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Functional Properties of Sorghum (*S. bicolor* L.) - Pigeonpea (*Cajanus cajan*) Flour Blends and Storage Stability of a Flaked Breakfast Formulated from Blends

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Abstract: The possibility of replacing treated (SSF) and untreated (USF) sorghum flour with different ratios of pigeon pea flour (CCF) was investigated. Their functional properties (Bulk density, viscosity, least gelation concentration, water absorption capacity, reconstitution time, pH and particle size distribution) were examined. Bulk density increased with the increased supplementation of pigeon pea flour the formulation resulting in a denser product. Sprouting and pregelatinization increased in the viscosity of the flour compared to the untreated samples. The least gelation concentration ranged between 0.2-0.4 g/g. Both pregelatinization and sprouting increased the strength of the gel of the treated samples unlike the untreated ones. The pregelatinized flours and their flour blends absorbed more water (7.00-8.00 g/ml) than the sprouted samples (7.00-7.50 g/ml) which caused some starch gelatinization and increased porosity of the corneous endosperm fragments. Higher absorption and lower solubility led to higher viscosity ($p<0.05$) or cooked paste viscosity. Untreated samples show marginally high oil absorption capacity of between 2.66 g/ml-3.23 g/ml, the pregelatinized flour and their composites showed higher ($p<0.05$) oil absorption capacity (2.66-3.04 g/ml) while the sprouted sample ranged between 2.85-3.23 g/ml. However, sample SSF + CCF (100:0) took 92.5 seconds to reconstitute while. PSF+CCF (60:40) took 20.0 seconds probably be due to heat treatment during pregelatinization which increased the action of alpha- and beta- amylases and modified the native starch. PSF + CCF (100:0) gave the least pH of 4.25 while USF + CCF (80:20) gave the highest value of 5.87 (all in the acidic range). Thus, the blending of the sorghum and pigeon pea could perform favorably in the formulation of breakfast cereal and infant foods. A high quality flaked breakfast cereal was prepared from sprouted and pregelatinized, packaged and stored on a shelf at room temperature (25±2°C) for 90 days. The storage stability was evaluated by analyzing periodically for changes in physical properties (water activity, colour change, temperature, relative humidity), chemical changes (development of peroxides and rancidity) and microbiological changes. Result show that colour, temperature, relative humidity, peroxide values and Thiobarbituric Acid (TBA) values remain practically constant during storage. Also, no significant ($p>0.05$) changes were observed in TBA values, peroxide value, water activity and moisture absorption of the packaged products during storage. The water activity (a_w) of all products was between 0.435-0.785 and none were attracted by microorganisms over the 3 months. The products did not exhibit bacterial, coliform and mold growth, especially for those in the bulk packages, which served as a double barrier to moisture, oxygen and other gases. Thus, the bulk packages are advantageous over the single packs thereby suggesting that the former could lead to better keeping quality for these products and the products also maintained their crispiness. By implication from the shelf life projection studies, the formulated products from the treated flours might be stored in high density polythene bags for up to six months or more at ambient conditions.

Key words: Sorghum, pigeon pea, functional properties, flaked breakfast cereal, peroxide values, thiobarbituric acid (TBA), bulk packages, single package, water activity

INTRODUCTION

In the tropics, cereal are the staple food of the people providing about 75% of their caloric intake and 67% of their protein intake (Adedeye and Adewoke, 1992). Cereals have also been used over the years as industrial raw material because of the high carbohydrate, low fat and protein contents. Meanwhile, proximate composition of a food material would not give indication of limited use because sorghum, millet, fonio("acha") among others. These under-utilized cereals lack some essential nutrients thereby reducing their uses. Also, their uses had been relegated to household preparation of local dishes. Their potentials could be brought to limelight when the under-utilized cereals are processed technologically into industrial or commercial products. Though, the cereal grains provide the bulk of the energy requirement in local meals because of their low cost, they are surplus in the essential sulphur-containing amino acid, methionine and cystine but poor in lysine (Siegel and Fawcett,

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1976). This deficiency could be complemented by others locally available, under-exploited legumes which incidentally are high in protein, mainly lysine but limited in cystine and methionine and probably tryptophan (Bressani, 1975). Cereals and legumes, therefore, complement each other in both traditional food preparation and for industrial uses (Oke, 1975; Nkama, 1990).

Legumes are traditionally consumed as human foods, along with cereals in various forms (Singh, 1980). Thus, the legumes with cereals play important role in the diets of many people in Africa and Asia and are the major sources of protein, calories, vitamins and minerals (Nkama *et al*., 2001). Some of the legumes include bambara groundnuts, lima bean, cowpea, Africa yam bean and pigeon pea to mention a few. These legumes are rich and economical dietary sources of good quality protein, carbohydrates, soluble and insoluble dietary fibre components and a variety of vitamins and minerals. Pigeon pea (*Cajanus cajan*) is a nutritionally important food crop of the leguminous family found in the tropical and subtropical regions of the world (Singh *et al*., 1984; Rampersad *et al*., 2003). Pigeon pea has been used in various foods human as a source of dietary protein) foods in several developing countries like Indonesia (Damardjati and Widowati, 1991); India (Vaidehi, 1991; Singh, 1989) and West Indies (Birla, 1991). Like other food crops, its chemical composition, bioavailability of nutrients and levels of the inherent anti-nutritional factors primarily determine the nutritional potential of pigeon pea as human food. Pigeon pea has a fairly high protein content (21.3%), relatively low fibre content and rather small seeds and is drought-resistant (Cheva-Isarakul and Tangtaweewipat, 1991). Pigeon pea could be used to complement under-utilized cereals like sorghum thereby improving the nutritional quality for status. Grain legumes and oil seeds are higher in protein density and lysine (Nkama and Malleshi, 1998). The supplementation of cereal grains with legumes has been suggested as one way of improving the protein quality of cereal-based diets (Nkama *et al*., 1995). Therefore, a combination of sorghum and pigeon pea would improve the nutritive value in product development such as breakfast cereals.

Also, from the previous work (Mbaeyi, 2005), it was shown from data obtained by means of the physicochemical and nutritional studies, that the flaked, formulated, packaged products prepared from sprouted and pre-gelatinized sorghum and pigeon pea blends grown in Nigeria, could be used as a base in the formulation of breakfast cereal (80:20) and weaning/complementary foods (70:30) respectively. By virtue of the low moisture content and high amylose content, the formulated products could probably be expected to be shelf-stable, at least for over a reasonable period. Shelf-stability of a food product may be expressed in terms of the preservation of active constituents and of structure and colour, qualities which are mainly influenced by the amount of moisture present (Ihekoronye, 1991). In the present investigations, the keeping quality of the flaked formulated products form sprouted and pregelatinized sorghum and pigeon pea blends/composite flours was analyzed by evaluating or studying the water activity during storage and the effect of storage temperature, relative humidity, packaging materials on the stability of the product chemical constituents as well as the microbiological assay of the formulated product.

Thus, the main objectives were to evaluate the functionality of the flours and their blends in the production of flaked breakfast cereal and to monitor the shelf stability of the formulated of flaked breakfast cereal.

MATERIALS AND METHODS

White variety of sorghum (*Sorghum bicolor L*.) grains and brown variety of pigeon pea (*Cajanus cajan*) seeds were procured from Nsukka main market, Enugu State of Nigeria.

Sample preparation: Sorghum grains and pigeon pea seeds were cleaned, sorted from foreign matter and divided into three equal portions (1 kg) each. The first portion was soaked for 22 hrs (wet steep) followed by 4 hrs air rest and 22 hrs (wet steep) at 28°C±2°C according to Etokakpan and Palmer (1990). The steeped grains were sprouted for 5 days and dried at 55°C for 20 hrs. The dried grains were kilned at 85°C for 4 hrs. The rootlets and cleoptile were devegetated. The sprouted grains were dry-milled using a hammer mill (Thomas Wiley Mill model ED-5). The resultant flour obtained was sieved by passing through a 1mm pore-size sieve and designated Sprouted Sorghum Flour (SSF) for the different sprouting periods respectively and used for analysis.

The last portion (1 kg) was cleaned, sorted and cracked using a disc attrition mill (Bentall superb model 200 L, 090) to produce grits, which were weighed into sub-portions of 10 g each. Each portion of grits was moistened with 100 ml of water and heated in a Gallenkamp water bath at different temperatures (60°C-100°C) for 5-60 min to estimate the optimal gelatinization conditions. The best of the pregelatinized grits were dried at 55°C to a constant weight and milled in a hammer mill, sieved by passing through a 1 mm pore-sized sieve, stored in polythene bags and designated as Pregelatinized Sorghum Flour (PSF).

The brown variety of pigeon pea seeds were cleaned, graded into sizes, cracked for easy oil absorption, mixed with 1% edible oil (Turkey vegetable oil) for dehulling, dried, dry milled and sieved to obtained the *Cajanus cajan* Flour (CCF).

The different flours were blended in the ratio of 100:0, 80:20, 60:40 and 50:50 of the treated/untreated sorghum

flour to the *cajanus cajan* flour. The various composite flours were conditioned, salted/sweetened, steamed aged at 4°C for 2 hrs, cut/diced, flaked (Kent, 1983), cooled and packaged in air tight polythene bags as Breakfast cereal.

Determination of some selected functional properties

Bulk density: Bulk density was determined by placing 20 g of each sample flour into a 100 ml-graduated cylinder. The cylinder was taped gently about 10 times against the palm and the final volume as expressed was g/ml as described by Onimawo and Egbekun (1998). All analysis were done in triplicate.

Viscosity: The method of Sathe and Salunkhe (1981) was used. An appropriate sample (2.5 g) was dispended in distilled/deionized water and magnetically stirred for 2 hrs at room temperature (28°C) prior to viscosity measurements. Each sample was prepared at concentration of 10, 20, 30, 40, 50, 70 and 100 g/litre and viscosity measured at 100 m temperature using universal Torsion viscometer (Gallenkamp Technico Compenstat, England) having corehead of 30 (standard) gauge 15/8 inches index and an approximate constant = 0.1 centipoises per second. All measurement were performed in triplicate and means, relative to distilled water were reported.

Least gelation concentration: The method of Sathe and Salunkhe (1981) were adopted. Appropriate sample suspensions of 2, 4, 6, 8, 10, 12, 14, 16, 18, 20% (w/v) was prepared in 5 ml-distilled water. The test tubes containing these then heated for one hour in a boiling water bath followed by rapid cooling under running cold tap waters. The test tubes were further cooled for 2 hrs at 4°C. The least gelation concentration was determined as that concentration at which the sample from the inverted test tube did not fall down or slip visually.

Water absorption: The water absorption capacity was determined by the method of Beuchat (1977). One gram of each sample was mixed with distilled water for 30 seconds in a mixer (Super mixer Cat No.1291, Labline Instruments Inc, USA). The samples were then allowed to stand at room temperature (25°C) for 30 min, centrifuged at 500 kg for 30 min and the volume of the supernatant noted in a 10 ml graduated cylinder. Density of water was assumed to be 1.0 g/ml and the results were expressed on dry weight basis after the determination of the density of the sample (ratio of the mass to volume). The difference of the densities gives the water absorption capacity of samples.

Oil absorption capacity: The oil absorption capacity was determined by the method of Beuchat (1977). One gram of each sample was mixed with 10ml of edible vegetable oil (Turkey vegetable oil) for 30 seconds in a mixer (Super mixer Cat No.1291 Labline Instruments Inc.,USA). Samples were allowed to stand at room temperature (25°C±1°C) for 30 min and then centrifuged at 5000 x g for 30 min and the volume of the supernatant noted in a 10 ml graduated cylinder. Density of oil was assumed to be 0.38 g/ml and the result was expressed on dry weight basis. The determinations of the density of samples were calculated as the ratio of mass to volume. The difference in densities gives the oil absorption capacity of the samples.

Reconstitution time: The reconstitution time was determined using the procedure described by Nwanekezi *et al*. (2001). A 2 g weight of each sample was dispersed onto the surface of 50 ml of cold distilled water in a 150 ml-graduated cylinder. The time taken for each of the sample to completely dissolve without stirring was recorded. The mean value of the four replicates was taken.

pH: The pH of the food samples was measured with a Townson pH meter as described by Jideani and Osume (2001). The sample homogenate was prepared by blending 10 g sample in 100 ml of deionized water. The mixture as filtered and the pH of the filtrate was measured. The average of triplicate readings was recorded for each sample.

Particle size distribution: The particle size of the flour blends was determined by the method described by Ihekoronye and Oladunjoye (1988). A nest of 12 sieves (B. S 8, 10, 12, 22, 30, 44, 60, 85, 120, 150 and 170 mesh screens) corresponding to sieve openings (2.0 mm, 1.7 mm, 1.4 mm, 1.00 mm, 0.699 mm, 0.50 mm, 0.35 mm, 0.25 mm, 0.178 mm, 0.124 mm, 0.104 mm and 0.089 mm respectively) was arranged in order. The upper sieve was provided with a cover and the bottom sieve with a receiver. A 50 g sample of the product was put in the top sieve, covered with the lid and the nest of sieves placed in a suitable mechanical sieve shaker (Endecott test sieve shaker, Britain). The material was sieved continuously for 5 min after which sieving was stopped, the nest removed and the residue on each sieve transferred to a tarred weighing dish using a brush. Each dish was weighed and the percentage of the product retained on each sieve was calculated as:

$$\frac{\text{Mass of material retained on specific sieve}}{\text{Total mass of sample}} \times 100$$

Storage stability studies: The formulated products were dried to an average moisture content of 5.5±0.5% in an oven at 40°C for 12 h. Two hundred grams of each sample was sealed in (10 x 4) cm^2 high density polythene bags with a thickness of 100 μm. A second

portion of the formulated product was stirred in (10 x 4) cm^2 high density polythene bags of a thickness of 100 µm and inserted in paper cartons. The third portion contained the formulated products wrapped with the aluminium foil while the last batch of the formulated products was packaged in foil as the primary package and inserted in the paper carton as secondary packaging materials. The packaged products were stored under room conditions of 25±1°C and relative humidity of 84%±2% for the three months. Samples were withdrawn periodically (fortnightly) and subjected to microbiological, peroxide, Thiobarbituric Acid (TBA) and water activity tests.

Microbiological analysis: Serial dilutions of sample (taken fortnightly for 3 months) were cultured by pour plate method as described by Collins and Patricia (1984) on acidified malt extract agar for mould count and the media was prepared. Samples were plated in triplicates and incubated for one week for mould growth. Enumeration of the discrete colonies was carried out using a Digital electronic colony counter (Gallenkamp colony counter, CNW 330-010X). Identification of the mould isolates was assigned to probable identify using taxonomic description in the manual by Harrigan and McCance (1981).

Determination of water activity (a_w): The water activity of each sample in the different packaging materials was measured by Moreyre and Peleg's method (1981). The water activity of sample packaged was determined at 2 weeks interval for 3 months at 25°C±1°C using the water activity meter (Wert-Messer Meter model 5803, Sufft, Germany).

Determination of peroxide value: The peroxide value was determined by the method described by Pearson (1978). The different samples in the various packaging materials were used for the determination and the test was carried out in subdued daylight. One gram of the sample was weighed into a clean dry boiling tube and while still liquid, 1 g of powdered potassium iodide and 20 ml of solvent mixture (2 volume glacial acetic acid and 1 volume of chloroform) were added. The tube was placed in boiling water bath to facilitate boiling of the liquid for 30 seconds. The contents were quickly poured into a flask containing 20 ml of potassium iodide solution (5%) washed out twice with 25 ml of water and titrated with 0.002M sodium thiosulphate solution using starch solution indicator. A blank was prepared and the perioxide value was reported as the number of ml of 0.002M (or N) sodium thiosulphate per g of sample. The value obtained was multiplied by 2 to give the milliequivalents of peroxide per kilogramme of sample (Meq/kg).

Determination of Thiobarbituric Acid value (TBA value): The TBA value was determined by the method of Pearson (1978). Samples from different packaging materials were used. A 10 g of each sample was macerated with 50 ml water for two min and washed into a distillation flasks with 47.5 ml water. About 2.5 ml of 4M hydrochloric acid was used to bring the pH to 1.5, followed by an anti-foaming preparation and a few glass beads. The flask was heated from the time boiling commenced. A 5 ml of the distillate was pipetted into a glass-stoppered tube and 5 ml of TBA reagent (0.2883 g/100 ml of 90% glacial acetic acid) added, stoppered, shaken and heated in boiling water for 35 min. The blank was prepared similarly using 5 ml water with 5 ml reagent. The tubes were cooled in water 10 min and absorbance measured against the blank at 538 nm using 1 cm cells. TBA value was calculated as thus:

TBA (as mg malonaldehyde per kg sample) = 7.8D

Determination of relative humidity: The relative humidity of the storage environment of the formulated products was determined using the wet and dry bulb. The values were converted to relate to the formular for saturation vapour pressures as specified by the World Meteorological Organization (1975).

Determination of colour: Colour of the product was determined by procedure described by Camire *et al.* (1990). A spectrophotometer (Pharmacia LKB Ultrospec III) was standardized with N-hexane of 99% minimum assay calibrated to 0.00 absorbance. The colour was extracted with N-hexane from 1 g of each sample. The extract was diluted to 10 ml the reagent and the mixture was stirred and allowed to stand overnight for colour development. The supernatant was gently filled into a glass curvette and absorbance read at 450 nm. Duplicate readings were taken and mean value calculated.

Experimental design and data analyses: The results obtained were statistically analyzed using the Analysis of Variance (ANOVA) in a completely randomized design. Differences among means were determined with the Least Significant Difference (L.S.D) at $p<0.05$ (Steele and Torrie, 1980).

RESULTS AND DISCUSSION

Functional properties

Bulk density: Table 1 shows the bulk density of the treated and untreated sorghum flours and their blends. The range of the bulk density was 0.5341g/cc-0.726g/cc. Sample USF + CCF (80:20) had the least bulk density of 0.5341g/cc while PSF + CCF (80:20) had the highest bulk density of 0.7267 g/cc. There was no significant

(p>0.05) difference between the sprouted and pregelatinized flours. However increased supplementation of *Cajanus cajan* flour in the formulations resulted in a more dense product. Similar results were obtained in the supplementation of soy-flour in maize used for the production of puffed soy-maize snack as reported by Lasekan and Akintola (2002). Also as seen from the Table 1, it followed a particular trend in the values of the bulk density probably due to the changes in the rate of the sorghum (treated and untreated) to pigeon pea. However, bulk density of the untreated sorghum blend with the pigeon pea was lower than that of the treated blends. Similar results were obtained by Mepba *et al*. (2007) in composite flour for formulated from wheat: plantain flour blends. The low bulk density of the blends could be an advantaged in the formulation of baby foods where high nutrient density to low bulk is desired. High nutrient density is a desirable characteristic in flours that can be used as a base for infant food formulation(Onweluzo and Nnabuchi, 2009). Nout *et al*. (1988) and Ariahu *et al*. (1999a,b) had reported similar reduction in bulk density. This was unlike the bulk density of the treated samples, which showed 0.1g/cc-0.2g/cc higher bulk densities than the control.

There was also no significant differences (p>0.05) between the bulk density of the flours and their blends. The implication is that it may not be totally accurate to generalize on the properties of the food powders from those of the particular constituent particles. Carr (1976) rightly observed that most food flours are cohesive meaning that their inter-particle attractive forces are significantly higher relative to the particle on weight, inter alia and with respect o the powders the additive effects and characteristics of individual particles comprising a powder systems may be different from those of the powder or flour in bulk.

Viscosity: The range of the viscosity (Table 1) was 113.0cps-137.3cps with USF + CCF (50:50) showing the least viscosity and PSF + CCF (80:20) the highest viscosity. The untreated flour blend had a viscosity range of 113.0cps-117.7cps followed by the pregelatinized samples (118.7cps-137.3cps) and lastly the sprouted samples(124.3-133.3cps). The untreated flour exhibited higher (p<0.05) viscosity than the treated(sprouted and pregelatinized) flours. The lower viscosity of the sprouted and pregelatinzed flours was attributed to the enzymic breakdown of the higher molecular weight polysaccharide and polypeptide to lower molecular weight dextrins and peptides during the treatment. Similar enzymic breakdown was observed by Onweluzo and Nnabuchi (2009) and this was attributed to the inherent starch in sorghum possessing its viscofying properties since it was modified during heating and fermentation. This implication of this decrease in viscosity is that gruels from the treated flours would permit the addition of higher quantity of the solid without a concomitant increase in viscosity. Viscosity values of the samples could probably be attributed to the starch moiety which was not ruptured by preprocessing to release assimilable sugars (amylose and amylopectin) for gelation and turn increases the viscosity.

During sprouting of the sorghum, there was increased activity of the alpha-and-beta amylases in the sprouts. There was digestion of the starch by these amylases to dextrin and maltose. The amylases breakdown the starch moiety leading to formation of gel network. According to Egbekun (1998), sprouting reduced the gel properties and the water holding capacity of flours prepared from the sprouted flours although the reconstitubility of the flours improved. Also, the decrease in apparent viscosity indicates increase in nutrient density as observed by Onweluzo and Nwabugwu (2009).

Pregelatinization also increased the bulk density of the flour blends as the viscosity decreased. The increased bulk density and decreased viscosity attributed to the use of pregelatinized flours for the formulation of weaning foods according to Draper (1994); FAO/WHO (1995) and BOSTID (1996). However, the preformulation treatments (sprouting and pregelatinization) evidently modified the rheological properties of the raw materials because low density is usually associated with weaning formulations from unmodified starchy staples (Nout *et al*., 1988).

Least gelation concentration: The results of least gelation concentration are shown in Table 1. It ranged between 0.2g/g-0.4g/g. The least gelation concentration of untreated sorghum was 0.4 g/g (4.0%). The sprouted samples and the pregelatinized samples had similar least gelation concentration of 0.2 g/g (2.0%). There was no significant (p>0.05) difference between the sprouted and pregelatinized flours. Akubor (1998) reported the least gelation concentration of germinated sorghum as 2.0%. Pregelatinization and sprouting increased the strength of the gel of the treated samples. The strength of the gel increased as the temperature of heating increased pregelatinization and sprouting. Thus, the least gelation concentration of the treated sample increased as the starch broke down into high amount of amylose and amylopectin molecules (enzymic breakdown of carbohydrates) as well as protein hydrolysis. Similar results were obtained by Kent (1975) who stated that sorghum, a waxy cereal, had a least gelation concentration due to the breakdown of starch into high proportion of amylopectin thereby affecting the strength of the gel. The low level of least gelation concentration was attributed to the possible formation of intermolecular hydrogen bonds between amylose molecules in the cooled gel. According to Ott (1987), the

Table 1: Functional properties of untreated and treated (Sprouted and pregelatinized) sorghum/pigeon pea flour blends

	Samples																
Functional properties	SSF + CCF (100:0)	SSF + CCF (80:20)	SSF + CCF (70:30)	SSF + CCF (60:40)	SSF + CCF (50:50)	PSF + CCF (100:0)	PSF + CCF (80:20)	PSF + CCF (70:30)	PSF + CCF (60:40)	PSF + CCF (50:50)	USF + CCF (100:0)	USF + CCF (80:20)	USF + CCF (70:30)	USF + CCF (60:40)	USF + CCF (50:50)	CCF (100:0)	LSD
BD (g/cc)	0.6177 ±0.017	0.6719 ±0.000	0.6397 ±0.013	0.6967 ±0.031	0.6714 ±0.020	0.6938 ±0.015	0.7267 ±0.023	0.7230 ±0.03	0.7119 ±0.05	0.7117 ±0.028	0.5393 ±0.051	0.5341 ±0.008	0.5519 ±0.072	0.5588 ±0.010	0.6178 ±0.034	0.6879 ±0.019	0.0028
Visc. (cps)	132.6 ±0.042	133.3 ±0.051	124.3 ±0.026	127.7 ±0.034	129.3 ±0.014	127.7 ±0.012	137.3 ±0.065	118.7 ±0.019	123.0 ±0.043	126.7 ±0.012	117.7 ±0.035	115.0 ±0.038	113.7 ±0.005	115.7 ±0.063	113.0 ±0.013	117.7 ±0.000	0.1645
LGC (g/g)	0.2 ±0.00	0.2 ±0.01	0.2 ±0.005	0.2 ±0.03	0.2 ±0.01	0.2 ±0.00	0.2 ±0.003	0.2 ±0.005	0.2 ±0.000	0.2 ±0.001	0.4 ±0.00	0.4 ±0.00	0.4 ±0.000	0.4 ±0.000	0.4 ±0.000	0.4 ±0.000	0.3364
WAC (g/g)	7.00 ±0.034	7.30 ±0.058	7.50 ±0.001	7.50 ±0.053	7.50 ±0.053	7.00 ±0.007	7.00 ±0.02	8.00 ±0.00	7.50 ±0.001	8.00 ±0.003	8.00 ±0.001	8.50 ±0.001	7.50 ±0.001	7.50 ±0.002	7.00 ±0.002	7.50 ±0.002	0.3364
OA (g/g)	3.23 ±0.003	2.93 ±0.001	2.85 ±0.004	3.04 ±0.002	2.85 ±0.002	3.04 ±0.000	2.66 ±0.001	2.85 ±0.004	2.66 ±0.000	3.04 ±0.000	3.23 ±0.003	2.66 ±0.001	2.85 ±0.002	2.85 ±0.002	2.74 ±0.002	2.66 ±0.001	0.0000
RT (s)	92.5 ±0.018	44.5 ±0.005	54.0 ±0.026	31.3 ±0.043	47.0 ±0.0037	35.0 ±0.000	38.3 ±0.002	31.8 ±0.001	20.0 ±0.000	27.0 ±0.003	28.8 ±0.004	26.8 ±0.000	27.5 ±0.003	28.5 ±0.001	28.8 ±0.005	22.5 ±0.002	0.0667
pH	5.03 ±0.003	5.03 ±0.0021	5.66 ±0.000	5.38 ±0.0043	5.36 ±0.015	4.25 ±0.002	4.66 ±0.0053	4.74 ±0.025	5.07 ±0.0082	5.16 ±0.0056	5.57 ±0.0031	5.87 ±0.000	5.86 ±0.002	5.64 ±0.037	5.66 ±0.001	5.83 ±0.000	0.0092

Values are means of triplicate determinations.

Key: USF + CCF (100:0) → 100%Untreated sorghum flour + 0% *Cajanus cajan* flour;
USF + CCF (80:20) → 80% Untreated sorghum flour + 20% *Cajanus cajan* flour;
USF + CCF (70:30) → 70%Untreated sorghum flour + 30% *Cajanus cajan* flour;
USF + CCF (60:40) → 60% Untreated sorghum flour + 40% *Cajanus cajan* flour;
USF + CCF (50:50) → 50% Untreated sorghum flour + 50% *Cajanus cajan* flour;
PSF + CCF (100:0) → 100% Pregelatinized sorghum flour + 0% *Cajanus cajan* flour;
PSF + CCF (80:20) → 80% Pregelatinized sorghum flour + 20% *Cajanus cajan* flour;
PSF + CCF (70:30) → 70% Pregelatinized sorghum flour + 30% *Cajanus cajan* flour;
PSF + CCF (60:40) → 60% Pregelatinized sorghum flour + 40% *Cajanus cajan* flour.
PSF + CCF(50:50) → 50% Pregelatinized sorghum flour + 50% *Cajanus cajan* flour.
SSF + CCF (100:0) → 100% Sprouted sorghum flour + 0% *Cajanus cajan* flour.
SSF + CCF (80:20) → 80% Sprouted sorghum flour + 20% *Cajanus cajan* flour.
SSF + CCF (70:30) → 70% Sprouted sorghum flour + 30% *Cajanus cajan* flour.
SSF + CCF (60:40) → 60% Sprouted sorghum flour + 40% *Cajanus cajan* flour.
SSF + CCF (50:50) → 50% Sprouted sorghum + 50% *Cajanus cajan* flour.
CCF → 100% Untreated *Cajanus cajan* flour.

LSD - Least significant difference. BD = Bulk Density (g/cc); Visc. = Viscosity (cps); LGC = Least Gelation Concentration (g/g); WAC = Water Absorption Capacity (g/g); OA = Oil Absorption (g/g); RT = Reconstitution time (s)

minimal value of the least gelation concentration could probably be due to the formation of continuous 3-dimensional solid network of granules when immersed in water.

Similar report was obtained by (Onweluzo and Nwabugwu, 2009) who stated that the least gelation concentration of the diet was required for gel formation in product development. The implication of these observations is that since sprouting and pregelatinization increased the flour concentration required for gel formation, blends of these pretreated flour could be used in infant formula to enhance nutrient density. Thus, diets that form gel at low concentrations are not ideal for weaning foods because they would require a lot of dilution in an attempt to improve digestibility in relation to volume (Ezeji and Ojimelukwe, 1993; Draper, 1994).

Water absorption capacity: The results of the water absorption capacity of the treated and untreated samples are shown in Table 1. The water absorption capacity ranged between 7.00g/g-8.50g/g. Sample USF + CCF (80:20) had the highest water absorption capacity of 8.50 g/g while the least water absorption capacity were in samples with 7.0 g/g. The pregelatinized flour and their blends absorbed more water (7.00 g/g-8.00 g/g) than the sprouted samples which absorbed between 7.00 g/g-7.50 g/g of water. The untreated samples also absorbed 7.00-8.5 g/g water. The treated and untreated samples did not differ ($p>0.05$) significantly. The water absorption capacity of the sorghum pigeon pea flour blends reported in the present research fell within the range reported for other flours. Mepba *et al*. (2007) reported an increase in water absorption for wheat flour blends while Lin *et al*. (1974) reported 130% water absorption for soyflour, 227.3% and 196.1% respectively for two commercial soy protein concentrates namely Isopro and promosoy. The results were higher than the values obtained by Sathe and Salunkhe (1981) who observed a water absorption capacity of 2.73 g/g for Great Northern bean and Egwu (1984) also obtained 2.6 g/g for Nigeria red groundnut (Ihekoronye and Oladunjoye, 1988). Also the water absorption capacity of the dry composite flours was high probably due to the cooking or drying process which caused some starch gelatinization and increased the porosity of the corneous endosperm fragments.

High water absorption capacity is related to the extent of gelatinization. Steaming of the gelatinized samples prior to drying may have partially or completely gelatinized the starch granules such that they imbibe water more readily. Similar results were obtained by Gomez *et al*. (1987). Higher absorption and lower solubility lead to higher viscosity or cooked-paste viscosity and vice versa for lower absorption. Thus, the difference in the water absorption capacities may be explained by their respective content of hydrophilic constituent such as carbohydrates which bind more water than either protein or lipids. Both carbohydrates and protein are more soluble in water probably due to the fact that water (as a medium) aids in the breakdown of complexes of starch and protein to their simpler forms (that is simple sugars and amino acids). Similar high water absorption had been attributed to either high protein content or more hydrophilic polysaccharides during the course of germination as reported by Fordham *et al*. (1975); Onimawo and Asugo (2004) and fermentation (Onweluzo and Nnabuchi, 2009). However, Mahgoub (1999) also reported a low water absorption capacity for cerelac in comparison to weaning diets formulated with sorghum and legumes. Water absorption capacity indicates the volume of water required to form gruel with suitable consistency for infant feeding (Onweluzo and Nwabugwu, 2009).

Oil absorption capacity: The trend of the oil absorption capacity (Table 1) differed from those of the water absorption capacity. The range of the oil absorption capacity was 2.66 g/g-3.23 g/g. The untreated samples showed a marginally high oil absorption capacity of between 2.66 g/g-3.23 g/g. The pregelatinized flour and their composites showed high oil absorption capacity, which ranged between 2.66 g/g-3.04 g/g while the value in the sprouted samples ranged from 2.85-3.23 g/g. The oil absorption ability of the sprouted samples did not differ ($p>0.05$) significantly from the pregelatinized and untreated samples. Oil absorption capacities of the blends increased progressively as the level of pigeon pea flour was increased. Similar results were obtained by Mepba *et al*. (2007). The high fat or oil absorption capacity in these flours are probably due to the breakdown of the edible oil by the lipolytic activity of the lipase during the absorption of the flours. The above results are comparable to the results reported by Manak *et al*. (1990) for soy protein (2.52 g/g) and peanut protein (0.90 g/ml). The high absorption of fat by food products improves the mouthfeel and flavour retention. The flour blends, which absorb oil, would be found to be suitable in formulating certain food products such as cakes, breakfast cereals and some others. Thus, the results showed that the blends would be useful in bakery products where hydration to improve handling is desired and in ground meat, doughnuts and pancakes where oil absorption property is of prime importance.

Reconstitution time: The reconstitution time of the flour and their composites is presented in Table 1. This property describes the ease of dispersibility of the flours. It ranged between 20.0 to 92.5 seconds with SSF + CCF (100:0) as the highest and PSF + CCF (60:40) as the least. The sprouted samples had a mean reconstitution time between 31.3-92.5 seconds while the

pregelatinized sorghum samples (that is the blends) had a mean reconstitution time between 20.0-38.3 seconds. The improved reconstitubility was more evident in the pregelatinized samples which took 20.0-38.3 seconds than the sprouted samples that took 31.3-92.5 seconds to reconstitute. The reason could probably be due to the heat treatment during pregelatinization which increased the activity of the alpha - and - beta amylases, thereby modifying the native starch faster than the sprouting (in cold water). The pregelatinzied samples showed a reconstituted time range that is comparable to that of the control. The control (the unblended sample) had a mean value of 22.5 seconds and reconstituted faster than the blends. Similar observation were reported by Nwanekezi *et al*. (2001) who reconstituted in cold, warm and hot water or milk. Sprouting and pregelatinization may have induced a change in the texture of the hydrophilic components of the flours to have influenced the ease of dispersibility of the flours. Ease of dispersibility is an important flour property in food formulation(Igene *et al*., 2005).

pH: Table 1 shows the pH of treated and untreated flours as well as their blends. The pH ranged between 4.25-5.87. Sample PSF + CCF (100:0) had the least pH value of 4.25 while sample USF + CCF (80:20) had the highest pH value of 5.87. The sprouted samples had a pH range of 5.03-5.66 while the pregelatinized samples had a range of pH between 4.25 and 5.16. The untreated samples had a pH range of between 5.57-5.87. There was no significant ($p>0.05$) difference between the treated and untreated samples. Apart from the pregelatinized samples which increased in pH as the ratio of sorghum to pregelatinized sorghum samples increased, the sprouted and untreated sorghum samples marginally increased. All the pH values were within the acidic range/region. This report agreed with those of Onuoha and Obizoba (2001) who reported that digestibility of fermented lima bean was facilitated by the acidic range. Furthermore, the pregelatinized sample recorded significantly ($p<0.05$) lower pH values than the sprouted samples. The decreases in pH were attributed to partial hydrolysis of carbohydrates which occurred during treatment of sample by sprouting and pregelatinization. Similarly, the reduction in pH by sprouting and pregelatinization was observed by Mbaeyi and Onweluzo (2002) and Mbaeyi (2005). The nutritional implication of the low acidic level to near neutral pH observed is that food formulated from the sprouted or pregelatinized flours would not be stored after preparation since it can easily encourage the growth of toxigenic microorganisms and constitute health hazard (Rampersad *et al*., 2003).

Particle size distribution: All the samples passed through the British Standard sieve size of 1.00-2.00 mm, which was evidence as no particle was retained in the sieve. It shows the percentage of a 50 g sample retained on a specified screen and 8 major fractions were identified out of the nest of 12 sieves. About 64%-80% of pregelatinized samples, 76%-80% of the sprouted samples, 75%-82% of the untreated samples and 66% to 80% of the unblended pigeon pea flour had a particle size range between > 0.699 to 0.50 mm. Thus, majority of the coarse particles ranged between 64%-82%. "Medium fine" particles passed through sieve size between 0.35 to 0.17 mm. About 78%-94% from sprouted samples, 78%-90% of the untreated samples and 92%-945 of the unblended pigeon pea. Thus, greater proportion of the "medium fine" articles passed through 0.35 mm to 0.17 mm sieves. "Very fine" particles passed sieves of pore sizes of between 0.124 mm to 0.089 mm. 92%-985 of the "very fine" particle were from the pregelatinized samples, 90%-98% were from the sprouted samples, 86%-98% were from the untreated samples and 92%-96% were from the unblended pigeon pea flour. Thus, the smaller the pore size in the sieves, the larger the proportion of the "very fine" particles.

Most of the particles had diameters between 0.35 mm to 0.17 mm, which corresponds to the particles retained by mesh 42 mesh 85 screens. The clustering of the particles of the sprouted pregelatinized and untreated sorghum blends as well as the unblended sample lie within this range. Carr (1976) and Cue Vas *et al*. (1985) reported that the properties of the fine fractions of samples had a lower degree of pregelatinization than the medium and coarse fractions. The fine fractions are responsible for most of the water uptake and viscosity development during mixing or blending while the major functions of the coarse particles is to disrupt the mixture which reduces the extent of pillowing or the formation of large pockets during baking or drying. In the gelatinization of pure starch (gels), Eliasson and Bohlin (1982) found that particle size distribution influenced the rheological properties of gels.

Storage stability studies: The packaged products were stored for 90 days at ambient conditions (temperature of 25±2°C and mean relative humidity of 83.0%) and parameters like relative humidity, colour change, peroxide value, TBA value, water activity and presence of microbes were monitored as indices of storage stability. Table 2-8 shows the change in the physical characteristics, microbiological and development of rancidity of the packaged products. Evidently, the proximate composition was found to be constant over the period of storage and also the sensory qualities of the formulation did not vary significantly ($p\geq0.05$) as the scores were all acceptable.

Relative Humidity (RH): Table 2 shows the results of the moisture content of the products monitored within three months. The mean relative humidity ranged from

Table 2: Relative humidity of stored samples as influenced by packaging materials

	Relative humidity (%)						
Time	0	15	30	45	60	75	90
9.00 am	92.0	88.0	84.0	88.0	80.0	92.0	84.0
10.00 am	80.0	88.0	76.0	80.0	88.0	88.0	88.0
11.00 am	84.0	84.0	88.0	84.0	88.0	88.0	92.0
12.00 pm	80.0	80.0	73.0	84.0	84.0	84.0	92.0
1.00 pm	92.0	80.0	80.0	84.0	92.0	80.0	92.0
2.00 pm	80.0	81.0	81.0	84.0	84.0	92.0	92.0
3.00 pm	84.0	77.0	77.0	84.0	80.0	80.0	87.0
4.00 pm	84.0	85.0	81.0	80.0	80.0	80.0	92.0
5.00 pm	81.0	74.0	84.0	80.0	84.0	92.0	88.0
6.00 pm	74.0	81.0	81.0	77.0	88.0	80.0	88.0

Values are means of triplicate reading at 25±1°C

80.4%-85.6%. The highest mean value was recorded on the 75th day while the least mean value was recorded on the 90th day from the results, there was little or no fluctuation in the relative humidity of the storage environment. This could be attributed to the stability of the temperature of the environment.

Colour change: Colour, as a physical parameter, was observed critically over the period of storage (Table 3). At 0-day, the mean value of the extracted colour ranged between 0.066-0.225 absorbance of the extract from the untreated samples ranged between 0.077-0.100 while that from pregelatinized products ranged between 0.070-0.095 and the sprouted samples ranged between 0.066-0.117. There was no significant ($p>0.05$) difference in the absorbance of the extracts from the products.

On the 30th day, the mean value of the extracted colour ranged between 0.076-0.093 for the untreated samples. The absorbance of the colour of the sprouted samples was between 0.062-0.116 while that of the pregelatinized products was between 0.066-0.093. The treatment did not affect the absorbance or colour. The packaging material may have aided in the preservation of the colour since there was no entry of air (oxygen) or moisture that could affect the colour. The unblended pigeon pea flour had an absorbance of 0.220.

On the 60th day, the mean value of the absorbance of the extracted colour reduced in all the samples. The pregelatinized samples had a range of between 0.036-0.047 absorbance and the sprouted products ranged between 0.051-0.068 absorbance while the untreated samples had a range between 0.031-0.080 absorbance. No browning or lightening occurred as the storage period increased.

The 90th day did not record any deviation in the absorbance of the extracted colour of the products. Thus, treatment did not have any observable effect on the colour of the products since the absorbance of the extracts on this day was quite low. Also, the ratio of the sorghum to pigeon pea did not affect the colour leading to any visible change over the period of 90 days.

By virtue of the low mean absorbance of the extracted colour, the stability had an added advantage to the acceptance of the products. Farris and Singh (1991) stated that colour attracts consumers to a product and accordingly the stable colour of the products after 90 days of storage would lead to its probable acceptance by consumers.

Microbiological analysis: No bacterial and yeast growth were recorded in the formulated breakfast cereals after the storage period. This was attributed to the low pH range of the products, which was not suitable for the microorganism to thrive. Besides, microorganisms have an absolute demand for water because without water, no growth can occur. The low moisture content of the product prevented the microbial growth, thereby maintaining the safety of the products for consumption. Also, the low water activity range (0.435-0.785) of the formulated products at storage prevented spoilage by spoilage microbes. Beuchat (1981) and Frazier (1977) noted that a_w between 0.86 and 0.95 was enough for bacterial proliferation and between 0.87 to 0.97 for toxin production. Since the a_w range of the samples were below this range, no bacterial growth was recorded. Also, the double packaged products were best preserved than those in the single package due probably to the extra barrier created against contamination by spoilage microorganisms. Thus, no yeast or bacteria could penetrate the packages to cause growth or spoilage.

Furthermore, USF (100:0) and USF (70:30) recorded low mold count of 2.0×10^1cfu/g and 1×10^1cfu/g respectively after three months. The only specie of mold identified was *Aspergillus niger* characterized by black colour colonies and spherical vesicle bearing phialides over the entire surface as well as "mop-like head" of conidia. This species of mold has been identified in spoiled food and soil as the commonest isolate (Harrigan and McCance, 1981). According to Beuchat (1981) the lowest or minimal water activity needed for *Aspergillus* species growth is between 0.78 and 0.83 while between 0.83 to 0.93 is needed for toxin production.

Table 3: Colour of stored samples as influenced by packaging

	Storage period (days) and colour change			
Sample	0	30	60	90
USF+CCF(100:0)	0.079	0.078	0.044	0.033
USF+CCF(80:20)	0.95	0.093	0.031	0.028
USF+CCF(90:30)	0.100	0.092	0.037	0.038
USF+CCF(60:40)	0.078	0.076	0.049	0.033
USF+CCF(50:50)	0.077	0.076	0.080	0.047
PSF+CCF(100:0)	0.076	0.074	0.047	0.042
PSF+CCF(80:20)	0.079	0.077	0.036	0.035
PSF+CCF(70:30)	0.070	0.066	0.043	0.039
PSF+CCF(60:40)	0.087	0.086	0.040	0.045
PSF+CCF(50:50)	0.095	0.093	0.037	0.036
SSF+CCF(100:0)	0.117	0.116	0.061	0.047
SSF+CCF(80:20)	0.075	0.072	0.059	0.054
SSF+CCF(70:30)	0.087	0.084	0.068	0.064
SSF+CCF(60:40)	0.068	0.066	0.055	0.064
SSF+CCF(50:50)	0.066	0.062	0.051	0.050
CCF (100:0)	0.225	0.214	0.198	0.102

Values are means of duplicate readings. SSF - Sprouted Sorghum Flour; PSF - Pregelatinized Sorghum Flour; USF - Untreated Sorghum Flour; CCF - *Cajanus cajan* Flour

Lastly, the different processing were an added advantage to the stability of the products. Sprouting, pregelatinization, heating, drying and flaking were effective in reducing the available moisture and in turn, destroying the microorganisms thereby ensuring the safety of the formulated products.

Water activity: Table 4-7 show the water activity of the formulated products in different packaging materials and levels (single/double packages). The products in polythene bags (single package) showed higher water activity at 25±1°C and relative humidity of 80.04-85.6% unlike those in the double packages (polythene + carton and foil + carton) and foil alone. The single packaged products were more prone to moisture absorption from the environment as evident from the relative humidity of the environment unlike the doubly packaged products. Products above a_w of 0.68 were deemed to be free and unaffected by microbes. As a result of the a_w range of the formulated products (0.435-0.785), none was attacked by microorganisms. At the end of the 3 months, most of the products remained fresh, crispy and dry. They were neither attacked by fungi, mold nor bacteria probably due to the immobilization of available moisture in the dried formulated products.

Peroxide value: The peroxide value of the packaged products was used as an index of stability since rancidity is identified by the presence of the intermediate products (hydroperoxides) but negligible results were obtained. The values were very minimal/low probably due to the fact that the conditions necessary for the acceleration of rancidity (exposure to heat, light, moisture and presence of metals) were not available for the packaged breakfast cereals. Also, the packages served as barriers to the uptake of oxygen and because the products were not fatty, there was no formation of peroxides that would be responsible for rancid taste and odour development. The breakfast cereal products were therefore found to be stable against rancidity developing for the period of 90 days as evident from the negligible peroxide value.

Thiobarbituric Acid (TBA) value: Table 8 shows the Thiobarbituric Acid (TBA) values of the formulated breakfast cereal products stored for 90 days in both single and double packages. For the day 1, the TBA values for the polythene + carton were 0.020-0.420, for foil 0.082-0.410 and for foil + carton 0.043-0.480. These values were quite low. This could probably be attributed to the fact that the packaging materials prevented lipid peroxidation evident by the absence of malonaldehyde.

Table 4: Water activity (a_w) of stored samples as influenced by packaging material-polythene bags (single package)

	Storage period (days) and colour change						
Sample	0	15	30	45	60	75	90
USF+CCF(100:0)	0.650	0.580	0.635	0.570	0.595	0.600	0.610
USF+CCF(80:20)	0.549	0.575	0.615	0.625	0.630	0.620	0.615
USF+CCF(70:30)	0.540	0.520	0.620	0.655	0.640	0.650	0.670
USF+CCF(60:40)	0.535	0.590	0.630	0.650	0.630	0.645	0.650
USF+CCF(50:50)	0.580	0.615	0.640	0.670	0.650	0.640	0.655
PSF+CCF(100:0)	0.571	0.500	0.620	0.530	0.570	0.585	0.590
PSF+CCF(80:20)	0.530	0.595	0.655	0.635	0.640	0.645	0.650
PSF+CCF(70:30)	0.635	0.620	0.660	0.575	0.590	0.610	0.580
PSF+CCF(60:40)	0.649	0.570	0.650	0.600	0.630	0.615	0.625
PSF+CCF(50:50)	0.675	0.620	0.590	0.705	0.650	0.640	0.655
SSF+CCF(100:0)	0.610	0.520	0.535	0.650	0.570	0.590	0.600
SSF+CCF(80:20)	0.615	0.570	0.550	0.580	0.600	0.610	0.615
SSF+CCF(70:30)	0.489	0.580	0.550	0.630	0.590	0.615	0.600
SSF+CCF(60:40)	0.590	0.530	0.610	0.575	0.585	0.590	0.600
SSF+CCF(50:50)	0.635	0.640	0.560	0.590	0.575	0.580	0.605
CCF (100:0)	0.490	0.630	0.620	0.665	0.670	0.660	0.630

Values are means of duplicate readings. SSF - Sprouted Sorghum Flour; PSF - Pregelatinized Sorghum Flour; USF - Untreated Sorghum Flour; CCF - *Cajanus cajan* Flour

Table 5: Water activity (a_w) of stored samples as influenced by packaging material-foil (single package)

	Storage period (days) and colour change						
Sample	0	15	30	45	60	75	90
USF+CCF(100:0)	0.530	0.510	0.500	0.520	0.535	0.500	0.540
USF+CCF(80:20)	0.565	0.555	0.540	0.535	0.540	0.570	0.600
USF+CCF(70:30)	0.575	0.560	0.550	0.580	0.570	0.600	0.610
USF+CCF(60:40)	0.610	0.590	0.580	0.600	0.605	0.620	0.615
USF+CCF(50:50)	0.655	0.640	0.635	0.630	0.620	0.650	0.630
PSF+CCF(100:0)	0.435	0.440	0.450	0.470	0.500	0.515	0.520
PSF+CCF(80:20)	0.510	0.520	0.530	0.515	0.560	0.585	0.570
PSF+CCF(70:30)	0.555	0.550	0.545	0.540	0.555	0.570	0.560
PSF+CCF(60:40)	0.570	0.560	0.570	0.555	0.560	0.565	0.570
PSF+CCF(50:50)	0.600	0.590	0.580	0.570	0.600	0.615	0.620
SSF+CCF(100:0)	0.410	0.450	0.470	0.490	0.500	0.500	0.510
SSF+CCF(80:20)	0.525	0.530	0.540	0.530	0.520	0.540	0.520
SSF+CCF(70:30)	0.580	0.570	0.560	0.575	0.570	0.585	0.580
SSF+CCF(60:40)	0.595	0.580	0.570	0.575	0.585	0.590	0.600
SSF+CCF(50:50)	0.630	0.620	0.610	0.625	0.630	0.645	0.670
CCF (100:0)	0.640	0.630	0.610	0.620	0.625	0.635	0.640

Values are means of duplicate readings. SSF - Sprouted Sorghum Flour; PSF - Pregelatinized Sorghum Flour; USF - Untreated Sorghum Flour; CCF - *Cajanus cajan* Flour

Table 6: Water activity (a_w) of stored samples as influenced by packaging material-polythene + carton (Double package)

	Storage period (days) and colour change						
Sample	0	15	30	45	60	75	90
USF+CCF(100:0)	0.585	0.700	0.640	0.720	0.730	0.680	0.700
USF+CCF(80:20)	0.550	0605	0.630	0.640	0.700	0.675	0.690
USF+CCF(70:30)	0.530	0.610	0.650	0.660	0.670	0.695	0.680
USF+CCF(60:40)	0.560	0.680	0.600	0.680	0.700	0.700	0.690
USF+CCF(50:50)	0.640	0.640	0.660	0.705	0.725	0.670	0.710
PSF+CCF(100:0)	0.780	0.750	0.740	0.740	0.740	0.735	0.745
PSF+CCF(80:20)	0.675	0.720	0.660	0.680	0.720	0.700	0.710
PSF+CCF(70:30)	0.650	0.700	0.720	0.670	0.735	0.695	0.700
PSF+CCF(60:40)	0.570	0.700	0.710	0.630	0.660	0.590	0.600
PSF+CCF(50:50)	0.715	0.750	0.720	0.650	0.655	0.660	0.630
SSF+CCF(100:0)	0.749	0.660	0.675	0.730	0.730	0.710	0.720
SSF+CCF(80:20)	0.785	0.690	0.600	0.740	0.700	0.715	0.730
SSF+CCF(70:30)	0.570	0.620	0.635	0.610	0.640	0.590	0.600
SSF+CCF(60:40)	0.560	0.600	0.620	0.660	0.630	0.600	0.610
SSF+CCF(50:50)	0.685	0.630	0.690	0.630	0.695	0.705	0.700
CCF (100:0)	0.650	0.680	0.690	0.690	0.705	0.690	0.700

Values are means of duplicate readings. SSF - Sprouted Sorghum Flour; PSF - Pregelatinized Sorghum Flour; USF - Untreated Sorghum Flour; CCF - *Cajanus cajan* Flour

Table 7: Water activity (a_w) of stored samples as influenced by packaging material-foil + carton (Double package)

	Storage period (days) and colour change						
Sample	0	15	30	45	60	75	90
USF+CCF(100:0)	0.570	0.640	0.610	0.690	0.710	0.655	0.670
USF+CCF(80:20)	0.505	0.520	0.650	0.675	0.700	0.570	0.580
USF+CCF(70:30)	0.615	0.640	0.590	0.620	0.710	0.600	0.630
USF+CCF(60:40)	0.485	0.530	0.640	0.680	0.650	0.610	0.630
USF+CCF(50:50)	0.650	0.585	0.660	0.620	0.640	0.620	0.590
PSF+CCF(100:0)	0.600	0.580	0.590	0.615	0.620	0.630	0.580
PSF+CCF(80:20)	0.525	0.650	0.680	0.620	0.640	0.635	0.625
PSF+CCF(70:30)	0.645	0.600	0.655	0.625	0.690	0.610	0.620
PSF+CCF(60:40)	0.615	0.655	0.600	0.650	0.670	0.690	0.710
PSF+CCF(50:50)	0.650	0.570	0.610	0.680	0.650	0.600	0.630
SSF+CCF(100:0)	0.580	0.640	0.610	0.635	0.640	0.670	0.690
SSF+CCF(80:20)	0.650	0.720	0.675	0.620	0.680	0.700	0.715
SSF+CCF(70:30)	0.505	0.530	0.620	0.580	0.665	0.670	0.620
SSF+CCF(60:40)	0.600	0.640	0.650	0.600	0.670	0.670	0.620
SSF+CCF(50:50)	0.635	0.560	0.675	0.620	0.645	0.640	0.630
CCF (100:0)	0.480	0.620	0.590	0.610	0.640	0.620	0.580

Values are means of duplicate readings. SSF - Sprouted Sorghum Flour; PSF - Pregelatinized Sorghum Flour; USF - Untreated Sorghum Flour; CCF - *Cajanus cajan* Flour

Table 8: Thiobarbituric Acid (TBA) value of formulated products as influenced by storage and packaging

	Storage period (days) and packaging materials															
	0				30				60				90			
Sample	P	P+C	F	F+C	P	P+C	F	F+C	P	P+C	F	F+C	P	P+C	F	F+C
USF+CCF(100:0)	0.243	0.020	0.082	0.043	0.162	0.024	0.071	0.056	0.072	0.063	0.056	0.420	0.140	0.135	0.115	0.120
	±0.01	±0.03	±0.00	±0.00	±0.10	±0.00	±0.02	±0.00	±0.00	±0.00	±0.01	±0.00	±0.00	±0.02	±0.03	±0.00
USF+CCF(80:20)	0.104	0.085	0.090	0.044	0.152	0.093	0.083	0.057	0.400	0.610	0.10	0.550	0.175	0.160	0.095	0.100
	±0.00	±0.05	±0.01	±0.03	±0.00	±0.01	±0.00	±0.02	±0.00	±0.02	±0.03	±0.00	±0.13	±0.10	±0.02	±0.02
USF+CCF(70:30)	0.050	0.100	0.210	0.090	0.058	0.104	0.245	0.097	0.042	0.520	0.350	0.032	0.180	0.150	0.092	0.135
	±0.00	±0.00	±0.00	±0.00	±0.00	±0.00	±0.00	±0.00	±0.07	±0.00	±0.00	±0.01	±0.07	±0.00	±0.00	±0.03
USF+CCF(60:40)	0.360	0.210	0.100	0.110	0.470	0.235	0.109	0.113	0.880	0.340	0.230	0.110	0.280	0.175	0.156	0.143
	±0.01	±0.12	±0.04	±0.01	±0.00	±0.00	±0.07	±0.00	±0.00	±0.00	±0.00	±0.00	±0.00	±0.01	±0.00	±0.00
USF+CCF(50:50)	0.095	0.098	0.400	0.120	0.100	0.117	0.432	0.132	0.420	0.350	0.060	0.209	0.360	0.250	0.138	0.174
	±0.02	±0.00	±0.03	±0.00	±0.01	±0.03	±0.01	±0.03	±0.13	±0.01	±0.04	±0.00	±0.00	±0.00	±0.00	±0.01
PSF+CCF(100:0)	0.420	0.200	0.210	0.300	0.305	0.320	0.230	0.410	0.580	0.240	0.231	0.115	0.405	0.315	0.177	0.276
	±0.00	±0.03	±0.00	±0.02	±0.00	±0.00	±0.00	±0.04	±0.00	±0.00	±0.00	±0.00	±0.00	±0.00	±0.01	±0.00
PSF+CCF(80:20)	0.124	0.210	0.300	0.310	0.268	0.470	0.315	0.275	0.730	0.300	0.258	0.264	0.320	0.270	0.144	0.168
	±0.00	±0.00	±0.01	±0.02	±0.00	±0.03	±0.08	±0.00	±0.00	±0.00	±0.04	±0.01	±0.01	±0.00	±0.00	±0.00
PSF+CCF(70:30)	0.090	0.300	0.410	0.420	0.490	0.351	0.400	0.243	0.860	0.075	0.255	0.340	0.360	0.255	0.205	0.243
	±0.00	±0.00	±0.00	±0.03	±0.00	±0.00	±0.07	±0.12	±0.04	±0.00	±0.07	±0.06	±0.00	±0.07	±0.07	±0.00
PSF+CCF(60:40)	0.050	0.400	0.200	0.240	0.425	0.255	0.217	0.250	0.690	0.270	0.330	0.132	0.160	0.175	0.167	0.155
	±0.09	±0.01	±0.03	±0.00	±0.09	±0.00	±0.02	±0.00	±0.00	±0.01	±0.00	±0.11	±0.01	±0.00	±0.05	±0.01
PSF+CCF(50:50)	0.044	0.200	0.240	0.360	0.285	0.314	0.333	0.493	0.920	0.490	0.290	0.250	0.260	0.240	0.200	0.215
	±0.00	±0.00	±0.00	±0.03	±0.08	±0.00	±0.01	±0.10	±0.03	±0.00	±0.04	±0.00	±0.11	±0.00	±0.00	±0.00
SSF+CCF(100:0)	0.300	0.280	0.210	0.380	0.435	0.206	0.249	0.311	6.300	0.280	0.090	0.072	0.085	0.090	0.095	0.074
	±0.00	±0.03	±0.00	±0.00	±0.00	±0.05	±0.05	±0.00	±0.00	±0.00	±0.01	±0.00	±0.00	±0.02	±0.06	±0.01
SSF+CCF(80:20)	0.240	0.420	0.300	0.240	0.150	0.243	0.309	0.327	0.485	0.350	0.058	0.110	0.080	0.095	0.095	0.100
	±0.01	±0.17	±0.05	±0.00	±0.03	±0.01	±0.06	±0.00	±0.02	±0.00	±0.01	±0.03	±0.01	±0.01	±0.00	±0.00
SSF+CCF(70:30)	0.440	0.320	0.360	0.200	0.092	0.303	0.418	0.451	0.630	0.210	0.434	0.085	0.100	0.084	0.180	0.095
	±0.01	±0.23	±0.03	±0.08	±0.01	±0.00	±0.00	±0.11	±0.00	±0.00	±0.00	±0.01	±0.00	±0.04	±0.00	±0.00
SSF+CCF(60:40)	0.410	0.220	0.200	0.180	0.065	0.413	0.209	0.279	0.072	0.315	0.235	0.310	0.270	0.200	0.125	0.175
	±0.01	±0.00	±0.01	±0.08	±0.00	±0.07	±0.03	±0.10	±0.01	±0.01	±0.03	±0.00	±0.02	±0.01	±0.00	±0.00
SSF+CCF(50:50)	0.240	0.300	0.290	0.480	0.050	0.239	0.285	0.410	0.510	0.343	0.153	0.208	0.135	0.130	0.093	0.101
	±0.04	±0.00	±0.00	±0.05	±0.00	±0.05	±0.00	±0.08	±0.00	±0.02	±0.00	±0.00	±0.01	±0.00	±0.00	±0.00
CCF (100:0)	0.184	0.100	0.220	0.310	0.200	0.119	0.256	0.325	0.780	0.065	0.285	0.200	0.115	0.120	0.080	0.098
	±0.00	±0.03	±0.04	±0.00	±0.04	±0.00	±0.01	±0.00	±0.00	±0.00	±0.01	±0.02	±0.00	±0.00	±0.00	±0.01

Values are means of duplicate readings. SSF - Sprouted Sorghum Flour; PSF - Pregelatinized Sorghum Flour; USF - Untreated Sorghum Flour; CCF - *Cajanus cajan* flour. P = Polythene; P+C = Polythene + Carton; F = Foil; F+C = Foil + Carton

On the 30th day, the TBA values for polythene ranged between 0.050-0.490 with SSF + CCF (50:50) showing the least value and PSF (70:30) showing the highest value. For the polythene + carton, the TBA values ranged between 0.024-0.470 with USF + CCF (100:0) as the least while PSF + CCF (80:20) had the highest TBA. The TBA value for the doubly packaged product (polythene + carton) recorded much lower values than the singly packaged product (polythene). The double package probably prevented the oxidation of lipid since the extra barrier was provided. For the foil (single package), the TBA value ranged between 0.071-0.432 while the foil + carton (double package) ranged between 0.056-0.493. The double package acted as extra barrier to oxygen and moisture which would have enhanced lipid oxidation.

On the 60th day, the TBA values for the different packaged products read thus: for polythene 0.042-0.920 with USF + CCF (70:30) having the least TBA value and PSF + CCF (50:50) having the highest TBA value. For polythene + carton, the range for the TBA value was 0.063-0.610 with USF + CCF (100:0) having the least TBA and USF + CCF (80:20) having the highest TBA value. The TBA values for both packaged did not vary significantly ($p>0.05$). For the foil and carton (double package), the range for the TBA value was 0.032-0.550 with USF + CCF (70:30) having he least TBA value and USF + CCF (80:20) having the highest TBA value. The extra barrier prevented lipid oxidation and there was no evidence of malonaldehyde (mg/kg of sample).

On the 90th day, the TBA values of the different packaged products did not fluctuate significantly. For polythene, the TBA value ranged between 0.080-0.405 with SSF + CCF (80:20) having the least value and PSF + CCF (100:0) having the highest TBA value. For the polythene and carton (double package), the range of TBA value was 0.084-0.315 with SSF + CCF (70:30) having the least and PSF + CCF (100:0) having the highest TBA value. The extra barrier hindered lipid oxidation. For foil (single package), the range of the TBA values was between 0.080-0.205 with CCF (100:0) having the least TBA value and the sample PSF + CCF (70:30) had the highest TBA value. Foil + carton (double package), the range of the TBA value was 0.074-0.276 with SSF + CCF (100:0) having the least TBA value and PSF + CCF (100:0) having the highest TBA value. The absence of oxygen probably led to the very low TBA values and thus, lipid oxidation did not occur.

From all the results, there was no evidence of malonaldehyde thus indicating that lipid oxidation did not occur and spoilage was also prevented with the 90 days storage period. Also, the TBA values were significantly very low and this could be attributed to the fact that lipid peroxidation may not have occurred at room temperature constant and did not fluctuate or increase significantly at storage. Thus, the formulated breakfast cereals were shelf quite stable over the storage period.

Conclusion: From the results, it is evident that nutritious diets can be formulated by complementing unexploited legume and cereal like pigeon pea and sorghum respectively. Such blends could be used to diversify their uses to develop new products. Also, it is apparent that the sprouting and pregelatinization treatments of sorghum and pigeon pea (as economic processing methods) improved the nutritional quality of the plant foods and their functional, properties of the flours. Particle size, viscosity, least gelation concentration and reconstitution time increased with the addition of pigeon pea(protein supplement) to sorghum flour while the oil absorption capacity decreased. The high nutrient density and low bulk of the flours could serve as good base ingredients or to be used especially in the weaning/ complementary foods, for the young children feeding breakfast cereals to enhance dietary diversification. Since sprouting and pregelatinization are common techniques, they could be adopted at household levels in Nigeria and beyond.

Also, the shelf stability studies of the formulated flaked breakfast were done for 90 days. There was no evidence of microbial growth (probably due to low water activity), no oxidative or hydrolytic oxidation and no thiobarbituric acid produced. No change in colour was developed. This could probably be due to the use bulk packaged, which incidentally kept the crispiness of the formulated breakfast cereals throughout the period of storage.

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