



Composition and some physicochemical properties of microwaved starch blends from cocoyam (*Xanthosoma sagittifolium*) and bambara groundnut (*Voandzeia subterranean*)

A. O ASHOGBON¹ and A. G. OLAREMU²

^{1,2}Department of Chemical Sciences, Adegunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria

*Correspondence author Email address: ashogbonadeleke@yahoo.com

Abstract

Keywords:

Microwave radiation, Cocoyam starch, Bambara groundnut starch; starch blend, dispersibility, modification

The extracted cocoyam starch (100CYS) and bambara groundnut starch (100BBS) were blended in three ratios (70CYS/30BBS, 50CYS/50BBS, 30CYS/70BBS) (% w/w) and all the starch samples were microwave(MW) irradiated. The compositional and some physicochemical properties of the starch samples were evaluated to study the changes made as a result of MW irradiation. There was reduction in moisture and ash content, but an increased in the lipid and protein content of MW-irradiated native starches (NSs) and starch blends (SBs). A new trend was developed in apparent amylose (AAM) content. With just one exception (M70CYS/30BBS blend), the AAM content of the NSs increased and that of the SBs decreased as a result of MW irradiation. For the MW-treated SBs, the values for dispersibility, bulk density and pH ranged from 85-98%, 0.79-0.90gmL⁻¹ and 6.9-7.3, respectively. With the exception of the 50CYS/50BBS blend, there was increased in the swelling power of the remaining starch samples due to MW irradiation. Alterations were also observed in water solubility index of the starch samples micro waved as a result of their different chemical constitution. The non-irradiated starches manifested different trend in pasting properties as a result of MW irradiation when compared to the SBs as observed in peak, breakdown and final viscosities.

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INTRODUCTION

The uniqueness of starch is undeniable among the polysaccharides. It is the second most abundant organic compound, apart from cellulose in the biosphere. Furthermore, starch is the most significant carbohydrate in the human diet (Ashogbon, 2017). The source of starch is the plant kingdom; it is mostly obtained from cereal, root and tuber, legume and green fruits (Ashogbon and Akintayo, 2014). Starch is the only polymer that had the tendency to gelatinize among the natural and synthetic polymers. It is a condensation

polymer and the presence of ubiquitous hydroxyl groups facilitates chemical modification.

The search for starch with the appropriate physicochemical and functional properties for industrial application is a continuous process. The limitation of native starches (NSs) due to inherent insolubility in water and tendency to easily retrograde is popularly acknowledged. In addition, NSs has many weaknesses, such as narrow peak viscosity range, poor process tolerance, low shear stress resistance, thermal decomposition and cooked starches will formed a weak, cohesive and rubbery paste (Hazarika and Sit, 2016). In view of

consumers increasing request for safe and non-additive foods, there is a growing interest for physically modified starch over chemically or enzymatically modified starches because starch functionality can be improved without introducing any foreign substances (Jacobs and Delcour, 1998). Physical modification is simple, cheap and safe because it requires no chemicals or biological agents (Ashogbon and Akintayo, 2014). Starch blending and microwave (MW) radiation are examples of physical modification.

Starch blends are not additives and the quantity utilized is not regulated. Blending of starches from different botanical sources is not an entirely new process. Sweet potato starch had been previously blended with wheat starch (Zhu and Corke, 2011); Irish potato starch blended with pigeon pea starch (Abu et al., 2012); cocoyam starch blended with wheat starch (Ashogbon, 2014a) and bambara groundnut starch blended with cassava starch (Ashogbon, 2014b).

Microwave (MW) irradiation is non-ionizing and one of the physical modification methods that can treat starch and alter its functionality (Brasoveanu and Nemtanu, 2014). The impacts of MW interaction with matter depended on the MW energy which is delivered directly to the material through molecular interaction with the electromagnetic field (Brasoveanu and Nemtanu, 2014). When MW radiation is incident on matter, some of the energy is reflected and others transmitted. It is part of the transmitted energy that is absorbed which is useful for interaction with starch molecules. It is the absorbed energy that is later converted to heat when starch molecules are penetrated by MW irradiation. There are many documented studies based on the interaction of MWs with starch.

Generally, MWs could bring about rearrangement of intra- and intermolecular structure and consequent alterations in physicochemical and functional properties of starches from various botanical sources depending on starch type and experimental treatment parameters (Brasoveanu and Nemtanu, 2014).

Cocoyam (*Xanthosoma sagittifolium*) belongs to the Aracca family and it is the sixth most important root and tuber crops world-wide (Jennings, 1987). The high carbohydrate content of cocoyam and its

wide availability in the tropical countries makes it a very good source of starch for domestic and industrial applications (Lawal, 2004). It is a highly under-utilized tuber when compared to cassava and potato starches in terms of industrial application. Cocoyam starch had been extensively studied (Falade and Okafor, 2014; Ogunmolayusi et al., 2016; Ukom et al., 2015).

Bambara groundnut (*Voandzeia subterranean*) is a good source of protein (19-21%) and carbohydrate (57-67%) (Kaptso et al., 2014). It is like sword bean and pigeon pea, an under-utilized legume. Bambara groundnut is drought tolerant and easy-to-cultivate legume (Siriwongpaisal, 2008). Bambara groundnut starch (100BBS) has been extensively studied (Afolabi, 2012; Kaptso et al., 2014; Oyeyinka et al., 2015). The industrial under-utilization of many crops including bambara may be ascribed to lack of sufficient research to unlock their potential and value addition (Oyeyinka et al., 2015).

Some generalizations from previous works on MW irradiated starches are worth-noting: (i) Alterations in physicochemical properties of cereal starches impacted by MW irradiation were less marked than for root and tuber starches (Lewandowicz et al., 1997; 2000); (ii) For tuber starches, a strong correlation existed between the moisture content and the extent of alterations by MW irradiation (Lewandowicz et al., 1997); (iii) The most noticeable alteration effected by microwaving was the conversion of potato starch crystal structure from type B to type A (Lewandowicz et al., 1997). There are plenty of works in the literature on individual native starches and starch blends (SB) (Ashogbon, 2014a, 2014b; Abu et al., 2012), but paucity of information on microwaved starch blends (MSB). Therefore, the aim of this work is to study the composition and some physicochemical properties of microwave irradiated starch blends.

MATERIALS AND METHODS

Materials

Cocoyam tubers (Fig. 1) and bambara groundnut seeds (Fig. 2) were purchased from a local market at Igbokoda, Ondo State, Nigeria. The seeds were screened to remove the defective ones. The tubers were peeled and those with dark spots were eliminated. All other chemicals were of analytical reagent grade.



Fig.1. Cocoyam

Fig. 2. Bambara groundnut

Starch extraction

The cocoyam starch (100CYS) was extracted by a method previously documented by Ogunmolasuyi et al. (2016) and Ukom et al. (2015). In brief, the cocoyam tubers were peeled, thoroughly washed and cut in to pieces and subsequently crushed in a laboratory blender. The starch slurry was mixed with appropriate volume of distilled water and filtered. The filtrate was allowed to stand for the formation of clear supernatant and starch sediment. Subsequently, the supernatant was decanted off and the sediment re-suspended in distilled water. This process of re-suspension and decantation continue until the white prime starch obtained was dried in an oven (N505F, YOGO11, Genlab Widnes, England) at 40°C for 48 hours.

Manually de-husked and dried bambara groundnut was ground to a powdery form in a laboratory grinder. Starch was extracted from the powdery form by a procedure of Adebowale and Lawal (2002) as modified by Sirivongpaisal (2008) and Oyeyinka et al. (2015).

Preparation of the starch blends

The method of Zhang et al. (2011) was adopted to ensure homogeneity of the starch blends. The blends were prepared from the isolated native starches (100CYS and 100BBS) in three proportions (70CYS/30BBS, 50CYS/50BBS and 30CYS/70BBS) (% , w/w). The starches were sieved and mixed in a laboratory blender.

Microwave irradiation of starch samples

The starch samples (100CYS, 100CYS and their blends: 70CYS/30BBS, 50CYS/50BBS and 30CYS/70BBS) were adjusted to 20% moisture by the addition of appropriate quantity of distilled water to the starch samples of known moisture content. The moistened starch samples were placed in glass beakers and sealed with perforated polyethylene foil designed for the MW oven

(Scanfrost Model SF 17N, China) emitting a 2450MHz MW frequency and 0.5W/g MW energy (Lewandowicz et al., 2000).

Gross chemical compositions of starch samples

Apparent amylose (AAM) content (%) was determined by a colorimetric iodine assay index method, according to Juliano (1985). The moisture, protein, lipid, and ash content in the starch samples were determined using procedure of AACC method (2000).

Swelling power and solubility

Swelling power (SP) and water solubility index (WSI) determinations were carried out in the temperature range 55-95°C at 10°C intervals using the method of Leach et al. (1959).

Bulk density

This was determined by the method of Wang and Kinsella (1976) as modified by Ashogbon and Akintayo (2012).

Dispersibility

This was determined by the method described by Kulkarni et al. (1991) as modified by Akanbi et al. (2009).

pH

Starch samples (5g) were weighed in triplicate into a beaker, mixed with 20 mL of distilled water. The resulting suspension stirred for 5 min and left to settle for 10 min. The pH of the supernatant was measured using a calibrated pH meter (Benesi 2005).

Pasting properties

The pasting properties of the starch samples were evaluated using a Rapid Visco Analyzer (Newport Scientific, RVA Super 3, Switzerland). Starch suspensions (9%, w/w, dry weight basis; 28g total weight) were equilibrated at 30°C for 1min, heated

at 95°C for 5.5min, at a rate of 6°C /min, held at 95°C for 5.5min, cooled down to 50°C at a rate of 6°C/min and finally held at 50°C for 2 min. Parameters recorded were pasting temperature (PT), peak viscosity (PV), trough viscosity (TV), final viscosity (FV), and peak time (Pt). Breakdown viscosity (BV) was calculated as the difference between PV and TV, while setback viscosity (SV) was determined as the FV minus TV. All determinations were performed in triplicate and expressed in rapid viscosity unit (RVU).

Statistical analysis

Experimental data were analyzed statistically using Microsoft Excel and SPSS V. 12 .0. The least significant difference at the 5% probability level (P<0.05) was calculated for each parameter.

RESULTS AND DISCUSSION

Proximate Composition

Generally, microwave irradiation causes physical and chemical alterations in starch, such as evaporation of water, reduction of protein, solubility or swelling power to an extent which is related to the starch type and its moisture content, exposure time to microwave, processing temperature and absorbed energy (Brosoveanu and Nemtanu, 2014).

The moisture content recorded for all the starches (2.80-13.09%) are shown in Table 1. They fall within the acceptable limit, necessary for stable shelf life (Juliano and Villareal, 1993). Low moisture content reduces the susceptibility of starches to spoilage by microbes and increases their storage stability. The modified starches have the

lowest moisture content. This reduction in water content as a result of MW treatment could be ascribed to slipping of water out of starch and its subsequent evaporation due to MW heating. Similar reduction in water content of MW treatment (6 min at 85°C and half power of 650W) of lentil starch (25% moisture content) was previously documented (Gonzalez and Perez,2002).

Other studies involving reduction in water content of MW-irradiated wheat flour and potato starch has been reported (MacArthur and D'Appolonia, 1981; Choi and Ko, 1984). The extent of reduction in water content was obviously not the same due to variations in the MW parameters utilized. Significant decrease (P<0.05) were recorded for ash content following MW treatment of the starches while the protein contents for the microwaved blends increased, this may be attributed to leaching of the internal protein (Lowry et al., 1981) or the exhibition of additive tendency of the protein contents of the individual starches making up the blends, most especially the legume (bambara) known to contain conjugate protein which is difficult to remove during starch isolation. Minor components (mainly protein and lipids) are known to restrict swelling and solubility (Debet and Gidley, 2006). The low fat content of the starches is an indication that products made from them will not be easily susceptible to rancidity (Akanbi et al., 2009). The increase in the lipid content of the MW-irradiated samples could be attributed to the separation of some of the lipids in complexation with amylose. This is probable due to the long duration (60 minutes) that the samples were in the MW.

Table 1: Gross chemical composition of Starch samples

Sample	Moisture (%)	Ash (%)	Lipid (%)	Protein (%)	Amylose (%)
100CYS	12.96±0.02 ^a	0.30±0.01 ^a	0.02±0.00 ^a	0.14±0.31 ^a	24.84±0.14 ^a
M100CYS	3.60±0.02 ^b	0.08±0.02 ^b	0.10±0.00 ^a	1.03±0.02 ^b	25.08±0.43 ^b
100BBS	13.09±0.01 ^a	0.20±0.00 ^a	0.17±0.02 ^a	1.60±0.01 ^c	22.93±64 ^c
M100BBS	2.80±0.00 ^c	0.70±0.13 ^c	0.74±0.02 ^b	2.00±0.21 ^d	28.52±0.14 ^d
30CYS/70BBS	13.18±0.02 ^a	0.68±0.18 ^c	0.08±0.04 ^a	1.21±0.08 ^c	31.26±0.00 ^e
M30CYS/70BBS	8.37±0.03 ^d	0.07±0.04 ^b	0.76±0.05 ^b	2.04±0.04 ^d	29.18±0.07 ^f
50CYS/50BBS	12.85±0.01 ^a	0.28±0.03 ^a	0.08±0.00 ^a	1.52±0.01 ^c	31.51±0.07 ^e
M50CYS/50BBS	4.85±0.04 ^e	0.08±0.20 ^b	0.75±0.02 ^b	2.18±0.13 ^c	26.98±0.19 ^b
70CYS/30BBS	12.77±0.03 ^a	0.19±0.02 ^a	0.84±0.01 ^b	1.08±0.03 ^b	27.61±0.14 ^f
M70CYS/30BBS	6.47±0.02 ^f	0.03±0.01 ^b	0.87±0.03 ^b	2.22±0.31 ^c	33.28±0.00 ^g

Different superscripts along columns indicate statistically significant difference ($P < 0.05$)

The ash content of starches is known to consist of sodium, potassium, calcium, magnesium and phosphorus (Lares and Perez, 2006). Gonzalez and Perez (2002) reported that MW treatment of lentil starch caused a decrease of moisture, crude protein, crude fiber, water absorption, solubility, swelling power and an increase of ash, reducing sugars and absolute density. Similarly, for canna starch, Lares and Perez (2006) reported lower values of moisture, crude protein, crude fat and crude fiber than in the native form. The reduction in ash content in this work could be ascribed to the migration of water soluble minerals from starch into water and subsequent lost through evaporation as a result of MW treatment (Lares and Perez, 2006). It is obvious that the residual ash still remaining in the MW-treated starches could be due to the insoluble metallic salts.

The value of the apparent amylose (AAM) content (22.93 %) recorded for native bambara starch (100BBS) is higher than the values (21.67 %, 21.71 %) reported by Sirivongpaisal (2008) and Naushad and Taylor (2013), respectively. The AAM content of 100CYS fell within the range (15-25 %) reported by Moorthy (2002) for root and tuber starches. For the non-irradiated starches and blends, the 50CYS/50BBS blend has the highest AAM content thus showing that the individual starches show additive effect with respect to amylose content. Following MW modification, the AAM contents of the modified control starches increased significantly ($P < 0.05$). In contrast, the AAM contents of the MW-treated starch blends also decreased significantly ($P < 0.05$) with few exceptions (M70CYS/30BBS).

The latter blend possesses the highest AAM (Table 1). The increase in AAM content of the control starches could be attributed to leaching out of amylose from the starch granule due to exposure to MW radiation (Palav et al., 2007). Furthermore, the increase in AAM content of the irradiated native starches could also be ascribed to the dissociation of some of the AM in the amylose-lipid complexes. The opposite might be the case in the decrease in AAM contents of MW-modified starch blends. It must be noted that the starch blends are complex than the control starches (100CYS and 100BBS). The mixing ratio, morphologies and starch types of the individual starches that constitute the starch blends are factors to be taken into consideration in discussion involving the blends.

It has been documented that amylose (AM) is more susceptible or vulnerable to microwave irradiation when compared to amylopectin (AP). In one

particular study, cereal starches (wheat, corn and waxy corn) were subjected to MW radiation, normal corn and wheat starches underwent pronounced alterations, whereas under the same condition waxy corn starch was almost unaffected (Lewandowicz et al., 2000). Therefore, the physicochemical properties of the modified blend (M70CYS/30BBS) with the highest AM content are expected to be more impacted when compared to the other starch samples. The latter statement can only be true if the AM content is not affected by other factors like the presence of free lipid that could form complexes with AM. Starches of high AM content like the blend (70CYS/30BBS) could easily find applications in the production of noodles (Ashogbon, 2014b) and formation of resistant starch. The health benefit of the latter is boundless.

A trend is gradually being established that the impact of MW irradiation on AM content of the control starches differ from that on the starch blends. With the exception of the 70CYS/30BBS blend, MW modification resulted in decrease in the AM of starch blends and an increase in the AM contents of the control starches (Table 1).

Swelling power and solubility

Generally, for all the starch samples, both MW modified and the unmodified ones, an increase in temperature brings about a simultaneous raise in swelling power (SP) though the extent of these increase differ (Fig. 3). The SP and WSI of the control starches, starch blends and their irradiated counterparts were heated from 55 to 95°C at 10°C interval and the results summarized in Fig. 3 and 4. With the exception of the blend (50CYS/50BBS), there were increased in SP of the rest starch samples as a result of MW irradiation. This could be ascribed to the distortion in the starch granules due to irradiative treatment that leads to weakening of intra- and intermolecular bonds and enhanced water percolation into the granules and resultant increase in SP. The bonding between AM-AM and AM-AP could have been seriously slackened and perhaps some ruptured and promote amylose leaching (AML), thereby encouraging increase in SP.

The decrease in SP of the blend (M50CYS/50BBS) due to MW radiation could be attributed to the restructuring that occurred inside granules (Zeng et al., 2016). Another possible elucidation for reduced swelling might be the rearrangement of crystalline regions within the starch granules, which might become more randomly distributed within the starch granules (Brasoveanu and Nemtanu, 2014), resulting in more crystalline perfection. Similar

reduction in the SP of lotus seed starch as a result of MW irradiation has been documented in the

literature (Zeng et al., 2016).

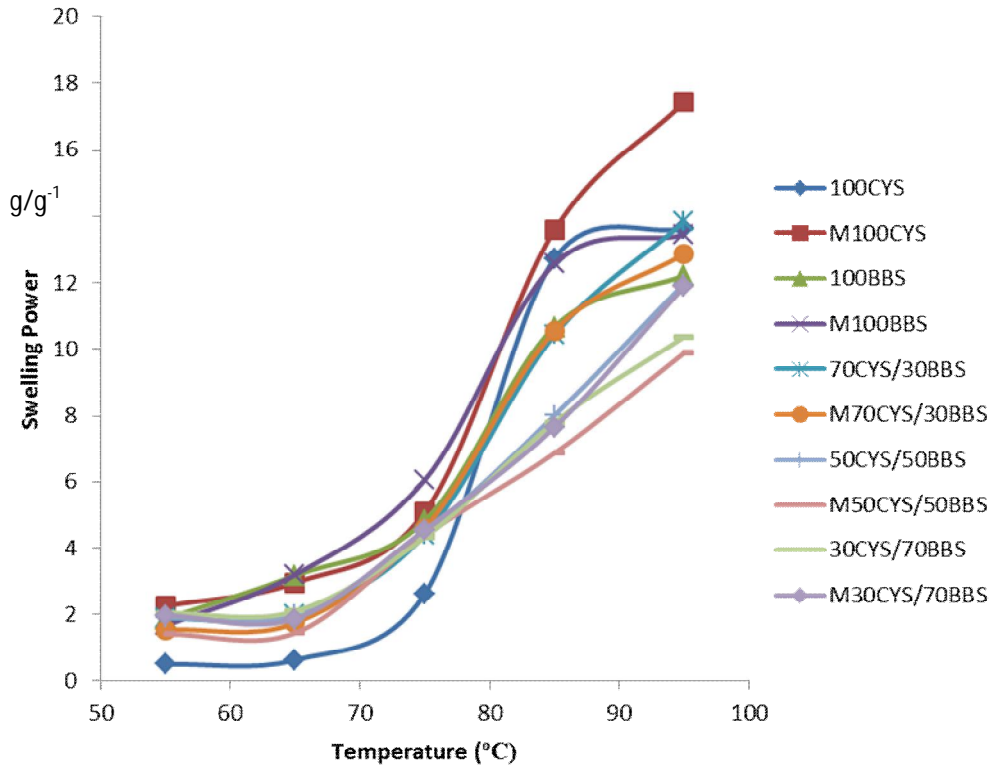


Fig. 3. Effects of temperature on swelling power

Generally, WSI increases with increase in temperature (Fig. 4). Pivotaly, the association of solubility with AM and AML as a result of granule rupture is not always the case, other factors like the presence of residual lipid and protein (Debet and Gidley, 2006) must also be taken into consideration. As a result of MW irradiation, there was reduction in the WSI of some samples. For example, reduction in WSI of M100BBS compared to 100BBS and M70CYS/30BBS compared to 70CYS/30BBS (Fig. 4).

This type of trend is the one commonly documented in the literature (Lewandowicz et al., 2000), but it must be noted that most of the time we compared results obtained with different MW parameters.

For all the starch samples, a tremendous increase in WSI takes place at 70°C, but the MW modification brings about a decrease in M100BBS and M70CYS/30BBS blend compared to 100BBS and 70CYS/30BBS blend, respectively. This decrease could be attributed to some structural changes which make solubilization in water more difficult (Lewandowicz et al., 2000). Similar reduction in solubility has been previously reported in MW irradiated wheat and normal corn starches (Lewandowicz et al., 2000). Such structural changes caused by MW radiation could include an increase in bond strength (AM-AM, AM-AP) that enhances crystalline perfection. Additionally, activities that decrease AML, like the complexation of free AM with lipids will certainly retard solubility in water.

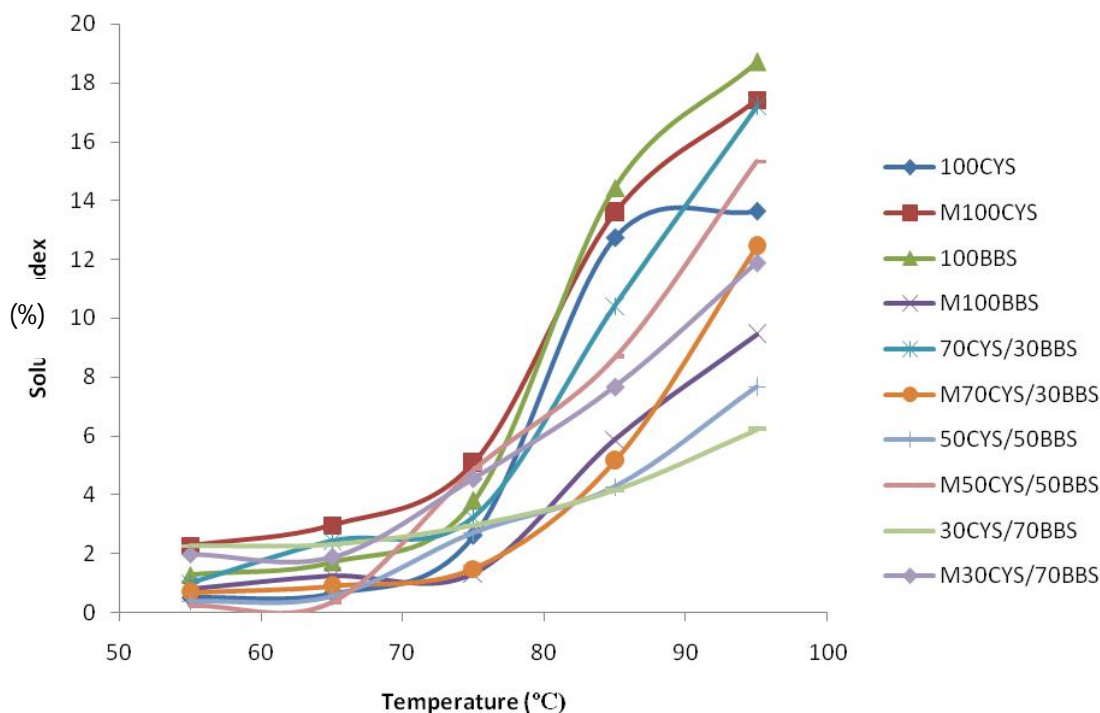


Fig. 4. Effects of temperature on water solubility index

Dispersibility, bulk density and pH

For the irradiated starch blends, the values for dispersibility (DP), bulk density (BD) and pH ranged from 85-98%, 0.79-0.90 gmL^{-1} and 6.9-7.3, respectively (Table 2). DP is a measure of the reconstitution of starch flour in water. The higher the values of DP, the better the starch flour reconstitute (Kulkarni et al., 1991). In other words, DP gives an idea of the settling rate of starch particles in solution. Furthermore, it also determines the arrangement of starch particles within an unshaken beaker for a period of time.

The modified starch blend (M70CYS/30BBS) had the highest percentage DP among all the starch samples. This means that the starch particles were more compacted and better arranged to occupy the smallest volume possible when compared to the particles of the other starch samples. With the exception of the 50CYS/50BBS blend, the remaining starch blends had an increase in percentage DP as a result of MW irradiation. This

obviously means the blend particles are further broken up into smaller particles and these are potentially useful in adsorptive activities in the chemical industries. The removal of ions from water system by adsorption (Wang et al., 1987) is a typical example.

The BD is a measure of the degree of smoothness or coarseness of the starch particles. There was obvious trend in the MW-irradiated control starches. In adversity, MW-treated SBs had higher BD than their untreated counterparts. Among all the starch samples, the modified 30CYS/70BBS blend had the highest BD and the untreated 70CYS/30BBS, the lowest. Such blend with the lowest BD could be potentially useful for pharmaceutical tablets, cosmetic dusting powder and photographic papers (Singh et al., 2006).

Microwave irradiation significantly ($P < 0.05$) alters the pH of the starch samples and ranged from slightly acidic to slightly alkaline or basic. It is difficult to establish any obvious trend, but MW modifications tend to increase the pH of the SBs as proven by two of the modified blends (Table 2).

Table 2: Some functional properties of starch samples

Sample	Dispersibility (%)	Bulk density (g/mL)	pH
100BBS	86±0.2 ^a	0.86±0.1 ^a	7.3±0.2 ^a
100CYS	83±0.6 ^b	0.80±0.4 ^a	6.7±0.3 ^b
M100BBS	85±0.3 ^c	0.88±0.3 ^a	7.2±0.1 ^c
M100CYS	85±0.1 ^c	0.75±0.2 ^b	7.0±0.4 ^d
50CYS/50BBS	86±0.4 ^d	0.77±0.5 ^b	6.8±0.3 ^e
M50CYS/50BBS	85±0.1 ^c	0.79±0.3 ^b	7.0±0.5 ^e
30CYS/70BBS	85±0.5 ^c	0.88±0.4 ^a	7.3±0.3 ^a
M30CYS/70BBS	86±0.3 ^d	0.90±0.1 ^c	6.9±0.2 ^f
70CYS/30BBS	87±0.5 ^e	0.73±0.2 ^b	7.0±0.4 ^d
M70CYS/30BBS	98±0.6 ^f	0.80±0.3 ^a	7.3±0.2 ^a

Different superscripts along columns indicate statistically significant difference (P<0.05)

Pasting properties of starch samples

Pasting simply refers to the changes occurring in the viscosity of starch suspension after gelatinization (Shevkani et al., 2017) and continuous heating. Rapid visco-analyzer (RVA) was used to study the effect of MW heating on the pasting characteristics of native starches and their blends. Significant changes (P<0.05) were observed in pasting parameters for both microwave-treated native starches and blends when compared to non-treated native starches and blends. The pasting parameters were summarized in Table 3. There is always a positive correlation amongst PV, BV and SP (Ashogbon, 2014b), indicating that starches with high SP are easily fragmented and their granules are not thermal resistant (Shevkani et al., 2011).

There is an uncanny relationship between the pasting characteristics of the control starches (100CYS and 100BBS). It is to be noted that 100CYS has been previously declared to possess a higher SP than 100BBS. Furthermore, AAM content of 100CYS (24.84%) was higher than that of 100BBS (22.93%) (Table 1). It is unusual but possible for the AM content of root and tuber starches to be higher than that of legume starches. Elsewhere, the AM content of 100BBS has been reported to fall within the range of 21-28% (Kaptso et al., 2014; Sirivongpaisal, 2008) and 20-38% (Oyeyinka et al., 2015), respectively depending on source and variety.

100BBS has a higher PV than 100CYS but the BV for 100CYS is higher than that of 100BBS (Table 3). The BV value for 100CYS was more significant (P<0.05) than the PV value for 100BBS. It is rationally justifiable to state that the 100CYS granules easily swells and get rupture faster when compared to the granules of 100BBS. There was reduction in the PV of MW-modified starches (from 100CYS to M100CYS and 100BBS to M100BBS). In adversity, MW-treated starch blends has higher PV than the untreated starch blends (Table 3). With few exceptions, the first case is more common, i.e., MW treatment brings about reduction in the PV of the modified starches compared to the untreated starches. The reduction in the microwave irradiation is more pronounced for M100CYS than M100BBS.

There is an emerging trend between MW irradiated control starches and starch blends. For example the PV, BV and FV of MW modified control starches decreased while those of modified starch blends increase. The decrease as a result of microwave radiation could be ascribed to the rearrangement of major starch components that enhances crystalline perfection. The components within the granules are better organized with possible increase in bond strength. On the other hand, the increases in the pasting parameters (PV, BV and FV) are indications that the starch blends are more sensitive to MW invasion than the control starches. These increases are associated with factors inherent in the starch blends, the mixing ratio, water content and

possible interactions between the individual starches that constitute the blend. The smallest value of BV (157.63 RVU) for the 30CYS/70BBS blend is indicative of its strong

thermal resistant and inability to be easily fragmented by mechanical forces. This type of blend is potentially useful in sterilization and for canned food.

Table 3: Pasting properties of Starch Samples

Sample	PVTV	BV	FV	SV	Pt(min)	PT(⁰ C)
100CYS	476.42±0.60 ^a	214.75±0.75 ^a	261.71±0.12 ^a	314.16±0.16 ^a	99.41±0.41 ^a	4.16±0.03 ^a 81.20±0.60 ^a
M100CYS	366.37±5.83 ^b	197.00±2.47 ^b	169.37±3.35 ^b	278.58±8.01 ^b	81.58±5.53 ^b	4.36±0.04 ^b 81.67±0.03 ^b
100BBS	478.50±2.01 ^c	264.37±0.88 ^c	214.12±2.89 ^c	413.87±4.77 ^c	149.50±5.65 ^c	4.33±0.00 ^b 84.92±1.31 ^c
M100BBS	433.29±3.28 ^d	239.12±0.88 ^d	194.16±4.12 ^d	399.29±7.95 ^d	160.17±7.07 ^d	4.40±0.00 ^b 84.12±0.03 ^d
30CYS/70BBS	406.40±0.72 ^e	249.27±0.03 ^e	157.63±0.04 ^e	395.34±0.93 ^e	146.74±0.01 ^e	4.51±0.02 ^c 82.25±0.07 ^e
M30CYS/70BBS	435.16±14.61 ^f	246.37±0.17 ^f	191.29±11.25 ^f	363.58±2.70 ^{fm}	119.71±0.65 ^f	4.50±0.04 ^c 81.67±0.03 ^b
50CYS/50BBS	382.54±7.12 ^g	209.33±3.79 ^g	173.20±3.35 ^g	322.75±3.64 ^g	113.41±0.12 ^g	4.40±0.00 ^b 82.47±0.03 ^f
M50CYS/50BBS	412.91±3.71 ^h	225.21±3.75 ^h	187.71±6.30 ^h	336.41±1.29 ^h	110.91±5.31 ^h	4.33±0.00 ^b 82.60±0.28 ^b
70CYS/30BBS	362.33±3.88 ⁱ	193.87±3.95 ⁱ	168.46±0.05 ⁱ	291.20±5.12 ⁱ	97.33±1.18 ⁱ	4.33±0.00 ^b 82.60±0.28 ^b
M70CYS/30BBS	413.92±0.70 ^j	216.62±0.06 ^j	197.29±0.76 ^j	325.17±5.77 ^j	108.54±5.83 ^j	4.23±0.04 ^a 81.22±0.60 ^a

Different superscripts along columns indicate statistically significant difference (P<0.05), PV = Peak viscosity; TV = Trough viscosity; BV = Breakdown viscosity; FV = Final viscosity; SV = Setback viscosity; PV = Peak viscosity; PT = Pasting temperature. All viscosities are in rapid viscosity unit (RVU).

The normal high retrogradation associated with legume starches because of their relatively high AM content is also displayed in 100BBS (SV = 149.50 RVU). This type of starch is not utilized for frozen foods. The low SV of M100CYS (81.58 RVU) is highly appreciated and utilized in the food industry because of their low retrogradation rate. Generally, it can be seen that MW heating have tremendous impact on the pasting parameters of control starches and their blends (Table 3). The highest pasting temperature was possessed by 100BBS, meaning that it needs the highest temperature to be cooked with the higher cost implication associated with it. The importance of TV is connected to its use in the computation of BV (PV - TV) and SV (FV - TV).

CONCLUSION

The extracted native cocoyam starch (100CYS) and bambara groundnut starch (100BBS) were blended in three ratios and microwaved. The respond of the different starch samples to microwave (MW) irradiation varies, obviously due to their different

chemical constitution, starch type and mixing ratio. Generally, the moisture and ash contents of the starch samples decreased as a result of MW modification, but the lipid and protein contents increased. There was also a developing trend, where the behavior of the control starches (100CYS and 100BBS) and starch blends differ when subjected to MW irradiation. This was pretty obvious in the areas of amylose content and some pasting parameters like peak, breakdown and final viscosities.

Abbreviations

AAM = Apparent amylose; AM = Amylose; AML = Amylose leaching; MW = Microwave; NSs = Native starches; SBs = Starch blends; SP = Swelling power; WSI = Water solubility index; 100CYS = Cocoyam starch (native); 100BBS = Bambara groundnut starch (native); M100CYS = Microwaved cocoyam starch; M100BBS = Microwaved bambara groundnut starch; 70CYS/30BBS = Starch blend obtained by mixing 70g of 100CYS with 30g of 100BBS; M70CYS/30BBS = Microwaved starch blend. The rest blends followed the same sequence of nomenclature.

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