ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 6, Issue, 10, pp.9181--9187, October, 2014

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

PHYSICOCHEMICAL COMPARISON OF SOME STARCH BLENDS-COCOYAM AND WHEAT STARCHES VERSUS PIGEON PEA AND RICE STARCHES

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ARTICLE INFO

Article History:
Received 15th July, 2014
Received in revised form
06th August, 2014
Accepted 10th September, 2014
Published online 25th October, 2014

Key words:

Physicochemical,
Cocoyam starch,
Pigeon pea starch,
Blending,
Pasting

ABSTRACT

Cocoyam starch (CYS), wheat starch (WS), pigeon pea starch (PPS) and rice starch (RS) were blended in different proportions (70CYS/30WS, 50CYS/50WS, 30CYS/70WS) (CYS/WS) and (70PPS/30RS, 50PPS/50RS, 30PPS/70RS) (PPS/RS) and their physicochemical properties were evaluated and compared. The apparent amylose contents of the CYS/WS blends ranged from 30.99% (50CYS/50WS) to 44.00% (30CYS/70WS) compared with 33.14% (30PPS/70WS) to 42.63% (50PPS/50RS) of the PPS/RS blends. The dispersibility and pH of the CYS/WS blends was additive compared to the non-additive nature of these parameters in the PPS/RS blends of their individual components. The swelling power and water solubility index of the PPS/RS blends were restricted compared to the CYS/WS blends where these parameters were higher than their component starches. The pasting viscosities were non-additive, but the peak time and pasting temperature were additive for both blends (CYS/WS and PPS/RS) of their individual components. The under-utilized 100CYS and 100PPS could be more important industrially by substituting part of it into the more expensive 100WS and 100 (RS). 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 starches 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.

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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 (100PPS) blended with rice starch (RS) (Ashogbon, 2014c), bambarra starch blended with cassava starch (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 pigeon pea (*Cajanus cajan*) starch (Ashogbon *et al*., 2011), rice (*Oryza glaberrima*) starch (Ashogbon and Akintayo, 2012a), 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; (70CYS/30WS, 50CYS/50WS and 30CYS/70WS) versus (70PPS/30RS, 50PPS/50RS and 30PPS/70RS) 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

Materials

Cocoyam tubers, wheat grains, pigeon pea seeds and rough hulled rice grains were purchased from a local market at Igbokoda, 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

Starch was isolated from new cocoyam tubers by a method previously described by Lawal (2004). Isolation of native wheat starch (100WS) was carried out by a method reported by Finnie *et al*. (2010). Pigeon pea starch (100PPS) was isolated from pigeon pea seeds by the method reported by Singh *et al*. (2004). Rice starch (100RS) was isolated from rice flour by the alkaline deproteinization method of Lim *et al*. (1999) as modified by Ashogbon and Akintayo (2012b).

Preparation of starch blends

Starch blends were prepared from the isolated control starches (100CYS, 100WS, 100PPS and 100RS) in six proportions (70CYS/30WS, 50CYS/50WS, 30CYS/70WS) and (70PPS/30RS, 50PPS/50RS, 30PPS/70RS) (%, 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

For the purpose of this discussion, the blends (70CYS/30WS, 50CYS/50WS and 30CYS/70WS) will be represented as

CYS/WS and the blends (70PPS/30RS, 50PPS/50RS and 30PPS/70RS) as PPS/RS. The gross chemical composition of the control starches (100CYS, 100WS, 100PPS and 100RS) and their blends are presented in Table 1. The moisture and ash contents of the CYS/WS blends were additive compared to the non-additive tendency of the PPS/RS blends of their individual components. The moisture content of the blended starches ranged from 11.70 to 13.50% and falls within the commercially accepted range (less than 14.0% moisture content; Juliano and Villarreal, 1993). This range is not easily vulnerable to spoilage by micro-organisms. The moisture content in the PPS/RS blends was lower than their control starches. Contrarily, the moisture content of the CYS/WS blends was in-between that of their control starches. Moisture content is a vital parameter in the packaging, transportation and spoilage of starches.

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

Sample	Moisture (%)	Ash (%)	Lipid (%)	Protein (%)	AM (%)
100CVS	12.62±0.02	0.15±0.01	0.08±0.00	0.09±0.01	22.60±0.10
70CYS/30WS	11.76±0.10	0.30±0.02	0.45±0.01	0.18±0.01	38.57±0.30
50CYS/50WS	11.85±0.20	0.22±0.01	0.06±0.00	0.07±0.00	30.99±0.30
30CYS/70WS	12.65±0.01	0.12±0.02	0.40±0.01	0.18±0.02	44.00±0.20
100WS	10.35±0.30	0.40±0.01	0.70±0.02	0.45±0.10	27.69±0.30
100PPS	8.72±0.20	0.10±0.00	0.15±0.02	0.20±0.01	28.40±0.00
70PPS/30RS	13.00±0.01	0.40±0.10	0.33±0.00	0.18±0.02	37.85±0.10
50PPS/50RS	13.50±0.02	0.20±0.01	0.49±0.03	0.26±0.01	42.63±0.01
30PPS/70RS	12.00±0.10	0.40±0.01	0.56±0.10	0.18±0,02	33.14±0.02
100RS	11.74±0.02	0.24±0.01	0.40±0.01	0.40±0.01	26.04±0.10

The low ash content of the control starches was an indication of their high purity before blending. It is important to note the higher content of the minor components (lipids and protein) of cereal starches (100WS/100RS) compared to the tuber and legume starches. The lipid content of the CYS/WS blends was additive compared to the non-additive nature of the PPS/RS blends of their individual components. Among the blended starches, the highest protein content was observed in the 50PPS/50RS blend. The apparent amylose (AAM) contents of the blended starches were higher than that of their individual control starches. In a study by Abu *et al*. (2012), the AAM content of blended Irish potato and pigeon pea starches was lower than that of their control starches. The AAM of the blended lima bean and cassava starches was intermediate to that of their control starches (Novelo-Cen and Betancur-Ancona, 2005). The AAM content of the blended starches seems to depend on the blending ratio and sources of the component control starches. This study indicates that blended starches possessed higher AAM content compared to their individual component starches.

The blends (30CYS/70WS and 50PPS/50RS) with higher AAM could be desired in the making of noodles (Tan *et al*., 2009). These high-AAM 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 polymer structure (Santelia and Zeeman, 2011). Furthermore, high AAM blended starches (30CYS/70WS and 50PPS/50RS) could also find applications in the production of corrugated board and paper (Jobling, 2004). The manifestation of higher AAM content in the CYS/WS blends was dependent on high proportion of 100WS and the PPS/RS blends on high proportion of 100RS. Therefore, the cereal starches are the main determinant of the high AAM content in the blended starches.

Some 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 summarized in Table 2. The BD of the CYS/WS blends was higher compared to that of the PPS/RS blends. The bulk densities of the starch blends ranged from 0.62 to 0.87 g/mL. The highest BD was observed for the 70CYS/30WS blend and the lowest for 100RS. BD is a measure of the degree of coarseness or smoothness of the starch particles. This means that the 70CYS/30WS blend had the coarsest particles. It also implies that 100RS, 100WS and the 30PPS/70RS blend are the smoothest and could be useful for making paper and photographic paper powder, cosmetic dusting powder and laundry stiffing agent (Singh *et al*., 2006a, 2006b). Furthermore, the smaller BD starches may provide smooth texture that exhibits fat mimetic properties (Otegbayo *et al*., 2013). The bulk densities of both blends (CYS/WS and PPS/RS) were additive of their individual components.

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

Sample	Bulk density (g/mL)	Dispersibility (%)	pH
100CYS	0.80±0.03	83.00±0.04	6.50±0.04
70CYS/30WS	0.87±0.01	84.00±0.05	3.72±0.01
50CYS/50WS	0.86±0.02	85.00±0.03	3.11±0.03
30CYS/70WS	0.84±0.01	87.00±0.06	2.90±0.05
100WS	0.67±0.03	90.00±0.02	4.40±0.02
100PPS	0.82±0.02	82.00±0.07	7.60±0.02
70PPS/30RS	0.76±0.01	83.00±0.06	7.17±0.05
50PPS/50RS	0.73±0.02	8I.00±0.03	7.39±0.01
30PPS/70RS	0.64±0.01	80.00±0.05	7.39±0.01
100RS	0.62±0.03	89.00±0.04	7.24±0.04

The higher the DB, the better the starch flour reconstitutes in water (Kulkarni *et al*., 1991). With the exception of 100CYS and 100PPS, the DB of the control starches was higher compared to the blended starches. The additive tendency of the blends (CYS/WS and PPS/RS) with respect to DB was obvious as seen in Table 2. Since the higher the DB, the better the flour reconstitutes, the values obtained for 100RS, 100WS and the 30CYS/70WS blend were higher and better than that of other investigated starches. Furthermore, these percentage dispersibility 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 high DB starches will probably be suitable for applications where large quantity of

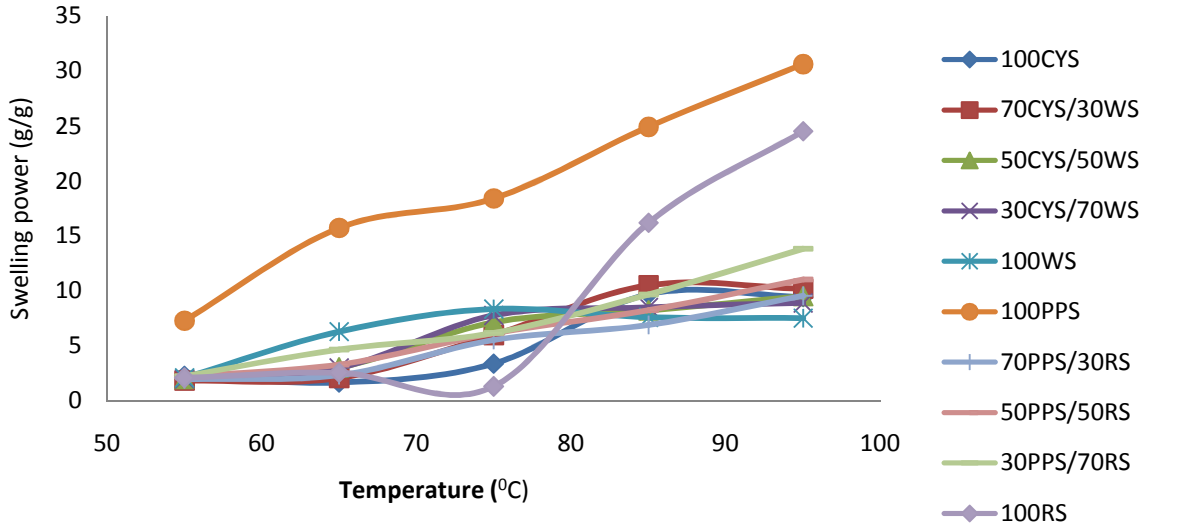

Fig.1. Effect of temperature on SP

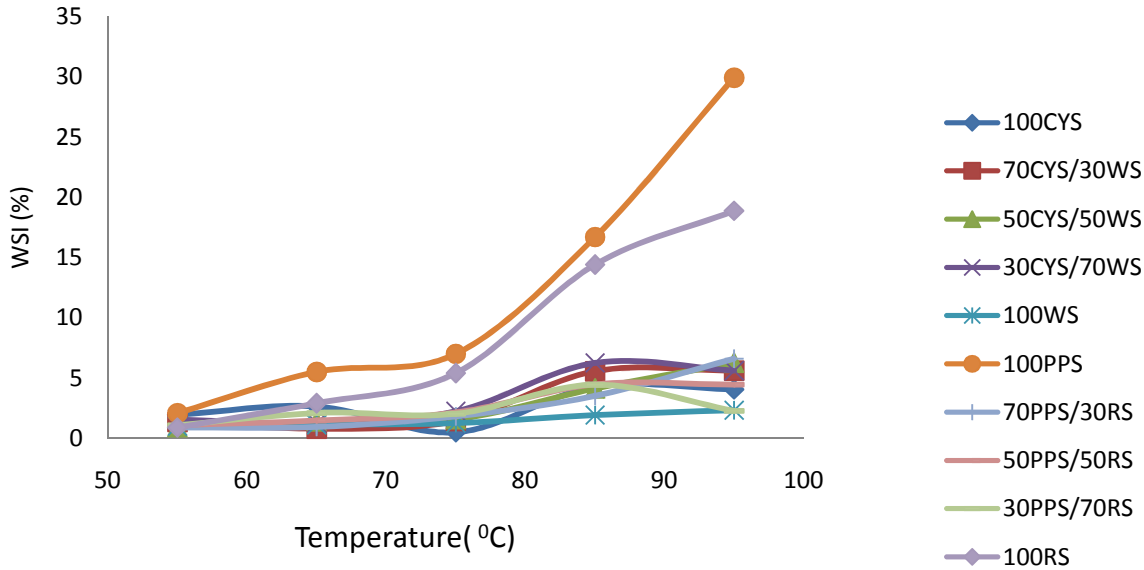

Fig. 2. Effect of temperature on WSI

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 the CYS/WS blends was additive compared to the non-additive nature of the PPS/RS blends. The pH of the CYS/WS blends was lower and more acidic than that of the PPS/RS blends. The pH of 100PPS was the highest and most alkaline compared to that of the other starches. pH values (3.71-3.77) identical to that of the CYS/WS blends had been previously obtained for some cultivar of rice starches (Ahmed *et al*., 2007). AM had been widely documented to be responsible for WSI and AP for SP. The importance and effects of residual protein, lipid, native and temperature-induced amylose-lipid complexes on these two parameters (SP and WSI) were also emphasized (Ashogbon, 2014a). The SP and WSI of the control starches and their blends heated from 55 to 95^{0}C at 10^{0}C interval were presented in Fig. 1 and Fig. 2, respectively. For all the blends (CYS/WS and PPS/RS), the SP increases as the temperature was raised. For the CYS/WS blends, at 55, 65 and 75^{0}C, as the proportion of 100WS in the blends was raised, the SW also increased proportionately. At all the temperature investigated for the PPS/RS blends, as the temperature was elevated, the SP also increased. In the PPS/RS blends, the values of SP and WSI were lower than their control starches and vice versa for the CYS/WS blends. Blending inhibited the SP and WSI of the starch blends (PPS/RS) because the starches share the same available solvent (Park *et al*., 2009). This decreased swelling as a result of blending might result in increased rigidity of swollen starch granules (Park *et al*., 2009) and an increase in AAM content of the blends (Ashogbon, 2014c). The low SP of

the PPS/RS blends was attributed to their low AP content. In the CYS/WS blends, it was not possible to establish a relationship between SP and AP. The rather low SP of the cereal starches (100WS and 100RS) at low temperature despite their high AP content could be attributed to their high anti-swelling and anti-solubility minor components (mainly lipid and protein). Starches that contain less protein and lipid swell more rapidly on heating and tend to be more shear sensitive (Debet and Gidley, 2006). The higher SP of 100PPS, 30PPS/70RS blend and 100RS (only at high temperature) could be potentially suitable as additive in sausage type meat products, as this property is essential for proper texture in these foods (Carballo *et al*., 1995). In the CYS/WS blends, the SP was additive at 75^0C and 95^0C compared to the non-additiveness of the PPS/RS blends at all the temperature investigated. The WSI of the CYS/WS blends was additive at 75^0C compared to that of the PPS/RS blends that was additive at 95^0C. In the PPS/RS blends, the WSI was restricted, while in the CYS/WS blends, the control starches have higher WSI than the blends. SP and WSI of starches provide evidence of interactions between water molecules and starch chains in amorphous and crystalline domains (Ratnayake *et al*., 2002).

Pasting properties of the control starches and their blends

The pasting properties of the control starches and their blends are summarized in Table 3. All the pasting viscosities of the starch blends (CYS/WS and PPS/RS) were non-additive of their individual components. The blended starches with the highest PV values were 50CYS/50WS and 50PPS/50RS blends. The control starches of the tuber (100CYS) and legume (100PPS) have higher PV values than the cereal (100WS and 100RS). These high PV starches and blends indicate weaker intra-molecular and intermolecular bond holding the polymeric molecules together. Therefore, their granules easily get distended when thermally agitated. The rigid nature of the granules of the cereal starches (100WS and 100RS) and the 30PPS/70RS blend were observed in their low PV values. The manifestation of low PV in the blends was due to high proportion of cereal starches (100WS and 100RS) in the mixtures. This is expected as low SP and PV values are always associated with the cereal starches. The high PV starches (100CYS and 100PPS) and blends (50CYS/50WS and 50PPS/50RS) could be used in products where high SP is required, e.g., in tablet and capsule formulations (Okunlola and Odeku, 2009). Furthermore, these viscous starches and blends may also be utilized as thickeners, binders, fillers and disintegrants for fast release of drugs (Otegbayo *et al*., 2013). High paste viscosity suggests suitability as a finishing agent in the textile and paper industries (Wani *et al*., 2012).

Special attention should be given to the blends (50CYS/50WS and 50PPS/50RS). They possessed the highest PV, TV, BV and FV values among the blended starches. These high pasting viscosities could be potentially vital for industrial applications. The TV of the blended starches ranged from 78.75 to 250.22 RVU with the 50CYS/50WS blend having the highest value. The TV aids in the computation of BV and SV values. Furthermore, TV had also been associated with the ability of the blends to withstand breakdown during cooling (Abu *et al*., 2012). Generally, with the exception of the 50CYS/50WS blend, the control starches have higher TV values compared to the blended starches. This implies the 50CYS/50WS will be more able to withstand breakdown during cooling than the other blended starches. The exceptional low BV values of the control starches (100WS and 100RS) and the 30PPS/70RS blend are associated with thermal stability of their granules. The granules of these cereal starches and the blend are not easily fragmented or ruptured during thermal processing. These high thermal stability and rigidity could be exploited in canned foods and products that require sterilization (Novelo-Cen and Betancur-Ancona, 2005). In contrast, the high BV blends (50CYS/50WS and 50PPS/50RS) and control starches (100CYS and 100PPS) were associated with weak internal structure. This is further corroborated by their possession of high PV values. These high PV starches swell easily when thermally agitated. The close relationship between PV and BV was also observed in this study. The PV and BV values of the 50CYS/50WS blend were higher compared to the 50PPS/50RS blend.

Table 3. Pasting properties of control starches and their blends

Sample	PV(RVU)	TV(RVU)	BV(RVU)	FV(RVU)	SV(RVU)	Pt(min)	PT(^{0}C)
100CYS	499.25±0.20	233.10±0.10	226.15±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±0.36	132.25±0.20	4.13±0.20	80.00±0.20
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
100PPS	558.00±0.20	333.40±0.10	224.60±0.10	510.00±0.20	176.60±0.30	4.37±0.20	74.00±0.20
70PPS/30RS	320.33±0.10	149.75±0.10	170.58±0.30	332.25±0.20	182.50±0.20	4.40±0.10	81.65±0.30
50PPS/50RS	429.42±0.20	163.92±0.20	265.50±0.20	347.25±0.10	183.33±0.10	4.53±0.10	83.25±0.20
30PPS/70RS	171.08±0.30	78.75±0.10	92.33±0.20	196.83±0.30	118.08±0.10	4.93±0.20	87.30±0.10
100RS	268.25±0.10	227.33±0.20	40.92±0.30	329.92±0.10	102.50±0.20	6.36±0.30	83.02±0.10

The characteristic high retrogradation and syneresis associated with the legume starches due to their high AAM content was observed in 100PPS. Contrarily, the low retrogradation of the cereal starches was displayed by 100WS (97.0 RVU) and 100RS (102.5 RVU) (Table 3). In the CYS/WS blends, the blended starches have higher SV values compared to their component starches. The same was true of the PPS/RS blends with the exception of the 30PPS/70RS blend. Unexpectedly, the manifestation of high SV values in the CYS/WS blends was due to high proportion of 100WS in the mixtures. Expectedly, the observation of high SV value in the PPS/RS blends was due to their higher AAM content. The high retrogradation values of the blended starches (50CYS/50WS and 50PPS/50RS) will not be suitable for frozen and refrigerated foods and liquid medicine with suspended particles. These high SV blended starches with high AAM content could be used in gluten-free paste and noodles (Emmambux and Taylor, 2013). In contrast, lower SV values of the cereal starches (100WS and 100RS) and the 30PPS/70RS blend could be utilized in refrigerated foods, deserts and cake filling (Novelo-Cen and Betancur-Ancona, 2005).

The close relationship between SV and FV was displayed in this study. It is because both viscosities (SV and FV) are mainly controlled by the structure and quantity of AAM content in the starches. Among the CYS/WS blends, the SV and FV values of the 50CYS/50WS were the highest. Highest values of SV an FV in the PPS/RS blends was also observed in the 50PPS/50RS blend. A high FV of starch indicates that the paste is more resistant to mechanical shear and may easily form a rigid gel (Zhang *et al*., 2011). The high FV values of 100PPS and the 50CYS/50WS could be desired in many food products (soups and sauces); they may also be used in the textile industry and wet stage paper production (Moorthy, 2002). Lower FV starch blend (30PPS/70RS) could be significant in the dry stage paper-making (Moorthy, 2002). Identical control starches were responsible for the manifestation of higher SV and FV values in the blended starches. The PT and Pt of both blends (CYS/WS and PPS/RS) was additive of their individual components. As the proportion of 100RS in the PPS/RS blends increased, PT values also raised proportionality. High PT starches (100WS and 30PPS/70RS) may not be an advantage in industrial applications where low PT (short cooking time) starches (100CYS and 70CYS/30WS blend) are usually preferred but could be an advantage in canned and sterilized foods processed at high temperatures (Otegbayo *et al*., 2013)

Conclusions

Blending of native starches from different botanical sources has come to replace the expensive and hazardous chemical and physical modification. Starch blending is cheap and easy to carry out. It has been shown that blending of different native starches can easily change their physicochemical properties. Starches with properties comparable to that obtained by chemical modification can be produced by blending different native starches. One clear advantage of blending different starches is that no chemical or biological agent is introduced into the blended starches. Some salient points emanating from this work are as follows:

- Cereal starches (100WS and 100RS) are the main determinant of high apparent amylose in the blended starches.
- The bulk densities of the blended starches were additive of their individual components.
- All the pasting viscosities of the blended starches were non-additive of their individual components.

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