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### Comparative characterization of the physicochemical properties of some starch blends-Bambarra groundnut and cassava starches versus cocoyam and wheat starches

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#### KEYWORDS

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Dispersibility,  
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#### A B S T R A C T

Bambarra groundnut starch (100BBS), cassava starch (CS), cocoyam starch (CYS) and wheat starch (WS) were blended in different proportions (70BBS/30CS, 50BBS/50CS, 30BBS/70CS) (BBS/CS) and (70CYS/30WS, 50CYS/50WS, 30CYS/70WS) (CYS/WS) and their physicochemical properties were evaluated and compared. The apparent amylose contents of the BBS/CS blends ranged from 33.23% (30BBS/70CS) to 41.52% (70BBS/30CS) compared with 30.99% (50CYS/50WS) to 44.00% (30CYS/70WS) of the CYS/WS blends. The bulk density and dispersibility of the CYS/WS blends was additive compared to the non-additiveness of the BBS/CS blends of their individual components. The pH values of the BBS/CS blends were higher than that of the CYS/WS blends. The swelling power of both blends (BBS/CS and CYS/WS) was additive of their individual components at 75 and 95°C. The exceptional water solubility index of the 50BBS/50CS blend at 85°C was worth-noting. The trough, final and setback viscosities were additive for the BBS/CS blends and non-additive for the CYS/WS blends. In terms of industrial utilization, the 50CYS/50WS blend seems the most significant. The under-utilized 100BBS and 100CYS could be more important industrially by substituting part of them into 100CS and 100WS. The overall results indicate that blending of starches from different botanical sources improves their properties.

#### Introduction

The different botanical sources of starches are cereal, legume, root and tuber and unripe fruit. The importance of starches lies in their abundant availability, cheapness, renewability, biodegradability, non-toxic nature and possession of ubiquitous hydroxyl groups.

The physicochemical properties of starch can be easily altered by all forms of modifications (Jobling, 2004). The uniqueness and individuality of starches from different botanical origin had been widely attributed to differences in

morphology, amylose/amylopectin ratio and soil type during growth. The mechanism of the physiology of starch component synthesis during plant germination and growth had also affected the uniqueness of the starches (Ashogbon, 2014a). It is these differences in its entirety that accounted for the diverse applications of these in the food and non-food industries.

The industrial utilization of native starches is limited due to inherent high rate of retrogradation, insolubility in water and fluctuation in viscosity during thermal processing (Ashogbon and Akintayo, 2014). Furthermore, instability of pastes and gels under various temperatures, shears and pH conditions also restricted the commercial applications of native starches. This deficiency of native starches is mitigated by physical and chemical modification, enzymatic and biotechnological modification, or their combinations. The introduction of chemicals (e.g. epichlorohydrin) in starchy food that tend out latter to be carcinogenic and banned is part of the problem associated with chemical modification (Ashogbon and Akintayo, 2014). Nowadays, market trends are towards natural food components, avoiding as much as possible any chemical treatments (Zhang et al., 2011). Chemical and physical modifications of starch are costly and frequently employ treatments with hazardous chemicals (Santelia and Zeeman, 2011).

Blending of starches from different botanical origin has come as a good alternative. It is cheap and does not involve the addition of chemicals or biological agents into the starches. Blending of starches is not an entirely new process. Cocoyam starch (100CYS) had been previously blended with wheat starch (100WS) (Ashogbon, 2014b); pigeon pea

starch blended with rice starch (Ashogbon, 2014c), bambarra starch (100BBS) blended with cassava starch (100CS) (Ashogbon, 2014a) and Irish potato starch blended with pigeon pea starch (Abu et al., 2012). Blended starches have been reported to exhibit either additive or non-additive properties depending on the combination of starch counterparts, mixing ratio and concentration of the starch mixture (Zhang et al., 2011). According to Waterschoot et al. (2014), tremendous disparity in granule size and swelling power (SP) between blended starches leads to uneven moisture distribution during heating of starch suspension. The consequence is that the behavior of the blend differ from what would be expected based on the behavior of the individual starches.

Amylose (AM) and amylopectin (AP), the major components of starch granules plays an important role in the determination of SP, solubility, pasting and gelatinization of the starches. The role of the anti-swelling and anti-solubility minor components (mainly lipids and proteins) has been widely reported in the literature (Debet and Gidley, 2006). The functionality of the two main components of starch differs significantly. AM has a high tendency to retrograde and produce tough gels and strong films (Ashogbon and Akintayo, 2014). In contrast, AP, when dispersed in water, is more stable and produces soft gels and weak films (Perez and Bertoft, 2010).

There are plenty of works on bambarra groundnut (*Voandzeia substerranean*) starch (Sirivongpaisal, 2008), cassava (*manihot esculenta*) starch (Ladeira at al., 2013), cocoyam (*Xanthosoma sagittifolium*) starch (Lawal, 2004) and wheat (*Triticuma estivum* L.) starch (Maningat and Seib, 2010). It was observed from literature review that there are limited works on blending of native

starches from different botanical sources in the areas of bulk density, dispersibility, pH and potential industrial applications of these blended starches. It is a rarity to see the comparative study of physicochemical properties of blended starches in different proportions; (70BBS/30CS, 50BBS/50CS and 30BBS/70CS) versus (70CYS/30WS, 50CYS/50WS and 30CYS/70WS) from different botanical origin in the literature. Therefore, the aim of this work is to study the physicochemical properties of these blended starches. Furthermore, their physicochemical properties will be compared and the likely potential industrial applications stated depending solely on their physicochemical properties.

### **Materials and Methods**

Bambarra groundnut seed, cassava roots, cocoyam tubers and wheat grains were purchased from a local market at Ikare, Ondo State, Nigeria. The defective roots and tubers were separated and discarded. The grains and seeds were screened and sieved to remove defective ones and eliminate dust particles. Chemicals utilized were of analytical reagent grade and were purchased at Finlab, Ikeja, Lagos.

### **Starch isolation**

Manually dehusked and dried bambarra groundnut was ground to a powdery form in a laboratory grinder. Starch was isolated from the powdery form by a procedure of Adebowale and Lawal (2002) as modified by Sirivongpaisal (2008). Isolation of native cassava starch was carried out by a method described by Benesi (2005). Starch was isolated from new cocoyam tubers by a method previously described by Lawal (2004). Isolation of native wheat starch was carried out by a method reported by Finnie et al. (2010).

### **Preparation of starch blends**

Starch blends were prepared from the isolated control starches (100BBS, 100CS, 100CYS and 100WS) in six proportions (70BBS/30CS, 50BBS/50CS, 30BBS/70CS) and (70CYS/30WS, 50CYS/50WS, 30CYS/70WS) (% w/w). The native starches were sieved and mixed in a laboratory blender.

### **Gross chemical compositions of isolated starches**

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

### **Bulk density**

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

### **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 5min and left to settle for 10min. The pH of the supernatant was measured using a calibrated pH meter (Benesi, 2005).

### **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).

### **Pasting properties**

The pasting properties of the starches were evaluated using a Rapid Visco Analyzer (Newport Scientific, RVA Super 3, Switzerland). Starch suspensions (9%, w/w, dry starch basis; 28g total weight) were equilibrated at 30°C for 1min, heated at 95°C for 5.5 min, at a rate of 6°C/min, held at 95°C for 5.5 min, cooled 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 minus TV, while total 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**

### **Gross chemical composition of control starches and their blends**

For the purpose of this discussion, the blends (70BBS/30CS, 50BBS/50CS and 30BBS/70CS) will be represented as BBS/CS and the blends (70CYS/30WS, 50CYS/50WS and 30CYS/70WS) as CYS/WS. The gross chemical composition of the control starches and their blends are

summarized in Table 1. The moisture content of the starch samples falls within the commercially accepted range (less than 14.0% moisture content; Juliano & Villareal, 1993). This range is not easily susceptible to spoilage by micro-organisms. The values of the moisture content of both blends (BBS/CS and CYS/WS) lay in-between that of the control starches. For the BBS/CS blends, the moisture content was additive, and non-additive in the CYS/WS blends of their individual components. Moisture content is an important parameter in the packaging, transportation and spoilage of starches.

The 100WS had the highest ash content (Table 1) compared to the blends and other control starches. The low ash content of the control native starches is an indication of their purity before blending. The ash content of the blended starches was non-additive of their individual components. The manifestation of higher value of ash in the BBS/CS was due to high proportion of 100BBS and for the CYS/WS blends due to high ratio of 100CYS (Table 1). The same control starches responsible for higher quantity of ash in the blends was also responsible for high lipid content in them. Generally, 100WS had the highest lipid content. The lipid content of the BBS/CS blends was higher than that of their control starches. The blended starches (BBS/CS and CYS/WS) in term of lipid content were non-additive of their individual components. As the proportion of 100BBS in the BBS/CS blends was increased, the protein content raised and vice versa for 100CS. Furthermore, the protein content was additive for the BBS/CS blends and non-additive for the CYS/WS blends of their individual components.

With the exception of the characteristic high apparent amylose (AAM) content of the

legume starch (100BBS), the AAM content of the blended starches was higher than that of their control starches. These indicate that blending increases the AAM content of the blended starches. The blends (70BBS/30CS and 30CYS/70WS) with higher AAM could be desired in the making of noodles (Tan et al., 2009). High-AM starches can be processed into 'resistant starch', which has nutritional benefits (Zhu et al., 2011; Bird et al., 2000). High AM starches could be very useful film-forming material, conferring better gel texture and adhesion capacity due to their strong gelation properties and helical linear polymer structure (Juliano, 1985; Santelia & Zeeman, 2011). Furthermore, high AAM starches (70BBS/30CS and 30CYS/70WS) could also find applications in the production of corrugated board and paper (Jobling, 2004).

The AAM content of the control starches and their blends differed significantly ( $P < 0.05$ ). The pasting, gelatinization, retrogradation, SP, WSI and starch vulnerability to enzymatic digestion are deeply influenced by the quantity and structure of AM (Gerard et al., 2001; You & Izydorczyk, 2002). The expression of higher AAM content in the BBS/CS blends depends on the proportion of 100BBS and CYS/WS blends on 100WS. The higher the AAM of the control starches, the greater their influence in the development of higher AM blended starches. The AAM content of the BBS/CS was additive compared to the non-additive tendency of the CYS/WS blends. As the proportion of 100BBS in the BBS/CS blends was increased, the AAM content also raised proportionately.

### **Functional properties of the control starches and their blends**

The bulk density (BD), dispersibility (DB) and pH of the control starches and their

blends are presented in Table 2. In the CYS/WS blends, the BD, DB and pH were additive of their individual components. Only the pH was additive in the BBS/WS blends. The bulk densities of the starch samples ranged from 0.67 to 0.88 g/mL. The highest BD was observed for the 70BBS/30CS blends and the lowest for 100WS. The degree of coarseness of the starch particles is measured by its BD. This signifies that the 70BBS/30CS blends had the coarsest particles. It also implies that 100WS particles are very smooth and could be used as excipient for pharmaceutical tablet, paper and photographic paper powder, cosmetic dusting powder and laundry stiffening agent (Singh et al., 2006a, 2006b). Furthermore, the small BD of 100WS could provide smooth texture that exhibits fat mimetic properties (Otegbayo et al., 2013).

The higher the DB, the better the starch flour reconstitutes in water (Kulkarni et al., 1991). The DB of the blended starches ranged from 83.00 to 87.00%. Since the higher the DB, the better the starch flour reconstitutes, the values obtained for the blends (30BBS/70CS and 30CYS/70WS) and 100WS (Table 2) were better than that of the other investigated starches. Furthermore, these DB values were better than 40.67% obtained by Akanbi et al. (2009) for breadfruit starch and 42.90% for blended Irish potato with pigeon pea starches (Abu et al., 2012). The implications are that higher DB starches (100WS, 30BBS/70CS and 30CYS/70WS) will probably be suitable for applications where large quantity of starches occupy small surface area. The high DB starches could be useful for adsorptive removal of ions from contaminated water system (Wang et al., 1987).



The pH of starch blends (BBS/CS and CYS/WS) are both additive of their individual components. The BBS/CS blends have higher pH values when compared to the CYS/WS blends. The pH of the BBS/CS blends was slightly alkaline when compared to the high acidic values of the CYS/WS blends. Intermediate pH values had been previously reported for some legume starches (6.20-6.88), rice starch (4.30) and cassava starch (5.56) (Ashogbon, 2014d). Furthermore, identical acidic pH values (3.71-3.99) to that of the CYS/WS blend had been reported by Ahmed et al. (2007) for some cultivars of rice starch.

AM had been widely documented to be responsible for WSI and AP for SP. The significance and effects of residual proteins, lipids, native and temperature-induced amylose-lipid complexes on these two parameters (SP and WSI) were also emphasized (Ashogbon, 2014c). The SP and WSI of the control starches and their blends, heated from 55 to 95<sup>0</sup>C at 10<sup>0</sup>C interval were summarized in Fig. 1 and Fig. 2, respectively. The SP of the starch blends (BBS/CS and CYS/WS) at 75 and 95<sup>0</sup>C was additive of their individual components. As the temperature was increased in the BBS/CS blends, the SP increased up to 65<sup>0</sup>C and subsequently plummeted to 75<sup>0</sup>C. Further thermal agitation after 75<sup>0</sup>C brings about an increase in SP. The decrease in SP of the blends (70BBS/30CS and 50BBS/50CS) at 75<sup>0</sup>C could be attributed to the formation of temperature-induced amylose-lipid complexes (Morrison et al., 1993). The formed amylose-lipid complexes inhibit swelling and difficult to dissociate thermally. Furthermore, temperature-denatured residual proteins could likely adhere to the starch granular surface and restrict swelling and exudation of AM (Olkku and Rha, 1978).

In the CYS/CS blends, as the temperature was increased, the SP also increased. It was not possible to establish a relationship between SP and AP of the blended starches. But such exist in the control starches. 100CS with the highest AP had the highest SP. This is closely followed by 100CYS. The rather low SP of the 100WS could be attributed to its high anti-swelling minor components (proteins and lipids). The low SP of the blends (BBS/CS), especially at low temperatures was probably due to their high AAM contents. Starches that contain less protein and lipid swell more rapidly on heating and tend to be more shear sensitive (Debet & Gidley, 2006). The higher SP of these blends (70CYS/30WS, 50CYS/50WS and 30BBS/70CS) especially at 95<sup>0</sup>C make them potentially suitable as additive in sausage type meat products, as this property is essential for proper texture in these foods (Carballo et al., 1995).

The WSI of the BBS/CS blends was additive at 55 and 65<sup>0</sup>C compared to the CYS/WS blends that was only additive at 75<sup>0</sup>C of their individual components. There was inconsistency in the WSI of the BBS/CS blends as the temperature increases, except with the 30BBS/70CS blend. The WSI of the blended starches (CYS/WS) increased when the temperature was elevated. The proportion of 100BBS in the BBS/CS blends was the major determinant of higher WSI at 55 and 65<sup>0</sup>C. As the proportion of 100BBS in the blends was increased at 55 and 65<sup>0</sup>C, there was proportionate raise in WSI. The decrease in SP and WSI at 75<sup>0</sup>C (in the BBS/CS blends) was likely due to the effects of residual proteins, lipids and temperature-induced complexes (Morrison et al., 1993). More amylose-lipid complexes might have been formed at 75<sup>0</sup>C, therefore swelling was inhibited and exudation of AM from starch granules that enhanced solubility was also restricted. This tendency

in the BBS/CS blends seem to have been disrupted at 85<sup>0</sup>C as the WSI increased. This increased in WSI might be due to the dissociation of amylose-lipid complexes at higher temperature. The higher solubility of the starch blends (CYS/WS) compared to the control starches may be due to their higher AAM content. SP and WSI of starches provided evidence of interactions between water molecules and starch chains in amorphous and crystalline domains (Ratnayake et al., 2002).

### **Pasting properties of control starches and their blends**

The pasting properties of the control starches (100BBS, 100CS, 100CYS and 100WS) and their blends are presented in Table 3. There is always a direct proportionality relationship between PV, SP and BV (Ashogbon, 2014a). Higher AP content is also associated with the manifestation of higher SP in starches. With the exception of the 50BBS/50CS blend, the control starches possessed higher PV values compared to the blended starches. The highest PV in the BBS/CS blends was 70BBS/30CS and of the CYS/WS blends was the 50CYS/50WS blend. This indicates the two blends have the weakest intramolecular and intermolecular bonding forces holding the polymeric molecules together within their granules. Therefore, their granules easily get distended when thermally agitated. The control starches (100BBS, 100CS and 100CYS) easily swell when heated due to their high PV values. The only exception was 100WS. The rigid nature of the 100WS granules was displayed by its small PV value (Table 3). The expression of higher PV values in the BBS/CS blends was due to 100BBS. As the proportion of 100BBS in the blends was increased, the PV values also increased. High proportion of 100CYS in the CYS/WS

blends was the major determinant of high PV values.

The unique nature of the 50CYS/50WS blend was worth-noting. It had the highest value of PV, TV, BV, FV and SV. It is also the blend with the highest AP when compared to the other blended starches. The high PV and SP of the 50CYS/50WS blend could be attributed to its high AP (low AM) (Zaidul et al., 2007) and low values of minor components. This blend is of special interest for potential industrial application. These high PV blended starches (50CYS/50WS, 70CYS/30WS and 70BBS/300CS) could find applications as thickening agent in foods and as a finishing agent in the paper and textile industries. In addition, these viscous starches and blends may be used in tablet and capsule formulations (Okunlola and Odeku, 2009) and also as drug disintegrants (Otegbayo et al., 2013).

The trough viscosity (TV), otherwise known as hot paste viscosity of the blended starches ranged between 143.92 to 250.33 RVU with the 50CYS/50WS blend having the highest value. The significance of TV is that, it aids in the computation of BV and SV values. The TV had been associated with the ability of the blends to withstand breakdown during cooling (Abu et al., 2012). Generally, with the exception of 100CS and the 50CYS/50WS blend, the control starches have higher TV values compared to the blended starches. The highest TV value of the 50CYS/50WS blend indicates that it will be more able to withstand breakdown during cooling than the other starch samples.

Breakdown viscosity (BV) is a measure of the ease of disrupting swollen starch granules and suggests the degree of stability during cooking (Adebowale & Lawal, 2003). The lower BV values of the BBS/CS blends compared to the CYS/WS blends

indicate they are more thermally stable and resistant to mechanical fragmentation of their granules. The higher BV values of the blended starches (50CYS/50WS and 70CYS/30WS) indicate the weak internal structures of their granules. The high thermal stability (low BV values) of 100WS and 50CYS/50WS blend could be utilized in canned foods and those products that require sterilization (Novelo-Cen & Betancur-Ancona, 2005). The BV of the blends (BBS/CS and CYS/WS) was non-additive of their individual components.

The characteristic high retrogradation and syneresis associated with the legume starches due to their high AAM content was observed in 100BBS. In contrast, the low retrogradation known for cereal starches was displayed by 100WS (97.0 RVU) (Table 3). The high retrogradation values of 100BBS and 50CYS/50WS blend will not be suitable for frozen and refrigerated foods and liquid medicine with suspended particles. The high retrogradation of some of the blends (70BBS/30CS) was expected due to their high AAM content. This implies they could be used in gluten-free paste and noodles (Emmambux & Taylor, 2013) where high retrogradation is desired. In contrast, lower SV values of some blends (30BBS/70CS) could be utilized in refrigerated foods, desserts and cake-filling (Novelo-Cen & Betancur-Cen, 2005). Additive tendency was observed in the BBS/CS blends and non-additive in the CYS/WS blends of their individual components. As the 100BBS proportion in the BBS/CS blends was increased, the SV values also increased proportionately. Expectedly, the manifestation of higher SV values in the BBS/CS blends were due high proportion of 100BBS in them. Unexpectedly, the expression of higher SV values in the CYS/CS blends was due to 100WS.

The close relation between SV and FV was displayed in this study. It is because both parameters (SV and FV) are mainly controlled by the structure and quantity of AAM content in the starches. For instance, the 50CYS/50CS blend had the highest SV and FV values among the blended starches. The 100BBS had the highest SV and FV values among the control starches. The FV values of the blended starches ranged from 296.67 to 428.92 RVU, the highest for the 50CYS/50WS blend. A high FV of starch indicates that the paste is more resistant to mechanical shear and may easily form a more rigid gel (Zhang et al., 2011). Generally, the blended starches possessed higher FV values compared to the control starches (with exception of 100BBS). The higher FV values of the blends and 100BBS could be attributed to their high AAM content. The expression of higher FV values in the BBS/CS blends was due to higher 100BBS content. On the other hand, the display of higher FV values in the CYS/WS blends was also due to higher 100CYS content. The FV of the BBS/CS blends was additive compared to the non-additive tendency in the CYS/WS blends. As the proportion of 100BBS in the BBS/CS blends was reduced, their FV values also diminished. This is to be expected, as a high AAM content was always associated with the development of high FV values in starches (Miles et al., 1985). High FV starches (50CYS/50WS, 70BBS/30CS and 100BBS) could be desired in many food products (soups, sauces and dressings); they can also be utilized in wet stage production of paper and the textile industry where high viscosity is required (Moorthy, 2002). Contrarily, the low FV starches (30CYS/70WS and 100CS) could be significant in the dry stage paper-making (Moorthy, 2002).



**Table.1** Gross chemical composition of control starches and their blends

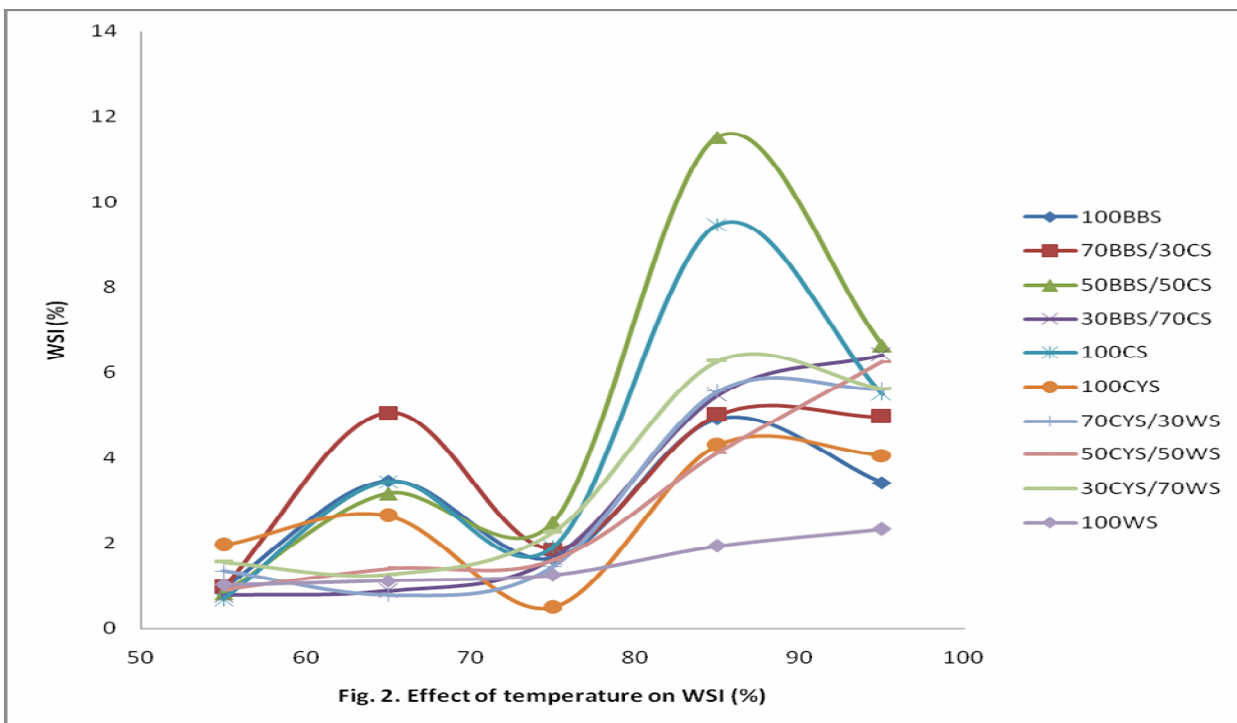
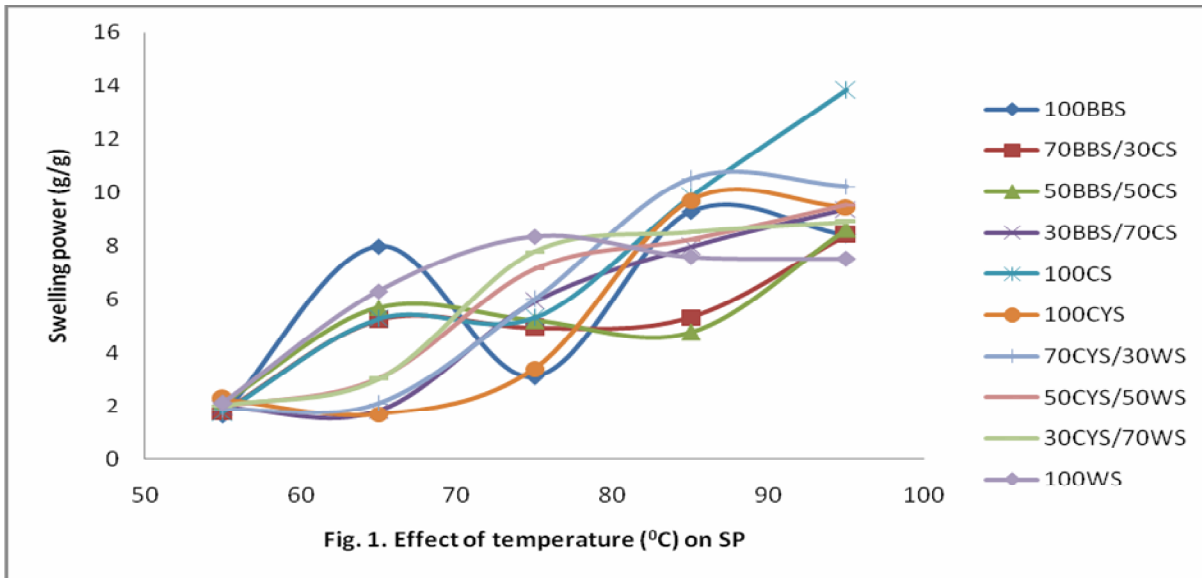
Sample	Moiture (%)	Ash (%)	Lipid (%)	Protein (%)	AM (%)	AP (%)
100BBS	11.00±0.02	0.05±0.01	0.31±0.02	0.18±0.01	37.31±0.10	62.69±0.10
70BBS/30CS	11.52±0.10	0.30±0.01	0.38±0.10	1.80±0.03	41.52±0.02	58.48±0.10
50BBS/50CS	11.95±0.20	0.21±0.01	0.49±0.03	0.80±0.01	36.26±0.01	63.74±0.02
30BBS/70CS	12.36±0.01	0.12±0.00	0.33±0.01	0.18±0.10	33.23±0.10	66.77±0.01
100CS	12.67±0.30	0.20±0.01	0.10±0.00	0.10±0.00	20.20±0.01	79.80±0.02
100CYS	12.62±0.02	0.15±0.01	0.08±0.00	0.09±0.01	22.60±0.10	77.40±0.01
70CYS/30WS	11.70±0.10	0.30±0.02	0.45±0.01	0.18±0.01	38.57±0.30	61.43±0.02
50CYS/50WS	11.85±0.20	0.22±0.01	0.06±0.00	0.07±0.00	30.90±0.30	69.01±0.01
30CYS/70WS	12.65±0.01	0.12±0.02	0.40±0.00	0.18±0.02	44.00±0.20	56.00±0.01
100WS	10.35±0.30	0.40±0.03	0.70±0.01	0.45±0.10	27.69±0.30	72.31±0.0

**Table.2** Bulk density, dispersibility and pH of the control starches and their blends

Sample	Bulk density (g/mL)	Dispersibility (%)	pH
100BBS	0.86±0.03	86.00±0.07	7.38±0.02
70BBS/30CS	0.88±0.01	86.02±0.06	7.32±0.04
50BBS/50CS	0.83±0.03	83.00±0.03	7.29±0.03
30BBS/70CS	0.87±0.02	87.00±0.05	7.21±0.01
100CS	0.72±0.01	85.00±0.04	7.03±0.03
100CYS	0.80±0.01	83.00±0.05	6.50±0.05
70CYS/30WS	0.87±0.03	84.00±0.06	3.72±0.02
50CYS/50WS	0.86±0.01	85.00±0.07	3.11±0.04
30CYS/70WS	0.84±0.02	87.00±0.04	2.90±0.03
100WS	0.67±0.01	90.00±0.05	4.40±0.01

**Table.3** Pasting properties of control starches and their blends

Sample	PV (RVU)	TV (RVU)	BV (RVU)	FV (RVU)	SV (RVU)	Pt (min)	PT (°C)
100BBS	432.38±0.20	247.04±0.20	185.34±0.30	401.34±0.10	154.29±0.20	4.73±0.10	84.13±0.20
70BBS/30CS	416.21±0.30	246.67±0.10	169.54±0.20	395.05±0.30	148.38±0.10	5.24±0.02	95.25±0.10
50BBS/50CS	362.34±0.20	212.75±0.20	149.59±0.20	345.13±0.10	132.38±0.10	5.33±0.10	94.95±0.10
30BBS/70CS	360.38±0.20	186.30±0.10	174.08±0.30	299.21±0.20	112.92±0.20	4.90±0.10	70.28±0.20
100CS	533.75±0.10	162.58±0.10	391.17±0.10	274.30±0.20	112.05±0.30	3.34±0.20	69.98±0.30
100CYS	499.25±0.20	233.10±0.10	266.15±0.10	353.70±0.10	120.60±0.30	4.30±0.10	81.45±0.30
70CYS/30WS	464.92±0.30	199.25±0.10	265.67±0.30	331.50±0.30	132.25±0.20	4.13±0.20	80.00±0.02
50CYS/50WS	559.00±0.20	250.33±0.20	308.67±0.20	428.92±0.10	178.59±0.10	4.89±0.10	82.45±0.10
30CYS/70WS	342.75±0.20	143.92±0.10	198.83±0.20	296.67±0.20	152.75±0.10	5.00±0.10	84.10±0.10
100WS	254.90±0.10	202.00±0.20	52.90±0.30	299.60±0.30	97.00±0.20	6.90±0.20	88.20±0.20



The pasting temperature (PT) of the blended starches was observed to be highest in the blends (70BBS/30CS). Furthermore, the PT of the blends (BBS/CS and CYS/WS) was additive of their individual components. As the proportion of 100BBS and 100WS in their various blends increased, their PT values were also raised proportionately. High PT may not be an advantage in the industrial application of the blends (70BBS/30CS and 50BBS/50CS) where low PT (short cooking time) are usually preferred but could be an advantage in canned and sterilized foods processed at high temperatures (Otegbayo et al., 2013). The peak time (Pt) of the BBS/CS blends was non-additive compared to the additive tendency in the CYS/WS blends.

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