Quality Characteristics of Stiff Porridges Prepared from Acha and Bambara Nut Starch Blends

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ABSTRACT

Objective: The objective of the study was to determine the quality attributes of stiff porridges prepared from acha and bambara nut starch blends.

Materials and methods: Starches were extracted from acha and bambara nut using wet extraction method. Starches were mixed in different proportions (100: 0; 90: 10; 80:20; 70:30; 60:40, 50:50 and 0:100 of acha and bambara nut starches respectively) and analysed for chemical and functional properties. The starch blends were further prepared into stiff porridges for sensory evaluation using a twenty-member sensory panel.

Results: Addition of bambara nut starch to acha starch led to increase in moisture (from 6.55 to 8.98%), protein (from 0.21 to 1.2%), fat (from 0.15 to 0.43%) and ash (from 0.15 to 0.48%) and amylose (from 25.29 to 31.68%) contents. Acha starch gave a yield of 38.48% while bambara nut was 41.57%. Addition of bambara nut starch to acha starch decreased bulk density (from 0.75 to 0.64g/cm3) and dispersability (from 48.60 to 36.11%) while blue value index and water absorption capacity increased from 37.30 to 52.46% and 2.38 to 2.80g water/g sample, respectively. Peak, breakdown, final and setback viscosities increased while peak time and pasting temperature decreased due to addition of bambara nut starch. There was no significant ($p \geq 0.05$) difference in colour, stickiness, mouldability and texture between stiff porridges prepared from 100% acha and bambara nut (up to 50:50) blends when compared to cassava starch stiff porridge. Stiff porridge prepared from 70:30 (acha : bambara nut) blend had the highest overall acceptability score than composite blends and 100% cassava starch stiff porridge.

Conclusion: The addition of bambara nut starch to acha starch improved some desirable functional and sensory attributes required in preparation of stiff porridge. Acha-bambara nut stiff porridge could serve as a functional food for groups with special caloric and glycemic requirements since the starch blends are low-digestible starch sources.

Keywords: Acha-bambara nut stiff porridge, chemical composition, functional properties, pasting properties, sensory properties

INTRODUCTION

As the number of people diagnosed with diabetes continues to increase around the world, nutritional approaches to diabetes prevention is one step researchers ought to take to address this serious situation by formulating diets to optimize health and counteract the risk factors of metabolic syndrome in an aging population [1]. For this reason, research into alternative starch sources with slow and or low digestibility in staple food preparations such as stiff porridges have been reported [2]. However, this study is a complementation of research efforts of these authors towards exploiting the potentials of non-conventional starch sources from traditional grains (cereals and legumes) that are abundant in Africa in stiff porridge preparations.

Acha starch is composed of resistant (2.1%) and digestible starch (41.4%) with low glycemic index [3]. Resistant starch is part of some ingredients that assist in preventing and managing pre-diabetes and type 2- diabetes [3]. Resistant starches have interesting functional properties for use in foods with better texture, appearance and better organoleptic properties [4]. Bambara nut starch like other legume sources, contain slow digestible starch that promote slow and moderate postprandial glucose and insulin responses, and have low glycemic values. Also, legume starch contain variable amount of lipids which interact with carbohydrates to play a significant role in their functional properties, end-product quality, shelf life and texture of starch-based foods[5].

As a new food formulation, it is important to consider the functional and sensory properties of acha and bambara nut starches. According to Abu *et al.* [2], regardless of the source, the suitability of starches in foods such as porridges would depend on not only their pasting and functional properties but also the sensory acceptability by the potential consumers.

Considering the importance of resistant starch in nutrition, especially the poor digestibility of legume starches compared to cereal starches [6], the use of resistant starch sources such as acha and legume starch from bambara nut starch may serve as a functional food for groups with special caloric and glycemic requirements such as obese or diabetic people. It will reduce total dependence on the use of cassava starch in stiff porridge preparation, reduce post-harvest losses and increase the utilization and potential of these largely underutilized crops in Nigeria and most parts of sub-Saharan Africa.

The objectives of the study were to characterize the physicochemical, functional and pasting properties of acha and bambara nut starch blends and to evaluate the sensory properties of *stiff porridges prepared from their blends.*

MATERIALS AND METHODS

Source of raw materials

Acha and bambara nut seeds used in this study were purchased at central market, Minna, Niger state, Nigeria. Cassava starch was purchased from Amigo supermarket, Abuja, Nigeria.

Starch extraction

Acha and bambara nut seeds were separately sorted, washed with clean tap water and soaked in water for 12 hours. The soaked seeds were wet-milled into slurries. The slurries were separately suspended in cold deionized water and sieved with a white muslin cloth to remove the fibrous material leaving the starch in solution. The starch layer was suspended in deionized water and centrifuged 6 to 7 times, until the settled starch gave a firm, dense deposit at the bottom. The final sediment was suspended in cold deionized water and screened through 150 µm screen to keep the cell wall off the starch slurry. Then the residue was amassed and deposited quietly for 6 h. The starch suspensions obtained were separately dried to 10% moisture content in a convection oven at 50°C . The dried materials were ground into flour using attrition mill (Globe P 44, China) and sieved using a 75 µm screen to obtain the starch. Starch yield was calculated as a percentage of weight of starch/weight of ground acha/ bambara nut seeds.

Mixing of the starch blends

Acha and bambara nut starches were mixed at different proportions (100: 0; 90: 10; 80:20; 70:30; 60:40, 50:50 and 0:100) where cassava starch served as control. A Binatone blender (Model no. BLG-450, China) was used for mixing samples at speed 2 for 3 minutes.

Determination of functional properties

The bulk density and water absorption capacity was determined by the method of Okezie and Bello [7]. The dispersibility was determined as described by Kulkarni *et al*. [8]. The method of Sathe and Salunkhe [9] was adopted to determine the swelling power and solubility. Blue value index was determined by modified iodine method of Birch and Prietly [10]. Pasting parameters was determined using rapid visco analyzer (Newport Scientific Pty Ltd., Warriewood NSW 2102, Australia). A 2.5 g of each starch sample was weighed into a dried empty canister, and 25 ml of distilled water was dispensed into the canister containing the sample. The suspension was thoroughly mixed and the canister was fitted into the rapid visco analyzer. Each suspension was kept at 50 °C for 1 minute and then heated up to 95 °C at 12.2 °C /min and held for 2.5 min at 95 °C. It was then cooled to 50 °C at 11.8 °C /min and kept for 2 minutes at 50 °C.

Determination of chemical properties

The moisture, protein, fat, ash and crude fiber contents were determined by AOAC method [11]. The moisture was determined by hot air oven method at 105°C for 5 hours. The macro kjeldahl method was used for the determination of protein content. The fat content was determined by extracting 5g of sample with petroleum ether (boiling point of 40 to 60°C) using soxhlet solvent extraction method. Ash was determined by weighing 5g of sample into a tarred porcelain crucible which was incinerated at 600 °C for 6 hours in an ash muffle furnance until ash was obtained. The crude fiber was determined by exhaustive extraction of soluble substances in sample using 1.25% H_2SO4 acid and 1.25% NaOH solution after which the residue was ashed and the loss in weight was recorded as crude fiber. Amylose content was determined as described by Williams *et al*. [12]. A 0.1 g of starch was weighed into a 100 mL volumetric flask, then 1 mL of 99.7–100% (v/v) ethanol and 9 mL 1N sodium hydroxide were carefully added. The mouth of the flask was covered with parafilm and the contents were properly mixed. The samples were heated for 10 min in a boiling water bath to gelatinize the starch (the timing was started when boiling began). The samples were removed from the water bath and allowed to cool, then made up to the mark with distilled water and shaken thoroughly. Then, 5 mL was pipetted into another 100 mL volumetric flask and 1.0 mL of 1 N acetic acid and 2.0 mL of iodine solution were added. The flask was topped up to the mark with distilled water. Absorbance (A) was read using a spectrophotometer at 620 nm wavelength. The blank contained 1 mL of ethanol and 9 mL of sodium hydroxide, boiled and topped up to the mark with distilled water. Finally, 5 mL was pipetted into a 100 mL volumetric flask; 1 mL of 1 N acetic acid and 2 mL of iodine solution were added and then topped up to the mark. This was used to standardize the spectrophotometer at 620 nm. The amylose content was calculated as:

Amylose content (%) = 3.06× absorbance × 20

Preparation of stiff porridge and sensory evaluation

Fifty grammes of starch blends were separately reconstituted into paste using approximately 150 ml of boiling water over a low gas flame with continuous stirring for five minutes. A twenty-member panel consisting of students and Staff of Food Science option, Department of Animal Production Federal University of Technology, Minna Nigeria were enrolled based on their familiarity with stiff porridge for the sensory evaluation. Stiff porridge samples from the various blends were provided in coded white plastic plates and cassava starch served as standard. The order of presentation of samples to the panel was randomized. Tap water was provided to each panelist to wash their hands in between evaluations. The samples were evaluated for appearance, colour, stickiness, mould ability, texture and overall acceptability on a 9-point Hedonic scale where 1=disliked extremely, 5= neither like nor dislike and 9= liked extremely.

Statistical analysis

Data were analyzed by analysis of variance [13]. The difference between mean values was determined by least significant difference (LSD) test. Significance was accepted at 5 % probability level [14]. All the data reported in the tables are average values of duplicate determinations.

RESULTS

Substitution of acha starch with bambara nut starch increased the moisture (from 6.55 to 8.98%), protein (from 0.21 to 1.2%), fat (from 0.15 to 0.43%), ash (from 0.15 to 0.48%) and amylose (from 25.29 to 31.68%) of the blends (Table 1). Acha starch gave a yield of 38.48% while bambara nut was 41.57% (Table 1).

Table 1: Chemical composition of acha and Bambara nut starch blends

Starch blend Acha: bambara nut	Starch yield (%)	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Amylose (%)
100:0	38.48+0.29	6.55+0.05^{c}	0.21+0.00^{a}	0.15+0.00^{a}	0.15+0.00^{a}	25.29+0.01^{e}
0:100	41.57+0.29	8.98+0.13^{a}	0.64+0.01^{a}	0.43+0.02^{a}	0.48+0.00^{a}	31.68+0.05^{a}
90:10	ND	7.23±0.04^{b}	0.24±0.00^{a}	0.17±0.01^{a}	0.19±0.01^{a}	25.87±0.14^{e}
80:20	ND	7.46+0.10^{ab}	0.27+0.01^{a}	0.20+0.01^{a}	0.22+0.01^{a}	26.43+0.23^{d}
70:30	ND	7.69±0.02^{ab}	0.33±0.00^{a}	0.22±0.00^{a}	0.24±0.00a	26.90±0.12^{d}
60:40	ND	7.90+0.09^{a}	0.38+0.01^{a}	0.25+0.01^{a}	0.25+0.00^{a}	27.58+0.05^{c}
50:50	ND	8.15±0.03^{a}	0.47±0.03^{a}	0.28±0.01^{a}	0.31±0.01^{a}	28.90±0.35^{b}

Mean values within a column with different superscript are significantly ($p \le 0.05$) different.
ND= Not determined

The functional properties of starch blends (Table 2) showed that addition of bamabara nut starch to acha starch decreased the bulk density (from 0.75 to 0.64g/cm^{3}) and dispersability (from 48.60 to 36.11%) while blue value index and water absorption capacity increased from 37.30 to 52.46% and 2.38 to 2.80g water/g sample, respectively.

Table 2: Functional Properties of Starch blends

Starch blends Acha:bambara nut	Bulk density (g/cm^{3})	Water absorption capacity (g water/ g sample)	Dispersability (%)	Blue value index (%)
100:0	0.75±0.03	2.38±0.01	48.60±0.93	37.30±0.18
0:100	0.64+0.01	2.80+0.02	36.11+0.72	52.46+0.40
90:10	0.74±0.00	2.42±0.02	45.29±0.65	43.72±0.43
80:20	0.72+0.01	2.51+0.00	44.90+0.80	45.24+0.35
70:30	0.71±0.02	2.65±0.02	42.58±0.68	46.90±0.79
60:40	0.70±0.01	2.72±0.01	40.17±0.77	48.36±0.55
50:50	0.68+0.03	2.75+0.01	38.63+0.56	49.35+0.12

Mean values within a column with different superscript are significantly ($p \le 0.05$) different.

The swelling power and solubility of the various starch blends increased with increase in temperature and bambara nut starch level (Table 3). The pasting properties of acha and bambara nut starch blends are presented in Table 4. Addition of bambara nut to acha starch significantly ($p \le 0.05$) increased the peak viscosity (from 237.34 to 472.20RVU), trough (from 95.19 to 381.42RVU), breakdown (from 90.78 to 142.15RVU), final viscosity (from 304.11 to 546.70RVU) and setback (from 170.90 to 224.63RVU) values of the blends while peak time and pasting temperature decreased from 5.09 to 4.55 min and 76.01 to 73.73 °C respectively.

The sensory properties of stiff porridge prepared from acha and bambara nut starch blends is presented in Table 5. There was no significant ($p \ge 0.05$) difference in colour, stickiness, mouldability and texture between stiff porridge prepared from 100% acha and bambara nut (up to 50 :50) blends when compared to cassava starch stiff porridge.

DISCUSSION

The higher starch yield of bambara nut than acha starch could be attributed to high starch content in bambara nut than acha. The increased moisture, protein, fat and ash contents of the blends with increasing level of bambara nut starch substitution could be due to the addition effect of bambara nut starch with higher moisture, protein, fat and ash contents than 100% acha starch (Table 1).

Amylose content is one of the important factors affecting starch pasting and retrogradation behaviours. It provides surface and textural regularity, elasticity and sticky characteristics to starch-based products [15]. The amylose contents of the blends increased with increase in bambara nut addition. In general, the amylose content of legume starch is higher than cereals, roots and tuber starches. Legume starches have previously been reported [16] to contain relatively high amylose content (30 to 40 %). The higher amylose content in the composite blends than 100% acha starch may be indicative of possible textural differences when used in stiff porridge preparations.

Table 3: Effect of temperature on the swelling power and solubility of acha and bambara nut starch blends

Starch blend Acha: bambara nut	Swelling power (g water/ g starch)/Solubility Temperature (°C)							
	60	70	80	90	60	70	80	90
100:0	$4.10+0.05^{c}$	$4.89+0.22^{f}$	$6.05+0.19^{g}$	$9.48+0.08^{f}$	$3.11-0.01^{c}$	$3.43+0.03^{f}$	$4.19+0.00^{e}$	$6.05+0.02^{e}$
0:100	6.28 ± 0.08^{a}	7.14 ± 0.15^{d}	8.23 ± 0.13^{e}	8.70 ± 0.04^{g}	2.68 ± 0.01^{e}	2.95 ± 0.01^{d}	3.11 ± 0.01^{d}	$4.60^{e}\pm0.01^{e}$
90:10	4.66 ± 0.10^{f}	5.96 ± 0.25^{c}	6.29 ± 0.26^{d}	7.18 ± 0.12^{e}	2.77 ± 0.00^{c}	3.41 ± 0.01^{e}	4.26 ± 0.00^{e}	5.74 ± 0.00^{d}
80:20	$4.85+0.14^{e}$	$6.10+0.07^{e}$	$8.47+0.04^{c}$	$10.77+0.10^{d}$	$3.21-0.01^{b}$	$3.57+0.00^{e}$	$4.85+0.02^{c}$	$6.35+0.01^{c}$
70:30	$5.30+0.05^{b}$	$8.17+0.23^{c}$	$9.75+0.43^{b}$	$12.60+0.05^{c}$	$3.77-0.01^{b}$	$3.88+0.00^{e}$	$5.19+0.01^{c}$	$6.91+0.01^{bc}$
60:40	$5.78+0.02^{ab}$	$9.28+0.14^{b}$	$10.30+0.11^{b}$	$14.26-0.03^{b}$	$3.85-0.00^{b}$	$4.28+0.01^{b}$	$5.80+0.00^{b}$	$7.56+0.11^{b}$
50:50	6.20 ± 0.11^{a}	10.55 ± 0.10^{a}	14.56 ± 0.24^{a}	17.95 ± 0.11^{a}	4.53 ± 0.00^{a}	5.11 ± 0.01^{a}	6.57 ± 0.01^{a}	8.20 ± 0.08^{a}

Mean values within a column with different superscript are significantly ($p \leq 0.05$) different.

Table 4: Pasting properties of acha and bambara nut starch blends

Starch sources	Peak (RVU)	Trough (RVU)	Break down (RVU)	Final viscosity (RVU)	Setback (RVU)	Peak time (min.)	Pasting temperature (°C)
100:0	$237.34^{g}\pm0.97$	$95.19^{g}\pm0.60$	$142.15^{a}\pm0.70$	$304.11^{g}\pm0.85$	$208.61^{e}\pm0.42$	$5.09^{a}\pm0.04$	$76.01^{a}\pm0.69$
0:100	$472.20^{a}\pm0.63$	$381.42^{a}\pm0.53$	$90.78^{g}\pm0.82$	$546.70^{a}\pm0.97$	$165.28^{f}\pm0.88$	$4.55^{e}\pm0.00$	$73.50^{e}\pm0.74$
90:10	$257.90^{f}\pm0.81$	$162.79^{f}\pm0.47$	$95.11^{f}\pm0.62$	$378.53^{f}\pm0.83$	$215.74^{c}\pm0.70$	$4.61^{d}\pm0.01$	$73.73^{d}\pm0.80$
80:20	$281.25^{e}\pm0.55$	$179.96^{d}\pm0.64$	$101.29^{e}\pm0.58$	$396.29^{d}\pm0.76$	$216.33^{b}\pm0.53$	$4.70^{c}\pm0.01$	$73.92^{c}\pm0.54$
70:30	$305.64^{d}\pm0.68$	$177.04^{e}\pm0.89$	$128.60^{c}\pm0.95$	$401.67^{c}\pm0.69$	$224.63^{a}\pm0.74$	$4.73^{c}\pm0.00$	$74.04^{b}\pm0.66$
60:40	$329.08^{c}\pm1.02$	$211.23^{c}\pm0.73$	$117.85^{d}\pm0.46$	$382.13^{e}\pm0.60$	$170.90^{d}\pm0.97$	$4.67^{c}\pm0.00$	$73.88^{b}\pm0.58$
50:50	$363.49^{b}+0.84$	$225.06^{b}+0.99$	$138.43^{b}+0.71$	$434.58^{b}+0.66$	$209.52^{c}+0.58$	$4.85^{b}+0.01$	$74.45^{b}+0.61$

Values are mean and standard deviation of two determinations.
Values followed by different superscript letters in a column are significantly ($p \leq 0.05$) different.

The decrease in bulk density of the starch blends with increasing level of bambara nut starch may partly be attributed to the low bulk nature of bambara nut starch as well as to variations in their particle sizes which could be of advantage during packaging and distribution of the starch blends. The slight increase in water absorption capacity of the starch blends with increasing level of bambara nut starch could be attributed to high water binding ability of bambara nut starch. Also, water absorption capacity of starch depends on molecules, lipids, shape, conformation attributes, hydrophilic and hydrophobic balance in the molecule, thermodynamic properties of the system (such as bond energy, interfacial tension etc.), physicochemical environment (such as pH, ion concentration, temperature, pressure etc.) and starch solubility[2]. The decrease in dispersiblity of starch blends with increasing level of bambara nut starch could be attributed to high quantity of dry matter contained in acha as compared to that contained in bambara nut or variations in starch solubility. Dispersibility values obtained in this study were higher than the value (40.66%) reported by Akanbi *et al.* [17] for breadfruit starch. Blue value index represents the degree of starch damage or fragility of starch [18]. High blue value index value in 100% bambara nut starch may be attributed to high damaged starch granules in bambara nut starch.

Table 5: Sensory properties of stiff porridge prepared from acha and bambara nut starch blends.

Starch blend Acha:bambaranut	Colour	Stickiness	Mouldability	Texture	Over all acceptability
100:0	7.6^{a}	7.2^{a}	7.5^{a}	7.4^{a}	7.8^{a}
0:100	6.5^{b}	6.9^{a}	6.4^{b}	6.2^{b}	6.3
90:10	7.1^{a}	7.1^{a}	7.3^{a}	6.6^{b}	7.4^{a}
80:20	7.3^{a}	7.0^{a}	7.3^{a}	7.0^{a}	7.7^{a}
70:30	7.3^{a}	7.1^{a}	7.3^{a}	7.2^{a}	8.0^{a}
60:40	7.1^{a}	7.1^{a}	7.4^{a}	7.2^{a}	7.2^{a}
50:50	7.0^{a}	6.8^{a}	7.3^{a}	7.0^{a}	7.0^{a}
Cassava starch	7.2^{a}	7.4^{a}	7.2^{a}	7.7^{a}	7.8^{a}

Mean value of twenty member panelist.
Mean values within a column with different superscript are significantly ($p \leq 0.05$) different.

Damage starch granules have greater affinity for water, resulting in increased water absorption and swelling power. The increase in swelling power of starch blends with increase in temperature could be attributed to swelling of the starch granules due to thermal effect which caused an increase in solubility value. Also, swelling power and solubility value of starch blends increased with increase in bamabara nut starch levels and this could be ascribed to decrease in amylose contents in the blends due to decrease in starch content, since amylose acts as a dilutor and a swelling inhibitor [19]. The high swelling power of starch blends could be an indication of increased textural properties of the blends[19].

The high peak viscosity, trough, break down and setback values of acha-bambara nut blends may be attributed to their high water absorption capacity that caused increased starch swelling as observed in this study. High values of breakdown are associated with high peak viscosities, which correlate the degree of swelling of starch granules during heating [20]. High peak viscosity is an important attribute of textural quality in foods [2, 21]. According to Abu *et al.* [2], starch blends with high peak viscosities produced stiff porridges with good textural properties. The pasting properties of acha-bambara nut starch blends is in line with the reports of Novelo-Cen and Betancur-Ancona [22] and Chinma *et al.* [23] for bean and cassava starch blends, and cassava starch- soy protein concentrate blends, respectively.

The sensory attributes of acha stiff porridge increased with increase in bambara nut level (up to 40%). The increase in texture and mouldability scores of acha-bambara nut stiff porridge with increased level of bambara nut could be attributed to high peak viscosity of the blends. In terms of overall acceptability, there was no significant ($p \geq 0.05$) difference between stiff porridges prepared from 100% cassava starch and composite blends. However, stiff porridge prepared from 70:30 (acha : bambara nut) blend had the highest overall acceptability score than composite blends and 100% cassava starch stiff porridge.

CONCLUSIONS

The functional, chemical and pasting properties of acha and bambara nut starch blends indicate that they may be useful as alternatives to cassava starch for the preparation of stiff porridge.

The sensory results show that acceptable stiff porridges could be prepared by using up to 70:30 acha and bambara nut starches. Stiff porridge prepared from acha-bambara nut starch blend could be used a as a nutrition therapy especially in situations requiring restricted intake of highly digestible starch-based foods by diabetic patients.

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