compared. CBS generally had significantly ($p < 0.05$) higher swelling power, solubility and water absorption capacity. While both methods of modification employed enhanced the oil absorption capacity of CBS (101.33–124.00%), they led to its decrease in PS (118.33–103.33%). Alkaline water retention increased with modifications in PS (1.04–1.20 g/g) and decreased in CBS (1.47–1.36 g/g). The modifications improved the gelation capacity of the starches. There were marked differences in the pasting properties of cooking banana and plantain starches. Micrographs showed irregular shaped ovoid and spheroid granules for the starches. HMT changed the diffraction patterns of both starches from B-type to C-type. Enhancement of the properties of CBS with hydrothermal modifications shown in this work exposed its potential as a latent valuable ingredient in food processing.

Efecto de las modificaciones hidrotérmicas en las propiedades funcionales, pastosas y morfológicas del plátano y el plátano macho surafricanos

RESUMEN

Se compararon los efectos de los tratamientos de recocido y con calor húmedo en las propiedades de los almidones del plátano (*Musa sapietum*) (CBS) y plátano macho (*Musa paradisiaca*) (PS) surafricanos. Los almidones de plátano generalmente tuvieron un poder de hinchazón significativamente mayor (p<0,05), como también mayor solubilidad y capacidad de absorción de agua. Mientras que los dos métodos de modificación utilizados mejoraron la capacidad de absorción de aceite de CBS (101,33-124,00%) y conllevaron a una reducción en el PS (118,33-103,33%). La retención de agua alcalina aumentó con las modificaciones en el PS (1,04-1,20 g/g) y disminuyó en el almidón de plátano (1,47-1,36 g/g). Las modificaciones mejoraron la capacidad de gelificación de los almidones. Se observaron diferencias marcadas en las propiedades pastosas de los almidones de plátano y plátano macho. Las micrografías mostraron una forma ovoide irregular y gránulos esferoidales en los almidones. HMT cambió los patrones de difracción de los dos almidones de tipo B a tipo C. La mejora de las propiedades de CBS con las modificaciones hidrotérmicas mostró en este estudio expuesto su potencial como ingrediente latente y valioso en el procesamiento de alimentos.

Introduction

Banana is a general name for a group of species and hybrids belonging to the genus *Musa* of the family Musaceae. Banana is produced in large quantities in tropical and subtropical areas of the world (Waliszewski, Aparicio, Bello, & Monroy, 2003). According to the Food and Agriculture Organization estimate, about 102 million tons of banana, of which 68% and 32% were classified as banana and plantain, respectively, were produced in the year 2003 alone (Food and Agriculture Organization of the United Nations [FAO], 2003). Banana as the world's largest herb and fruit crop is ranked among the important sources of nutrition, especially energy for people living in the humid tropic region of the globe (Aurore, Parfait, & Fahrasmane, 2009). Banana is a well-researched international crop with over 1200 seedless fleshy fruit varieties identified (Aurore et al., 2009; Waliszewski et al., 2003). Starch, the most abundant constituent of

banana (over 70% dry weight), has been extracted from some banana varieties of various origin, including plantain and characterized (Lii, Chang, & Young, 1982; Nwokocha & Wiiliams, 2009; Otegbayo, Lana, & Ibitoye, 2010; Pelissari, Andrade-Mahecha, Sobral, & Menegalli, 2012; Waliszewski et al., 2003). The potential of native and modified starches from these varieties for various industrial applications, especially in food processing, has also been enumerated (Carlos-Amaya, Osorio-Diaz, Agama-Acevedo, Yee-Madeira, & Bello-Pérez, 2011; Aurore et al., 2009). However, report on the properties of native and hydrothermally modified South African CBS is scarce in the literature. The use of South African cooking banana is mostly restricted to fresh consumption and in preparing domestic mash delicacy called *cali*, which is popular among South Africans. South African cooking banana variety is selected for investigation in this study because of scanty or no information on the

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characterization of the properties of its native and hydro-thermally modified starches. The study could provide baseline data on their industrial potential, especially in food processing and pharmaceuticals.

Starch which is composed of amylose (linear polymer) and amylopectin (branched polymer) is stored in abundant quantity as carbohydrate in plants. Its composition is responsible for the array of functional properties with attributes for many industrial applications (Thranathan, 2005). Many deficiencies of native starch which limit its industrial applications have been reported in the literature (Kaur, Ariffin, Bhat, & Karim, 2012). Different modification methods to enhance the application of starch for varying industrial uses have also been investigated (BeMiller, 1997; Tharanathan, 2005). However, hydrothermal modification is preferred for food product development and pharmaceutical applications because of safety concern and favourable changes it imparts to the properties of starch for specific industrial applications (Hoover & Vasanthan, 1994; Jyothi, Sajeev, & Sreekumar, 2010). Two types of hydrothermal modifications often used for food application are heat-moisture treatment (HMT) and annealing (ANN).

The objective of this work was to isolate the starch from South African cooking banana cultivar and study the effect of HMT and ANN on some of its properties. The native and modified starches from South African cooking banana cultivar (will be henceforth referred to as cooking banana in this report) were compared against West African plantain (will be subsequently referred to as plantain) starches.

Materials and methods

Matured green cooking banana (*Musa sapietum*) and plantain (*Musa paradisiaca*) were obtained from grocery stores in Ogbomosho, Nigeria and Pietermaritzburg, South Africa, respectively. They were immediately transported to the laboratory for starch extraction.

Starch extraction

Method of Kim, Wisenborn, Orr and Grant (1995) with slight modification was used for the extraction of starch from the two varieties. Pulps obtained after peeling the fruits were diced and rinsed immediately in citric acid solution. They were blended with equal volume of distilled water in a warring blender for 2 min at low speed. Slurry obtained was passed through muslin cloth with addition of distilled water to remove debris and filtered with 150 μm sieve. The starch suspension was allowed to settle and the supernatant was carefully discarded. The starch obtained (sediment) was washed several times with distilled water to further remove impurities and dried in a forced air circulation oven at 48°C for 24 h. Dried native starch was packed in airtight Ziploc bags for further analyses.

Heat moisture treatment

Method of Li, Ward, and Gao (2011) was used for HMT of starch samples. The moisture content of native starch, which was earlier determined, was raised to 20% by dispersion in distilled water. The sample was then heated at 110°C in a convective forced hot air circulation oven for 16 h. The treated sample obtained was subsequently cooled and packed in Ziploc bags for further analyses.

Annealing

ANN of the starch samples was done using the method described by Jacobs and Delcour (1998). Sealed container containing starch suspension in distilled water (1:2 w/v) was heated in a water bath at 50°C for 24 h. The slurry was passed through Whatman No. 1 filter paper. The residue obtained was ovendried at 35°C for 24 h, cooled and packed in Ziploc bags for further analyses.

Functional properties

Swelling power and solubility

Starch (500 mg) was dispersed in distilled water (20 mL) in a centrifuge tube and the weight was recorded. The dispersion was heated in a thermostated water bath with shaker at 60°C for 30 min. The resulting slurry was rapidly cooled and centrifuged with Avanti® J-26XPI superspeed centrifuge (Beckman Coulter, CA, USA) at 1900 × g for 15 min. The supernatant was carefully transferred into an evaporating dish. The weight of the residue was recorded for swelling power determination.

$$\text{Swelling power(SP)} = \frac{Y_2 - Y_1}{X} \qquad (1)$$

where Y_1 is the weight of the centrifuge and starch slurry, Y_2 is the weight of the centrifuge tube after decanting and X is the weight of the starch.

The evaporating dish containing the supernatant was weighed and dried at 110°C for 20 min. Starch solubilized in water was the remnant obtained after drying the supernatant. Solubility was expressed as grams per 100 g of starch.

Water absorption capacity

Water absorption capacity (WAC) of the starch samples was determined according to the procedure described by Beuchat, Cherry, and Quinn (1975). Ten millilitre distilled water was poured into a conical centrifuge tube containing 1 g starch sample. The suspension was left at room temperature for 1 h and then centrifuged using Avanti J-26XPI superspeed centrifuge at 200 × g for 30 min. The residue was weighed with the tube after draining the supernatant. Water absorption was expressed as change in weight based on percentage of the original sample weight.

Oil absorption capacity

The procedure described by Falade and Okafor (2014) was used for the determination of oil absorption capacity (OAC). Ten millilitres of sunflower oil (0.87 g/cm³ density) was properly mixed using stainless steel spatula with 1 g starch sample in a centrifuge tube of known weight. The resulting suspension was centrifuged using Avanti J-26XPI superspeed centrifuge at the speed of 350 × g for 15 min. The weight of the tube and its content was recorded after careful separation of the supernatant. The OAC, which is the increase in weight, is expressed as percentage of the sample.

Least gelation concentration

The method of Sathe and Salunkhe (1981) was applied for the determination of least gelation concentration. Starch sample (2–20% at 2% stepwise increase) was dispersed in test tube containing 5 mL distilled water and heated in a water bath at 80°C for 1 h. The lowest concentration at which the sample did not slip from the inverted tube was the least gelation concentration.

Alkaline water retention

The weight of test tube containing 1.0 g starch sample was taken as W_1. Five millilitres of 0.1 M $NaHCO_3$ was added into the test tube and mixed in a vortex mixer for 30 s. The mixture was left at room temperature for 20 min and thereafter centrifuged at 200 rpm. The supernatant was decanted at an angle of 10–15° to the horizontal. The weight of test tube and its content after draining was recorded as W_2 (Olayinka, Adebowale, & Olu-Owolabi, 2008).

$$\text{Alkaline water retention(AWR)} = W_2 - W_1 \qquad (2)$$

Pasting properties

A Rapid Visco Analyser (RVA model 4500, Perten Instruments, Australia) was used for the determination of the pasting properties of starch samples. The analyses were conducted on 14% moisture basis. Starch slurry (3.42 g starch in 25.08 g distilled water) in an RVA container was subjected to cycle of programmed heating and cooling under constant strain as described by Yadav, Guleria, and Yadav (2013). The idle temperature (peak temperature) was 91°C.

Microscopic studies

A scanning electron microscope (EVO LS15, ZEISS International, Germany) was used for the examination of the morphology of the starch granules. A thin layer of starch powder was coated with gold with the aid of an ion sputtering device (EIKO IB-3 ion coater, Eiko Engineering Company, Hitachinaka, Japan) before examination under microscope. Image analysis software (AnalySIS, Soft Imaging System, Berlin, Germany) was used to measure the granule size.

X-ray diffraction

X-ray diffractometer (Empyrean, PANanalytical, Almelo, the Netherlands) coupled with a sample changer and image plate detector was used to obtain the continuous X-ray diffraction (XRD) patterns of the starch samples. Bragg angle (2θ) of 3°–40° with generator settings of 40 KV and 40 mA was used to register the scanning region of diffraction. Scan step time was 8.255 s.

Data analyses

The experiments were arranged in a randomized complete block design with two cultivars and three treatments. Samples for the analyses, except pasting properties, were replicated three times. SPSS 15.0 (SPSS Inc., Chicago, IL, USA) was used to analyse the replicated data. The means of the results were separated using Duncan's multiple range test.

Results and discussion

Functional properties

Functional properties of native and modified starches of cooking banana and plantain are shown in Table 1. There is significant ($p < 0.05$) difference in the swelling power and solubility of the native starches of cooking banana and plantain. Swelling power and solubility were higher in cooking banana than in plantain. This agreed with the report of Otegbayo et al. (2010). Similar to the observation of Olayinka et al. (2008) and Yadav et al. (2013), HMT conferred higher swelling power and solubility on the starches of the two cultivars than ANN. The differences observed in the swelling power and solubility of the starches of the two cultivars were attributed to the extent of structural realignment induced by each treatment inside the granules (Adebowale, Henle, Schwarzenbolz, & Doert, 2009).

HMT significantly induced ($p < 0.05$) higher WAC in CBS (155.33%) than in PS (101.33%). HMT samples of the two cultivars (HBS: 155.33%; HPS: 101.33%) had higher WAC than annealed samples (ABS: 129.33%; APS; 96.33%). WAC of starch is related to the relative content and association of amylose and amylopectin in the starch granule (Otegbayo et al., 2010). Higher WAC could indicate higher amylose content in the granule (Pelissari et al., 2012) or weak association of amylose–amylopectin (Otegbayo et al., 2010) which allows permeability of water into the granule structure.

Table 1. Functional properties of cooking banana and plantain starches.

Tabla 1. Propiedades funcionales de los almidones de plátano y plátano macho.

Sample	Swelling power (g/g)	Solubility (g/100 g)	WAC (%)	OAC (%)	AWR (g/g)
NBS	1.631 ± 0.03[d]	2.200 ± 0.2[b]	150.67 ± 0.046[c]	101.33 ± 6.028[a]	1.47 ± 0.458[b]
ABS	1.155 ± 0.120[c]	2.067 ± 0.503[b]	129.33 ± 0.104[b]	111.67 ± 4.726[bc]	0.84 ± 0.212[a]
HBS	1.675 ± 0.079[d]	2.133 ± 0.115[b]	155.33 ± 0.01[c]	124.00 ± 2.00[d]	1.36 ± 0.086[ab]
NPS	1.081 ± 0.124[bc]	0.267 ± 0.115[a]	105.33 ± 0.076[a]	118.33 ± 1.155[cd]	1.04 ± 0.104[ab]
APS	0.869 ± 0.029[a]	0.267 ± 0.115[a]	96.33 ± 0.038[a]	107.67 ± 4.041[ab]	1.05 ± 0.291[ab]
HPS	0.929 ± 0.082[bc]	0.400 ± 0.200[a]	101.33 ± 0.085[a]	103.33 ± 5.774[ab]	1.20 ± 0.292[ab]

Data reported are means of triplicate. Means in the same columns followed by different superscript letter(s) are significantly different at 5% confident level ($p < 0.05$).

NBS: native cooking banana starch; AES: Annealed cooking banana starch; HBS: heat-moisture-treated cooking banana starch; NPS: native plantain banana starch; APS: annealed plantain starch; HPS: heat-moisture-treated plantain starch; WAC: water absorption capacity; OAC: oil absorption capacity; AWR: Alkaline water retention.

Los datos publicados son los promedios de tres réplicas. Los promedios en la misma columna seguidos por una letra diferente en el superíndice son significativamente distintos a un nivel de confianza de 5% (p < 0,05).

(NBS: Almidón de plátano nativo; AES: Almidón de plátano recocido; HBS: Almidón de plátano tratado con calor húmedo; NPS: Almidón de plátano macho nativo; APS: Almidón de plátano macho recocido; HPS: Almidón de plátano macho tratado con calor húmedo; WAC: capacidad de absorción de agua; OAC: capacidad de absorción de aceite; AWR: retención de agua alcalina)

Therefore, it could be explained that HMT enhanced hydrophilic tendency of the starch by weakening the amylose–amylopectin association.

The hydrothermal modification methods used had different effects on OAC of cooking banana and plantain starches. While both HMT and ANN led to increase in OAC of CBS, opposite was the finding for PS. Increase in OAC with hydrothermal modifications of CBS could make it a potential ingredient in such products as mayonnaise and batter in frying products where emulsifying capability is required.

Generally, while hydrothermal modifications led to the decrease in alkaline water retention (AWR) of CBS, they enhanced it for the PS. It should, however, be noted that HMT starches of both cultivars had higher AWR than the annealed starches. Knowledge of the AWR capability of the starches is expected to guide their use in processing under alkaline aqueous condition.

Least gelation concentration

Native CBS had higher gelation strength than native PS (Table 2). This is similar to the report of Otegbayo et al. (2010). In agreement with the observation of Adebowale et al. (2009), hydrothermal modifications improved the gelation capability of both starches (from 4% to 2% for cooking banana and from 12% to 10% for plantain). No difference

was observed on the effect of ANN and HMT on the gelation characteristics of the starches from the two cultivars. The improvement of gelation capability of the starches with hydrothermal modifications could position them as potential raw materials in product formulation where gelation capability is of essence, especially noodles.

Pasting properties

Pasting properties of native and modified cooking banana and plantain starches are shown in Table 3. The higher pasting temperature observed for native plantain banana starch (NPS) as compared to native cooking banana starch (NBS) showed that NPS required more thermal energy for the breakdown of granules and formation of paste. Pasting temperature was correlated with the strength of interactive forces within the starch granules by Eliasson (1980). Slight differences were observed in the pasting temperatures of the modified and native starches of both cultivars. Peak viscosity (PV) which is a measure of resistance of starch to swelling was generally higher in CBS than in PS and was generally decreasing with modification. Lower PV indicates stronger cohesive forces within the granules and higher resistance to swelling. The extra strength in the modified starches was reported by Gebre-Mariam and Schmidt (1996) to be due to the increased moisture imparted by the

Table 2. Least gelation capability of cooking banana and plantain starches.

Tabla 2. Menor capacidad de gelificación de los almidones de plátano y plátano macho.

Sample	State	Concentration (%)									
		2	4	6	8	10	12	14	16	18	20
NBS	Gelation	Nil	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel
	Appearance	Viscous	Soft	Soft	Soft	Firm	Firm	Very Firm	Very firm	Very firm	Very firm
ABS	Gelation	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel
	Appearance	Soft	Soft	Soft	Firm	Firm	Very firm	Very firm	Very firm	Very firm	Very firm
HBS	Gelation	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel	Gel
	Appearance	Soft	Soft	Soft	Firm	Firm	Very firm	Very firm	Very firm	Very firm	Very firm
NPS	Gelation	Nil	Nil	Nil	Nil	Nil	Gel	Gel	Gel	Gel	Gel
	Appearance	Liquid	Liquid	Liquid	Viscous	Viscous	Soft	Firm	Firm	Very firm	Very firm
APS	Gelation	Nil	Nil	Nil	Nil	Gel	Gel	Gel	Gel	Gel	Gel
	Appearance	Liquid	Liquid	Liquid	Viscous	Soft	Firm	Firm	Very firm	Very firm	Very firm
HPS	Gelation	Nil	Nil	Nil	Nil	Gel	Gel	Gel	Gel	Gel	Gel
	Appearance	Liquid	Liquid	Liquid	Viscous	Soft	Firm	Firm	Very firm	Very firm	Very firm

NBS: native cooking banana starch; AES: annealed cooking banana starch; HBS: heat-moisture-treated cooking banana starch; NPS: native plantain banana starch; APS: annealed plantain starch; HPS: heat-moisture-treated plantain starch.

(NBS: Almidón de plátano nativo; AES: Almidón de plátano recocido; HBS: Almidón de plátano tratado con calor húmedo; NPS: Almidón de plátano macho nativo; APS: Almidón de plátano macho recocido; HPS: Almidón de plátano macho tratado con calor húmedo

Table 3. Pasting properties of cooking banana and plantain starches.*

Tabla 3. Propiedades pastosas de los almidones de plátano y plátano macho *.

Sample	Pasting temperature (°C)	PV (cP)	Peak time (min)	Trough (cP)	FV (cP)	BV (cP)	SBV (cP)
NBS	75.10	6403	5.47	5443	7090	960	1647
ABS	75.15	6016	6.20	5776	7462	240	1686
HBS	75.80	5078	6.47	4959	6898	119	1939
NPS	83.15	5447	5.27	4783	7743	664	2960
APS	82.50	4765	5.20	4147	6918	618	2771
HPS	83.15	4092	5.47	3987	6739	105	2752

* Not replicated.

NBS: native cooking banana starch; AES: annealed cooking banana starch; HBS: heat-moisture-treated cooking banana starch; NPS: native plantain banana starch; APS: annealed plantain starch; HPS: heat-moisture-treated plantain starch; PV: peak viscosity; FV: final viscosity; BV: breakdown viscosity; SBV: setback viscosity.

* Sin réplica

(NBS: Almidón de plátano nativo; AES: Almidón de plátano recocido; HBS: Almidón de plátano tratado con calor húmedo; NPS: Almidón de plátano macho nativo; APS: Almidón de plátano macho recocido; HPS: Almidón de plátano macho tratado con calor húmedo; PV: viscosidad pico; FV: viscosidad final; BV; ruptura de la viscosidad; SBV: retroceso de la viscosidad)

treatment which lubricated the granules and enhanced the formation of crystallites in the amorphous region. Peak time, the time required for starch granules to disintegrate during processing, was higher in NBS and increased with modifications for the two starches. Breakdown viscosity (BV) gives the fragility of starch upon the application of heat and shear force. The two starches in their native forms showed very high tendency to disintegration under processing conditions of high temperature and shear force. The tendency was higher in NBS. Modification resulted in the reduction of BV and the effect was greater in HMT starches. Increased resistance to the effect of thermal and shear forces as a result of modification led to better paste stability. Setback viscosity (SBV) is an indication of retrogradation tendency of starch. High SBV suggests low retrogradation and, therefore, implies reduced staling rate during cooling (Falade & Okafor, 2014). Though plantain starches generally had higher SBV values compared to CBS, hydrothermal modification had contrasting influence on SBV of the cultivars. While modifications generally led to the increase in SBV values for CBS, reverse was the case for PS. The implication of this finding is that the application of both methods of modification on CBS would reduce its staling rate and could enhance its use in bakery and confectionery where control of staling is of essence (Falade & Okafor, 2014). The differences in the pasting properties of cooking banana and plantain starches could be due to the differences in the sizes of their granules, ratio of the amylose and amylopectin and their association within the granules (Zhou, Robards, Glennie-Holmes, & Helliwell, 1998). These factors were linked to botanical sources by Carlos-Amanya et al. (2011).

Microscopic studies

Scanning electron micrographs showing the shape and size of native and modified cooking banana and plantain starches are presented in Figure 1. Starches from the two cultivars had similar irregular shapes made up of elongated ovoid and spheroid granules, similar to the report of Coulibaly, Nemlin, and Amani (2006) and Pelissari et al. (2012) on banana starches. Few granule clusters observed in NPS (Figure 1d) as compared with NBS (Figure 1a) were due to the excess moisture on the surface of NPS. This confirmed the report that NBS had higher WAC than NPS (Table 1). Excess water not absorbed by NPS granules facilitated their clustering (Adebowale et al., 2009). Hydrothermal treatments did not cause damage of the granules. However, there were mucilage formation and clumping of granules which were ascribed to excess surface moisture due to the gelatinization of starch during the treatment procedures (Yeh, Chan, & Chuang, 2009).

X-ray diffraction patterns

The XRD patterns of starch samples are shown in Figure 2. The NBS and NPS showed similar B-type diffraction pattern as shown with the presence of peak around 5–7° (2θ). This agreed with the results of Carlos-Amaya et al. (2011). ANN treatment did not cause change in the diffraction patterns of the starches of both cultivars as reflected by the B-type pattern depicted by ABS and HBS. However, similar to the patterns reported by Waliszewski et al. (2003), HMT affected the diffractions of the starches of cooking banana and
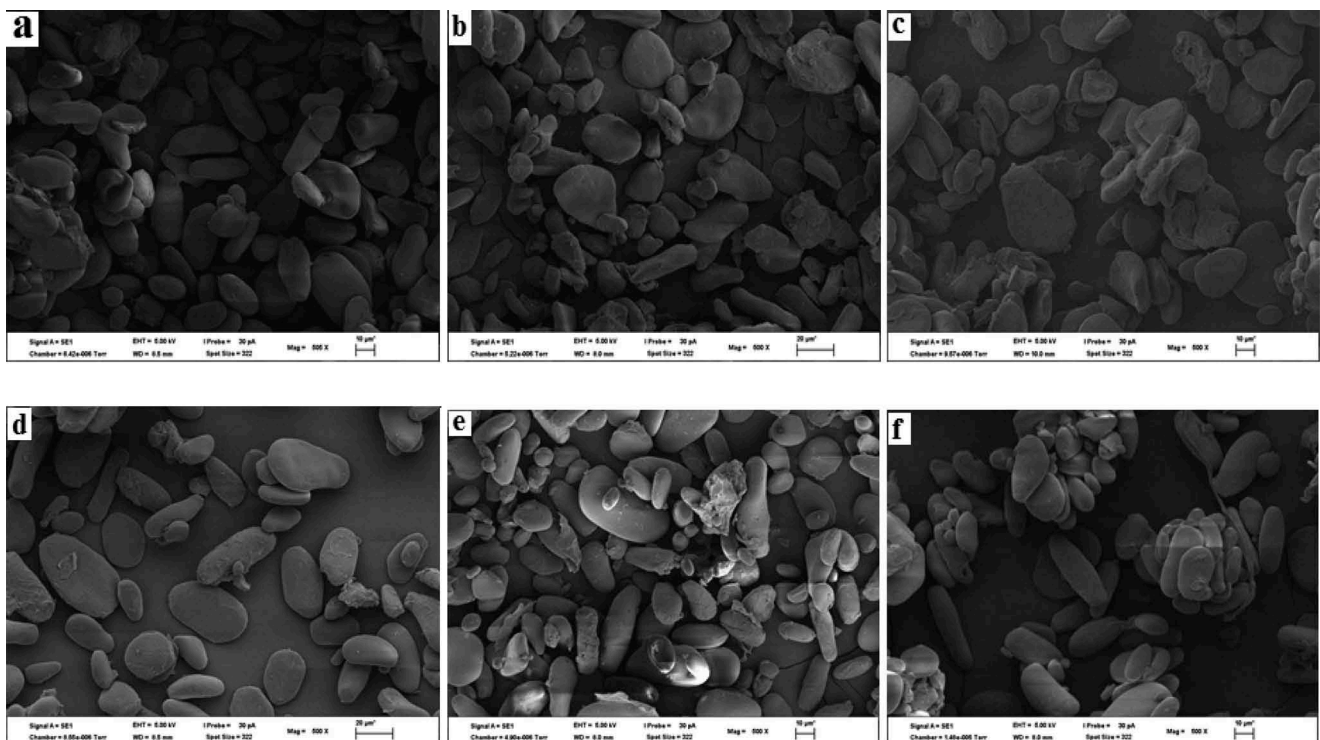

Figure 1. Micrographs of cooking banana and plantain starches: (a) native cooking banana starch; (b) annealed cooking banana starch; (c) heat-moisture-treated cooking banana starch; (d) native plantain banana starch; (e) annealed plantain starch; (f) heat-moisture-treated plantain starch. Magnification ×1000.

Figura 1. Micrografías de los almidones de plátano y plátano macho (a: Almidón de plátano nativo; b: Almidón de plátano recocido; c: Almidón de plátano tratado con calor húmedo; d: Almidón de plátano macho nativo; e: Almidón de plátano macho recocido; f: Almidón de plátano macho tratado con calor húmedo). Magnificación x1000.
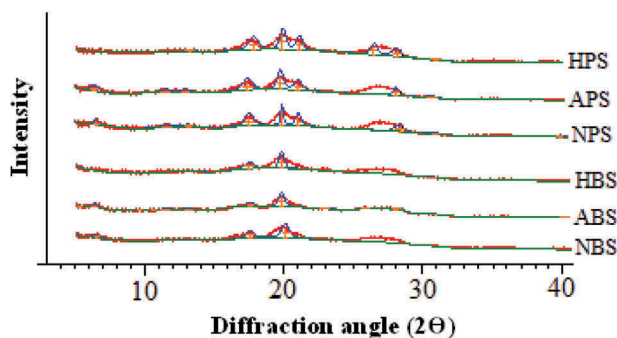
Figure 2. Diffraction patterns of cooking banana and plantain starches. NBS: native cooking banana starch; AES: annealed cooking banana starch; HBS: heat-moisture-treated cooking banana starch; NPS: native plantain banana starch; APS: annealed plantain starch; HPS: heat-moisture-treated plantain starch.

Figura 2. Patrones de difracción de los almidones de plátano y plátano macho (NBS: Almidón de plátano nativo; AES: Almidón de plátano recocido; HBS: Almidón de plátano tratado con calor húmedo; NPS: Almidón de plátano macho nativo; APS: Almidón de plátano macho recocido; HPS: Almidón de plátano macho tratado con calor húmedo).

plantain by changing them to C-type as evidenced with the absence of peak around 5–7° (2θ). Carlos-Amaya et al. (2011) also reported changes in the diffraction patterns of banana starch due to increased crystallinity percentage induced by modification treatments.

Conclusion

Hydrothermal modification methods of ANN and HMT improved the functional and pasting properties of cooking banana and plantain starches. The treatments, especially HMT, had greater impacts on the studied properties of CBS. The differences observed on the effects of modifications on the starches from the cultivars were previously reported by Otegbayo et al. (2010) to be due to the differences in the sizes of their granules as well as the relative content and association of amylose and amylopectin inside the granules. These affect the granules cohesion and the allowable extent of structural realignment that could occur inside the network during the treatment procedures. The positive impact of modifications on CBS implied better paste stability, improved gelling strength, good emulsifying capability, low retrogradation tendency and reduced staling rate. These characteristics could position it as an ingredient in binding, food thickening, stabilizing and emulsifying with utilization in such important food applications as sauce, mayonnaise, bakery and confectionery, among others.

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