EFFECT OF PROCESSING ON THE FUNCTIONAL AND PASTING PROPERTIES OF COMPLEMENTARY FOODS PREPARED FROM SORGHUM, SOYBEAN AND ROSELLE CALYCES FLOUR BLENDS

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Abstract: Flours were produced from sorghum, soybean and roselle calyces after subjecting them to varying processing treatments (germination, fermentation and roasting); and blends were produced using the Nutri Survey Linear Programming Package 2004 Version. Subsequently, pasting and functional properties of blends were determined using standard methods. Swelling capacity values ranged between 2.60 g/g for blend containing germinated sorghum and roasted soybean flour (GSRS) and 6.95 g/g for sorghum flour (SF). Water absorption capacity of the blends ranged from 1.20 ml/g to 2.40 ml/g for blend containing fermented sorghum and roasted soybean flour (FSRS), and blend of soybean flour and germinated soybean (SFGS) having the lowest and highest values respectively. Oil absorption capacity values ranged between 0.84 mL/g for blend of sorghum flour and roasted soybean flour (SFRS) and 1.67 mL/g for blend of sorghum flour and germinated soybean flour (SFGS). Packed bulk density ranged between 0.71 g/cm^3 for FSRS and 0.86 g/cm^3 for SF. Blends containing fermented sorghum flour had significantly ($p \leq 0.05$) higher peak viscosity values than blends containing germinated and untreated sorghum flour. There were significant differences ($p \leq 0.05$) in trough, breakdown, final and setback viscosities of samples. Values obtained for these parameters ranged from 14.00 to 444.50 RVU; 4.50 to 262.50 RVU; 24.50 to 993.50 RVU and 10.50-549.00 RVU, respectively. SF had lowest pasting temperature of 81.53^{o}C while SFGS had the highest value of 85.98^{o}C. The results from this study showed that blends containing germinated and fermented fractions of sorghum performed significantly ($p \leq 0.05$) better in most of the parameters studied than the untreated sample.

Keywords: Complementary food, fermentation, functional properties, germination, pasting

Introduction

As the age of an infant increases, the ability of breast milk to meet the requirements for micro and macro nutrients becomes limited (Goulet *et al.*, 2008). It is therefore imperative to introduce complementary foods for both nutritional and developmental reasons, and to enable the transition from milk feeding to family foods (Ugwuona *et al*., 2012). Complementary foods are defined as solid or liquid foods with nutritional values other than breast milk, offered to breast-fed infants (Guigluani & Cesar, 2000).

Complementary foods produced in Nigeria and other developing countries, are often of low nutrient density, and this has attracted attention both nationally and internationally (Mahgoub, 1999). Protein-energy malnutrition among children is the major health challenge posed to many of these countries (FAO, 2001; Ijarotimi & Keshinro, 2012). This is as a result of inappropriate complementary feeding practices, low nutritional quality of traditional foods, high cost of quality protein-based foods (Ijarotimi & Keshinro, 2012) and low income (Imtiaz *et al*., 2011).

Functional properties are the intrinsic physicochemical characteristics which may affect the behaviour of food systems during processing and storage (Osungbaro, 2009). Pasting and functional qualities of porridges depend on many factors, which include the type of cereal grains, variety, milling technique; particle sizes, steeping and fermentation periods etc. (Osungbaro, 2009). Processing of cereals and legumes such as soaking, fermentation, germination, roasting, etc. enhance their qualities (Egounlety, 1998). Ocheme *et al*. (2015) reported improved functional and starch gelatinization of sorghum flour subjected to germination. Soaking and malting were also found to improve the pasting and functional properties of sesame (*Sesamum indicum*) seed flour (Kajihausa *et al*., 2014); acha (*Digitaria exilis*) and tigernut (*Cyperus esculentus*) blends (Onuoha *et al*., 2014)

Adequate knowledge of functional and pasting indices of complementary foods provide an insight to their acceptability for industrial and domestic purposes (Fasasi *et al.*, 2006). This work was conducted to investigate the effect of processing treatments on the functional and pasting properties of complementary food produced from sorghum, soybean and roselle calyces.

Materials and Methods

Sources of materials

Sorghum (*Sorghum bicolor*), soybean (*Glycine max*), and fresh roselle calyces (*Hibiscus sabdariffa*) were purchased from Bodija market, Ibadan and were identified at the Department of Botany and Microbiology, University of Ibadan.

Sample preparation

Preparation of germinated sorghum flour

Germination was carried out according to the method described by Ariahu *et al.* (1999). Sorghum grains were manually cleaned to remove husks, stone and damaged seeds. The grains were washed in 5% (w/v) sodium chloride solution to suppress mould growth and soaked in tap water in ratio of 1:3 (w/v) grain for 12 h at room temperature (32±2°C), the water drained at 4 h interval and spread separately on a clean jute bag, covered with damp cotton and were allowed to germinate for 24 h. Water was sprinkled at 12 h interval to facilitate the germination process. At the end of germination, root hairs were removed from the germinated grains. Grains were dried at 60°C in an oven (Plus11 Sanyo Gallenkamp PLC, UK) and ground into flour using attrition mill (globe p44 China). Flour was passed through a 0.5 mm mesh size sieve. They were packaged in an air tight polyethylene bags, stored in plastic containers with lids and then stored in cool dry place (10±2°C).

Preparation of fermented sorghum flour

Fermented sorghum was prepared using the improved method of Akingbala *et al.* (1987). Sorghum was cleaned, sorted and steeped in tap water (1:3 w/v) for 72 h at ambient temperature (32±2°C). After decanting the steeping water, the sorghum was milled in a Premier Mill and wet-sieved (1:8 w/v) through a locally manufactured sieve (1 mm). The deposit was left to ferment at ambient temperature (32±2°C) for 12 h before decanting the water. The fresh *ogi* was dried (Plus11 Sanyo Gallenkamp PLC, UK) at 60°C for 24 h and milled and sieved using mesh size 1 mm. They were packaged in an air tight polyethylene bags, stored in plastic containers with lids and then stored in cool dry place (10±2°C).

Preparation of sorghum flour

The procedure described by Egounlety *et al.* (2002) was used. Sorghum was cleaned, sorted, washed and dried (Plus11 Sanyo Gallenkamp PLC, UK) at 60°C for 24 h. It was milled in a hammer mill (Christy & Lab), sieved using 0.5 mm mesh size and stored in cool dry place (10±2°C).

Preparation of roselle calyces flour

Fresh Roselle calyces were washed, dried (Plus11 Sanyo Gallenkamp PLC, UK) at 50°C for 5 h, milled (Premier Mill) and sieved using 0.5 mm mesh size (Fasoyiro *et al.*, 2005). The flour was packaged in an air tight polyethylene bags, stored in plastic containers with lids and then stored in cool dry place (10±2°C).

Preparation of germinated soybean flour

The method described by Ijarotimi and Keshinro (2012) was employed. Soybean was manually cleaned to remove husks, stone and damaged seeds. Beans were washed in 5% (w/v) sodium chloride solution to suppress mould growth and soaked in tap water in ratio of 1:3 (w/v) grain for 12 h at room temperature (32±2°C), the water drained at 4 h interval and spread separately on a clean jute bag, covered with damp cotton and were allowed to germinate for 4 days. Water was sprinkled at 12 h interval to facilitate the germination process. At the end of germination, root hairs were removed from the germinated beans. Beans were dried at 60°C in an oven (Plus11 Sanyo Gallenkamp PLC, UK) and ground into flour using attrition mill (globe p44 China). Flour was passed through a 0.5 mm mesh size sieve. The flour was packaged in an air tight polyethylene bags, stored in plastic containers with lids and stored in cool dry place (10±2°C).

Preparation of roasted soybean flour

This was done according to the procedure described by Omafuvbe *et al.* (2007). Soybean seeds were cleaned and sorted. The beans were soaked, dehulled and roasted at 160°C for 4 min in a frying pan over a gas cooker flame. The roasted beans were cooled, sorted to remove damaged beans, oven dried at 60°C (Plus11 Sanyo Gallenkamp PLC, UK) and milled using a laboratory blender (Philips HR2811 model).

Sample formulation

Sample formulation (Table 1) was done based on the specification of a joint FAO/WHO/UNU committee that recommended minimum levels of 16.7%, 6.0% and 375 Kcal/100g for protein, fat and energy, respectively (Egounlety *et al*., 2002). This was achieved using the NutriSurvey Linear Programming Package 2004 version.

Table 1: Formulation of sorghum-soybean-roselle based complementary foods

Component	Sample Description						
	GSGS	**GSRS**	**FSGS**	**FSRS**	**SFGS**	**SFRS**	**SF**
Sorghum flour (%)	-	-	-	-	58.2	58.2	100
Germinated sorghum flour (%)	58.2	58.2	-	-	-	-	-
Fermented sorghum flour (%)	-	-	58.2	58.2	-	-	-
Germinated soybean flour (%)	38.8	-	38.8	-	38.8	-	-
Roasted soybean flour (%)	-	38.8	-	38.8	-	38.8	-
Roselle calyces flour (%)	3	3	3	3	3	3	-

GSGS (Germinated sorghum, germinated soybean and roselle flour), GSRS (Germinated sorghum, roasted soybean and roselle flour), FSGS (Fermented sorghum, germinated soybean and roselle flour), FSRS (Fermented sorghum, roasted soybean and roselle flour), SFGS (Sorghum flour, germinated soybean and roselle flour), SFRS (Sorghum flour, roasted soybean and roselle flour) SF (Sorghum Flour); **Modified method of Egounlety *et al.* (2002)**

Sample analyses

Functional properties: bulk density (loose and packed); water and oil absorption capacities and swelling power were determined using the procedures outlined by Sasulki *et al*. (1996). Pasting characteristics of blends were evaluated using a Brabender visco-amylograph (Newport Scientific Pty Ltd. Warrie-wood NSW, Australia) at the Multidisciplinary Research Laboratory, University of Ibadan, Nigeria. Flour slurry, containing 12% solids (w/w, dry basis), was heated from 30 to 95°C at a rate of 2.5°C/min, held at 95°C for 15 minutes, and cooled at the same rate to 50°C (Chinma *et al*., 2013). The pasting performance was automatically recorded on the graduated sheet of the amylogram. The peak viscosities, trough viscosity, breakdown viscosity, final viscosity, setback viscosity, peak time and pasting temperature were read off the amylograph.

The statistical significance of the observed differences among the means of triplicate readings of experimental results obtained were evaluated by one way analysis of variance while means were separated using Duncan's multiple range test. This was achieved using the Statistical Package for the Social Scientists (SPSS) version 17.0)

Results and Discussion

Effect of processing treatments on the functional properties of soy-sorghum roselle

Complementary foods

The effect of processing methods on the functional properties of complementary foods is presented in Table 2. Processing methods had significant effect ($p \leq 0.05$) on the functional parameters under consideration. Values obtained for water absorption capacity, oil absorption capacity, loosed density, packed bulk density and swelling capacity ranged from 1.20 to 2.40 ml/g, 0.92 to 1.67 ml/g, 0.38 to 0.51 g/cm^3, 0.71 to 0.83 g/cm^3 and 2.60 to 5.65 g/g, respectively. Lowest values of 1.2 ml/g and 0.71 g/cm^3 were recorded for blend of fermented sorghum flour and roasted soybean (FSRS) in water absorption capacity and packed bulk densities, respectively; blend of sorghum flour and germinated soybean (SFGS) had highest values in of 2.40 ml/g and 1.67 ml/g in water and oil absorption capacities respectively; while sorghum flour (SF) recorded highest values of 0.86 g/cm^3 and 6.95 g/cm^3 in packed density and swelling capacity, respectively. Germination and fermentation reduced the listed functional properties significantly (p≤0.05). The reduction could be as a result of breakdown of complex compounds such as starch and proteins consequent to modification of sorghum and soybean by the fermentation and germination processes (Ocheme *et al*., 2015). Ocheme and Chinma (2008) also reported decrease in bulk density, gelation capacity and viscosity of germinated millet. High values in water and oil absorption capacities observed in blends containing germinated soybean (SFGS and GSGS) could be attributed to solubilization and dissociation of proteins leading to exposure of non-linear constituents in the protein matrices (Deepali *et al*., 2013).

Table 2: Functional properties of sorghum-soybean-roselle calyces based complementary foods

Sample	Water absorption capacity (ml/g)	Oil absorption capacity (ml/g)	Loosed bulk density (g/cm^3)	Packed bulk density (g/cm^3)	Swelling capacity (g/g)
GSGS	1.70 ± 0.01^c	1.30 ± 0.01^b	0.51 ± 0.01^a	0.79 ± 0.01^b	3.03 ± 0.01^e
GSRS	1.60 ± 0.02^d	0.97 ± 0.02^d	0.41 ± 0.02^b	0.76 ± 0.01^c	2.60 ± 0.02^f
FSGS	1.70 ± 0.01^c	1.01 ± 0.02^c	0.40 ± 0.02^b	0.75 ± 0.01^c	5.56 ± 0.02^b
FSRS	1.20 ± 0.03^e	0.92 ± 0.02^e	0.38 ± 0.02^b	0.71 ± 0.02^d	5.65 ± 0.01^a
SFGS	2.40 ± 0.01^a	1.67 ± 0.03^a	0.39 ± 0.02^b	0.83 ± 0.03^a	4.97 ± 0.02^c
SFRS	2.30 ± 0.02^b	0.84 ± 0.01^f	0.48 ± 0.02^a	0.81 ± 0.01^{ab}	4.78 ± 0.01^d
SF	2.20 ± 0.01^c	1.01 ± 0.01^c	0.49 ± 0.02^a	0.86 ± 0.01^a	6.95 ± 0.01^a

Values are means±standard deviations of triplicate scores. Means within a column with the same superscript were not significantly different (p>0.05). Key: GSGS (Germinated sorghum, germinated soybean and roselle flour), GSRS (Germinated sorghum, roasted soybean and roselle flour), FSGS (Fermented sorghum, germinated soybean and roselle flour), FSRS (Fermented sorghum, roasted soybean and roselle flour), SFGS (Sorghum flour, germinated soybean and roselle flour), SFRS (Sorghum flour, roasted soybean and roselle flour) SF (Sorghum Flour)

Table 3: Pasting characteristics of sorghum-soybean-roselle calyces complementary foods

Sample	PV (RVU)	TV (RVU)	BD (RVU)	FV (RVU)	SB (RVU)	Peak Time (min)	Pasting Temperature (^{o}C)
GSGS	35.00±1.41^e	14.00±1.41^e	21.00±0.00^d	24.50±0.71^e	10.50±0.71^e	3.93±0.00^d	82.43±0.00^c
GSRS	38.32±1.32^e	16.22±1.89e	20.42±0.05^d	24.54±0.21^e	11.02±1.22^e	3.94±0.07^d	82.23±0.02^c
FSGS	582.50±0.71^a	320.00±1.41^b	262.50±0.71^a	586.00±7.07^b	266.50±5.66^b	4.70±0.05^b	84.38±0.60^b
FSRS	532.10±0.04^b	332.11±1.11^b	258.53±0.63^a	578.00±0.32^b	276.20±3.24^b	4.71±0.00^b	84.32±0.08^b
SFGS	200.00±7.07^c	163.00±1.41^c	37.00±5.66^c	290.50±2.12^c	127.50±0.71^c	4.60±0.00^c	85.98±0.60^a
SFRS	131.00±4.24^d	126.50±4.95^d	4.50±0.71^e	236.50±6.36^d	110.00±1.41^d	6.87±0.00^a	82.63±0.02^c
SF	534.00±4.24^b	444.50±3.54^a	89.50±0.71^b	993.50±12.02^a	549.00±8.49^a	4.70±0.05^b	81.53±0.04^d

Values are means±standard deviations of triplicate scores. Means within a column with the same superscript were not significantly different (p>0.05). Key: GSGS (Germinated sorghum, germinated soybean and roselle flour), GSRS (Germinated sorghum, roasted soybean and roselle flour), FSGS (Fermented sorghum, germinated soybean and roselle flour), FSRS (Fermented sorghum, roasted soybean and roselle flour), SFGS (Sorghum flour, germinated soybean and roselle flour), SFRS (Sorghum flour, roasted soybean and roselle flour) SF (Sorghum Flour). PV=Peak viscosity; TV=Trough viscosity; BD=Break down: FV=Final viscosity; SB=Setback viscosity; RVU=Rapid Viscosity Unit.

Effect of processing treatments on the pasting profile of sorghum-soybean-roselle complementary foods

The effect of processing methods on the pasting profile of sorghum-soybean-roselle based complementary food samples is shown in Table 3. Peak viscosity ranged from 35.00 RVU in blend of germinated sorghum and soybean flours (GSGS) to 582.50 RVU in blend of fermented sorghum flour and roasted soybean flour (FSRS). Processing treatments had a significant effect (p≤0.05) on the peak viscosity of samples. Samples produced from fermented sorghum had significantly (p≤0.05) higher values than samples produced from germinated and un-germinated sorghum. Low peak viscosity values recorded in samples produced from germinated sorghum could be as a result of rupturing of starch molecules. Peak viscosity is correlated with the water binding capacity of the starch or mixture, which occurs at the equilibrium point between swelling causing an increase in viscosity while rupturing and alignment cause its reduction (Sanni *et al*., 2001).

Processing treatments also had significant (p≤0.05) effect on trough, breakdown, final and setback viscosity values of the samples. Values obtained for these parameters ranged from 14.00 to 444.50 RVU; 4.50 to 262.50; 24.50 to 993.50 and 10.50-549.00 RVU, respectively. Sorghum flour (SF) had a significantly (p≤0.05) higher trough of 444.50 RVU than samples subjected to fermentation, germination and roasting. Samples produced from fermented sorghum (FSGS and FSRS) had significantly (p≤0.05) higher trough than samples produced from germinated sorghum (GSGS and GSRS).

Higher setback viscosity recorded in sorghum flour suggests its susceptibility to retrogradation. Low setback viscosity was recorded for GSGS. Phattanakulkaewmorie*et al.* (2011) also reported low setback viscosity for germinated sorghum. Lowest peak time was recorded for samples produced from germinated sorghum. Sorghum flour (SF) had lowest pasting temperature of 81.53^{o}C while blend of sorghum flour and germinated soybean (SFGS) had the highest value of 85.98^{o}C. Higher pasting temperature values recorded for blends containing soybeans could be due to the buffering effect of fat (from soybean) on the starch component of sorghum (Oluwamukomi *et al.*, 2005).

Conclusion

From this study, it was discovered that germination and fermentation improved the functional properties of complementary foods produced from blends of sorghum, soybean and roselle calyces compared to the untreated sample. Samples produced from fermented sorghum had better pasting characteristics than samples produced from germinated and untreated sorghum samples.

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