EVALUATION OF NUTRIENT COMPOSITION, FUNCTIONAL AND SENSORY ATTRIBUTES OF SORGHUM, PIGEONPEA AND SOYBEAN FLOUR BLENDS AS COMPLEMENTARY FOOD IN NIGERIA

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ABSTRACT

Child malnutrition, due to poor quality of complementary foods, is a major cause of mortality among children in many sub-Saharan Africa, Nigeria inclusive. The study aimed to develop a nutritious complementary food from Nigeria's staple foods. Complementary food was developed from flour blends of sorghum, pigeonpea and soybean with the help of D-optimal mixture design, using Design Expert 9.0. The proximate and antinutrient composition, functional and sensory properties of the blends were determined. One-way analysis of variance was employed to analyse the data, and Duncan's multiple range test used to separate the means at $p < 0.05$. The moisture (8.60 - 9.71%), crude protein (21.84 – 22.63 %), crude fat (2.57 – 2.94 %), crude fibre (5.15 – 5.94 %), ash (3.71 – 4.12 %) and carbohydrate (56.06 – 57.44 %) contents of the blends varied significantly ($p < 0.05$) among the flour blends. The proteincontent of the blends increased as legumes increased in the formulation. There were significant ($p < 0.05$) differences in the antinutrient composition and pasting properties of the flour blends. Significant ($p < 0.05$) differences occurred in the functional properties of the blends except water absorption capacity. All the complementary foods were acceptable but the one obtained from flour blend of 71.4 % sorghum, 14.4 % pigeonpea and 14.3 % soybean had the highestoverall acceptability score. Hence, a nutritious and acceptable complementary food could be produced from flour blends of sorghum, pigeonpea and soybean.

Key words : Sorghum, pigeonpea, soybean, complementary food, antinutrient

RESUME

EVALUATION DE LA COMPOSITION EN NUTRIMENTS, DES ATTRIBUTS FONCTIONNELS ET SENSORIELS DES MELANGES DE FARINE DE SORGHO, DE POIS CAJAN ET DE SOJA EN TANT QU'ALIMENT COMPLEMENTAIRE AU NIGERIA

La malnutrition infantile, due à la mauvaise qualité des aliments complémentaires, est une cause majeure de mortalité parmi les enfants de beaucoup de pays d'Afrique subsaharienne, du Nigeria inclusivement. L'étude vise à développer des aliments complémentaires nutritifs des aliments de base du Nigéria. La nourriture complémentaire était développé à partir de mélanges de farine de sorgho, de pois cajan et de soja avec l'aide de D-optim Conception de mélange, en utilisant Design Expert 9,0. La composition biochimique et antinutritionnelle, les propriétés fonctionnelles et sensorielles des mélanges ont été déterminées. L'analyse de variance a été utilisée pour analyser les données, et le test multiple de Duncan a été utilisé pour séparer les moyens à p < 0,05. L'humidité (8,60 - 9,71 %), *les protéines brutes (21,84 - 22,63 %), la matière grasse brute (2,57 - 2,94 %), les fibres brutes (5,15 à 5,94 %), les cendres (3,71 à 4,12 %) et les glucides (56.06 à 57,44 %) des mélanges variaient significativement (p < 0,05) parmi les mélanges de farine. La teneur en protéines des mélanges a augmenté à mesure que les légumineuses augmentaient dans la formulation. Il y a (p < 0,05) des différences significatives dans la composition antinutritionnelle et les propriétés aglutinogènes des mélanges de farine. Des différences significatives (p < 0,05) se sont observées dans les propriétés fonctionnelles des mélanges sauf dans la capacité d'absorption d'eau. Tous les aliments complémentaires étaient acceptables mais celui obtenu à partir du mélange de farines de 71,4% de sorgho, 14,4 % de pois cajan et 14,3 % de soja a la plus grande valeur d'acceptabilité. Par conséquent, une alimentation complémentaire nutritive et acceptable pourrait être produit à partir de mélanges de farine de sorgho, de pois cajan et de soja.*

***Mots clés :** Sorgho, pois cajan, soja, nourriture complémentaire, aliment*

INTRODUCTION

Infant mortality is a perennial public health issue in sub-Saharan Africa, despite global significant improvements in child survival (Oyarekua, 2013 ; Ogbo *et al.*, 2017). Evidence suggests that infant mortality in this region could be reduced during the weaning period- a time when complementary foods are introduced to infants (WHO, 2002 ; Lartey, 2008 ; Muoki *et al.*, 2012 ; Bani *et al.*, 2013 ; Ogbo *et al.*, 2017). Mothers, due to economic challenges and inadequate nutrition knowledge, give nutritionally deficient complementary foods to their children. These complementary foods are made from starchy staple foods which, due to their heavy viscosity, have to be diluted with water before being given to children. This practice results in reduced nutrients and energy in the already deficient complementary food. Hence, protein-energy and micronutrient malnutrition are often associated with traditional complementary feeding (Muoki *et al.*, 2012). Commercial infant formulas, which could serve as alternative, are beyond the reach of low and middle class families, who constitute the majority of Nigerian population (Ijarotimi *et al.*, 2012). Nutritional improvement of staple foods has been advocated as a suitable means to reduce childhood malnutrition in developing countries (Muoki *et al.*, 2012).

Sorghum is the fifth most important cereal after wheat, rice, corn and barley (Awika and Rooney, 2004). It shows greater resistance to drought than wheat and maize (Nyachoti *et al.*, 1997). Nigeria is the third largest world producer, after the United States and India, and the largest producer of sorghum in West Africa (Gourichon, 2013). Utilisation of sorghum in complementary foods have been reported (Agbon *et al.*, 2009 ; Tizazu *et al.*, 2011 ; Nwakalor and Obi, 2014). It is a potentially important source of phytochemicals (Awika and Rooney, 2004 ; Ocheme *et al.*, 2015). Consumption of sorghum has been linked to reduced risk of some cancers in humans and promotion of cardiovascular health in animals (Awika and Rooney, 2004). Sorghum contains 60 - 80 % starch and thus needs to be enriched with affordable source of other essential nutrients needed by children. Pigeonpea (*Cajanus cajan* L.) is a nutritionally important grain in the tropics (Rampersad *et al.*, 2003). It is rich in protein (19 - 26 %) and minerals (Rampersad *et al.*, 2003). The antinutrients in pigeon pea are easily removed by processing (Odeny, 2007). Pigeonpea, though indigenous to many communities in south western Nigeria, is grossly underutilized and is virtually unknown to many of the young people in the communities. The use of pigeonpea to improve the protein quality of starchy staples has been reported (Adeola *et al.*, 2012 ; Muoki *et al.*, 2012). Soybean is rich in protein (38 %) and oil (18 %), and possesses desirable amino acid profile for children (Shiriki *et al.*, 2015). It is the only vegetable with complete protein used in the alleviation of child malnutrition (Niyibituronsa *et al.*, 2014).

The objective of the study was to develop and evaluate some quality attributes of sorghum-pigeonpea-soybean flour blends as a complementary food in Nigeria.

MATERIALS AND METHODS

MATERIALS

Sorghum (*Sorghum bicolor* (L) Moench, red variety), pigeonpea (*Cajanus cajan*) and soybean (*Glycine* max) seeds were obtained from local markets in Abeokuta, Ogun State, Nigeria.

PREPARATION OF SORGHUM FLOUR

Adoption of method for the preparation of flour was based on the expectations (simplicity and low cost) of the beneficiaries of the technology. A preliminary study was carried out to obtain a method that produced flour with the lowest tannin content, most desirable pasting properties (minimum peak and setback viscosities, maximum breakdown viscosity) and colour. Sorghum flour was therefore produced according to Figure 1. Briefly, the sorghum grains were soaked in water for 8 hr, dried at 100 °C in a cabinet dryer to moisture content of less than 10 % and milled to pass through a sieve of 250 micron.

Sorghum seeds
↓
Sorting
↓
Soaking (ambient temperature, 8 hr)
↓
Decant
↓
Drying (100 °C)
↓
Milling
↓
Sieving (250 µm)
↓
Sorghum flour

Figure 1 : Preparation of sorghum flour

Préparation de farine de sorgho

Source : Modified method Nwakalor and Obi (2014)

PREPARATION OF PIGEONPEA FLOUR

The flour was prepared according to Figure 2. The seeds were sorted and cleaned by removing damaged seeds and foreign materials such as sticks and stones. The seeds were then boiled in water for 20 min and drained. The boiled seeds were allowed to cool for about 5 - 10 min before decortication. Decorticated seeds were washed in clean water, to separate the seeds from the seed coats, and dried at 80 °C to less than 10 % moisture content in air cabinet dryer. The dried seeds were milled in a hammer mill to pass through a 250 micron sieve.

Pigeon pea seeds
↓
Sorting
↓
Boiling (20 min)
↓
Decant
↓
Cooling
↓
Dehulling
↓
Drying (80 °C, 18 hr)
↓
Milling
↓
Sieving
↓
Pigeon pea flour

Figure 2 : Processing of pigeon pea flour

Traitement de la farine de pois de cajan

Source : Fasoyiroe*t al.* (2010)

PREPARATION OF SOYBEAN FLOUR

The flour was prepared using the method shown in Figure 3. Stones, sticks, damaged seeds and other foreign particles were removed from the seeds. The seeds were soaked in clean water for one hour and the water decanted. The seeds were then boiled in water for 20 min and the water decanted. The seeds were allowed to cool for 5 - 10 min before manual decortication. The decorticated seeds were removed from the seed coats by flotation in water. The seeds were dried in air cabinet dryer at 60 °C to less than 10 % moisture content, pulverised and sieved with a 250 micron mesh.

Soybeans seeds
↓
Sorting
↓
Soaking (1 hr)
↓
Boiling (20 min)
↓
Decant
↓
Cooling
↓
Dehulling
↓
Drying (60 °C, 15 hr)
↓
Milling
↓
Sieving
↓
Soybean flour

Figure 3 : Production of soybean flour

Production de farine de soja

Source: Bonsi*et al.* (2014)

BLENDING OF FLOUR SAMPLES

Blending of the flour samples to achieve complementary mixture was approached by employing D-optimal mixture design using Design Expert 9.0. The design was based on sorghum content (40 – 85 %), pigeon pea (5 – 30 %) and soybean (5 – 30 %) flour. The outlay of the experimental trials is shown in Table 1.

Table 1 : Trial runs of the blends as generated by D-optimal mixture design

Essais d'essai des mélanges tels que générés par la conception du mélange D-optimal

Trial	Sorghum flour	Pigeonpea flour	Soybean flour
1	84.1	10.9	5.0
2	58.6	11.4	30.0
3	77.3	5.0	17.7
4	62.1	20.9	17.1
5	49.5	21.4	29.1
6	74.9	20.1	5.0
7	65.0	30.0	5.0
8	68.0	5.0	27.0
9	40.0	30.0	30.0
10	71.4	14.4	14.3
11	51.4	30.0	18.6

CHEMICAL ANALYSES

The proximate and mineral compositions of flour blends were determined according to AOAC (2005). About 5 g of flour sample was weighed into a crucible and dried to constant weight in an oven at 100 °C, for moisture determination. The dried sample from moisture determination was weighed into a crucible and put in a furnace at 600 °C for 6 hr, in order to determine the ash content. The fat content was determined by extraction with petroleum ether using soxhlet extractor. Protein was determined using Kjeldahl apparatus, and multiplying % N by 6.25. Crude fibre content was determined by adding 100 ml digestion reagent (20 g trichloroacetic acid, 50 ml nitric acid, 450 ml distilled water and 500 ml acetic acid) into a 250 ml conical flask containing about 2 g of the sample. The mixture was boiled, refluxed, cooled, washed with hot water and methylated spirit, filtered, dried overnight at 105 °C, cooled in a desiccator, weighed and incinerated in a muffle furnace at 600 °C for 4 hr.

Tannin, trypsin inhibitor, phytates and oxalate were determined according to AOAC (2005).

The bulk density was determined by the method of Oladunmoye *et al.* (2010), dispersibility by Kulkarni *et al.* (1991), swelling power and solubility index by Takashi and Sieb (1988) and water absorption index by Ruales *et al.* (1993). The pasting characteristics of the cold slurry of the blends were determined with the use of a Rapid Visco Analyser.

A 50-member panel comprising of nursing mothers were asked to assess the cooked gruel made from the blends of sorghum, pigeon pea and soybean flour. The gruels were served in similar coded bowls and panelists were exposed to the same environment. The panelists assessed the gruel in terms of colour, aroma, taste, viscosity and overall acceptability on a 9-point hedonic scale where 1 = dislike extremely, 5 = neither like nor dislike and 9 = like extremely.

DATA ANALYSIS

The experiments on chemical analyses were replicated thrice. The data were subjected to analysis of variance to determine differences, with Duncan's multiple range test used to separate the means at 5 % confidence level.

RESULTS

Proximate composition of complementary food from sorghum-pigeonpea-soybean flour blends

The proximate composition of the flour blends were significantly ($p < 0.05$) different (Table 2). The proximate composition, except protein and carbohydrate, did not follow any particular trend as the level of legumes increased in the blend. The moisture content of the complementary foods ranged between 8.60 % in 84.1 : 10.9 : 5.0 (sorghum : pigeonpea : soybean) flour blend and 9.71 % in 58.6 : 11.4 : 30.0 (sorghum : pigeonpea : soybean) flour blend. The protein which increased as the quantity of legumes increased in the blend, ranged from 21.84 % in 68.0 : 30.0 : 5.0 (sorghum : pigeonpea : soybean) flour blend to 22.63 % in 71.4 : 14.4 : 14.3 (sorghum : pigeon : soybean) flour blend. No significant ($p > 0.05$) difference was observed in the protein content of blends containing between 29.3 – 35.2 %, 44.5 – 60 % and 37.1 – 44.5 % legumes. The fat content of the flour blends was in the range of 2.57 % in 74.9 : 20.1 : 5.0 (sorghum : pigeonpea : soybean) flour blend to 2.94 % in 84.1 : 10.9 : 5.0 (sorghum : pigeonpea : soybean) flour blend. The crude fibre content of the blends varied from 5.15 % in 77.3 : 5.0 : 17.7 (sorghum : pigeonpea : soybean) flour blend to 5.94 % in 84.1 : 10.9 : 5.0 (sorghum : pigeonpea : soybean) flour blend, while the ash content varied from 3.71 % in 77.3 : 5.0 : 17.7 (sorghum : pigeonpea : soybean) flour blend to 4.12 % in 71.4 : 14.4 : 14.3 (sorghum : pigeonpea : soybean) flour blend. The carbohydrate contents of the blends ranged between 57.44 % in 74.9 : 20.1 : 5.0 (sorghum : pigeonpea : soybean) flour blend to 56.06 % in 58.6 : 11.4 : 30.0 (sorghum : pigeonpea : soybean) flour blend.

Table 2 : Proximate composition of complementary food from sorghum-pigeonpea-soybean flour blends

Composition biochimique d'aliments complémentaires à partir de mélanges de farine de sorgho-pois cajan-soja

Sorghum pigeonpea soybean flour blends ratio	Moisture (%)	Protein (%)	Fat (%)	Crude fibre (%)	Ash (%)	Carbohydrate (%)
84.1 : 10.9 : 5.0	8.62^{g}	21.84^{e}	2.94^{a}	5.94^{a}	4.09^{ab}	56.57^{e}
58.6 : 11.4 : 30.0	9.71^{a}	22.34^{bc}	2.84^{cd}	5.27^{i}	3.78^{f}	56.06^{g}
77.3 : 5.0 : 17.7	9.66^{a}	21.73^{e}	2.60^{hi}	5.15^{j}	3.71^{g}	57.15^{b}
62.1 : 20.9 : 17.1	8.74^{ef}	22.22^{cd}	2.67^{f}	5.79^{c}	4.09^{ab}	56.49^{f}
49.5 : 21.4 : 29.1	8.94^{c}	22.63^{a}	2.80^{de}	5.43^{g}	3.73^{fg}	56.47^{f}
74.9 : 20.1 : 5.0	9.13^{b}	21.73^{e}	2.57^{i}	5.37^{fg}	3.76^{fg}	57.44^{a}
65.0 : 30.0 : 5.0	8.71^{fg}	21.91^{e}	2.73^{e}	5.69^{d}	3.94^{e}	57.02^{c}
68.0 : 5.0 : 27.0	8.79^{def}	21.84^{e}	2.89^{ab}	5.87^{b}	4.00^{cd}	56.61^{e}
40.0 : 30.0 : 30.0	9.21^{b}	22.63^{a}	2.65^{gh}	4.85^{k}	4.07^{ab}	56.59e
71.4 : 14.4 : 14.3	8.60^{g}	21.74^{e}	2.91^{ab}	5.91^{ab}	4.12^{a}	56.72^{d}
51.4 : 30.0 : 18.6	8.83^{de}	22.34^{a}	2.75^{ef}	5.33^{h}	3.74^{fg}	57.01^{c}

Mean values (n = 3) in a column with same superscripts are not significantly different ($p < 0.05$)

Antinutrient composition of complementary food from sorghum-pigeonpea-soybean flour blends

There were significant ($p < 0.05$) differences in the antinutrient composition of the blends (Table 3). The phytate and oxalate contents varied respectively from 1.435 % in 84.1 : 10.9 : 5.0 (sorghum : pigeonpea : soybean) flour blend to 1.635 % in 49.5 : 21.4 : 29.1 (sorghum : pigeonpea : soybean) flour blend, and 1,155 % in 58.6 : 11.4 : 30.0 (sorghum : pigeonpea : soybean) flour blend to 1.330 % in 62.1 : 20.9 : 17.1 (sorghum : pigeonpea : soybean) flour blend. The tannin content was between 0.066 % in 51.4 : 30.0 : 18.6 (sorghum : pigeonpea : soybean) flour blend and 0.0805 % in 74.9 : 20.1 : 17.1 (sorghum : pigeonpea : soybean) flour blend while the trypsin inhibitor content was between 31.755 TIU/mg in 65.0 : 30.0 : 5.0 (sorghum : pigeonpea : soybean) flour blend to 32.140 TIU/mg in 77.3 : 5.0 : 17.7 (sorghum : pigeonpea : soybean) flour blend trypsin inhibitor.

Table 3 : Antinutritional factors of complementary food from sorghum-pigeonpea-soybean flour blends

Facteurs antinutritionnels des compléments alimentaires issus des mélanges de farine de sorgho-pois cajan-soja

Sorghum pigeonpea soybean flour blends ratio	Phytate (%)	Oxalate (%)	Tannin (%)	Trypsin inhibitor (TIU/mg)
84.1: 10.9: 5.0	1.435^{i}	1.280^{bc}	0.0800^{ab}	31.935^{d}
58.6: 11.4: 30.0	1.525^{ef}	1.155^{g}	0.0745^{cde}	31.870^{ef}
77.3: 5.0: 17.7	1.480^{gh}	1.240^{cde}	0.0710^{ef}	32.140^{a}
62.1: 20.9: 17.1	1.615^{ab}	1.330^{a}	0.0710^{ef}	31.935^{d}
49.5: 21.4: 29.1	1.635^{a}	1.250^{cd}	0.0730^{de}	31.950^{d}
74.9: 20.1: 17.1	1.525^{ef}	1.195^{efg}	0.0805^{a}	32.115^{a}
65.0: 30.0: 5.0	1.560^{cde}	1.195^{efg}	0.0785^{abc}	31.755^{g}
68.0: 5.0: 27.0	1.540^{def}	1.325^{a}	0.0760^{bcd}	32.025^{c}
40.0: 30.0: 30.0	1.460^{hi}	1.270^{bc}	0.0740^{de}	32.055^{bc}
71.4: 14.4: 14.3	1.580^{bcd}	1.310^{ab}	0.0680^{fg}	31.775^{g}
51.4: 30.0: 18.6	1.570^{cd}	1.175^{fg}	0.0660^{g}	32.095^{ab}

Means values (n = 3) in a column with same superscripts are not significantly different (p Â 0.05)

Functional properties of complementary food from sorghum-pigeonpea-soybean flour blends

The bulk density values were generally low, and though significant differences occurred in these values between the blends, the range (0.56 – 0.61 g/ml) was not wide (Table 4). The dispersibilities of the flour blends ranged between 64.67 and 70.0 %. There was no significant difference ($p > 0.05$) in the blends containing 28.7, 32 and 60 % legumes. The swelling power values ranged between 6.90 % in 40.0 : 30.0 : 30.0 (sorghum : pigeonpea : soybean) flour blend and 8.57 % in 84.1 : 10.9 : 5.0 (sorghum : pigeonpea : soybean) flour blend, suggesting that the blend with the highest sorghum had the highest swelling power while the one with the highest quantity of legumes had the lowest swelling power. The water solubility index ranged from 3.67 g/g in 77.3 : 5.0 : 17.7 (sorghum : pigeonpea : soybean) flour blend to 5.33 g/g in 84.1 : 10.9 : 5.0 (sorghum : pigeonpea : soybean) flour blend. There was no significant variation ($p > 0.05$) in the water absorption capacity of the flour blends.

The values of the pasting properties of the blends were generally low (Table 5). The flour blends exhibited 28.42 - 60.84 RVU for peak viscosity, 0.38 - 3.25 RVU for breakdown viscosity and 52.71 - 140.29 RVU for final viscosity. Blends with high sorghum content recorded high final and setback viscosity. The setback viscosity was between 29.33 and 82.71 RVU. The peak time was from 5.03 - 6.97 min while the pasting temperature was between 84.85 and 88.85 °C.

Table 4 : Functional properties of complementary food from sorghum-pigeonpea-soybean flour blends

Propriétés fonctionnelles des aliments complémentaires issus des mélanges de farine de sorgho-pois cajan et de soja

Sorghum pigeonpea soybean flour blend ratio	Bulk density (g/ml)	Dispersibility (%)	Swelling power (%)	Water solubility index (g/g)	Water absorption capacity (%)
84.1:10.9:5.0	0.59^{b}	70.00^{a}	8.57^{a}	5.33^{a}	2.00^{a}
58.6:11.4:30.0	0.59^{b}	67.33^{c}	7.97^{b}	5.00^{ab}	2.00^{a}
77.3:5.0:17.7	0.59^{b}	69.67^{a}	6.97^{c}	3.67^{d}	2.00^{a}
62.1:20.9:17.1	0.56^{c}	64.67^{d}	6.93^{c}	4.33^{bcd}	1.00^{a}
49.5:21.4:29.1	0.61^{a}	67.00^{c}	6.97^{c}	4.00^{cd}	1.00^{a}
74.9:20.1:17.1	0.59^{b}	70.00^{a}	7.03^{c}	5.00^{ab}	2.00^{a}
65.0:30.0:5.0	0.59^{b}	69.67^{a}	6.97^{c}	4.67^{abc}	2.00^{a}
68.0:5.0:27.0	0.61^{a}	68.00^{b}	7.13^{c}	4.67^{abc}	3.00^{a}
40.0:30.0:30.0	0.61^{a}	68.00^{b}	6.90^{c}	4.33^{bcd}	3.00^{a}
71.4:14.4:14.3	0.59^{b}	68.00^{b}	7.03^{c}	4.33^{bcd}	3.00^{a}
51.4:30.0:18.6	0.61^{a}	65.00^{d}	7.03^{c}	4.67^{abc}	3.00^{a}

Mean values ($n = 3$) in a column with same superscripts are not significantly different ($p < 0.05$)

Table 5 : Pasting properties of complementary food from sorghum-pigeonpea-soybean flour blends

Propriétés aglutinogènes d'aliments complémentaires à partir de mélanges de farine de sorgho-pois cajan-soja

Sorghum pigeonpea soybean flour blends ratio	Peak viscosity (RVU)	Trough viscosity (RVU)	Break down viscosity (RVU)	Final viscosity (RVU)	Setback viscosity (RVU)	Peak time (min)	Pasting temperature (°C)
84.1: 10.9: 5.0	60.84^{a}	57.59^{a}	3.25^{a}	140.29^{a}	82.71^{a}	5.24^{cd}	84.85^{e}
58.6: 11.4: 30.0	33.63^{ef}	33.25^{ef}	0.38^{g}	79.17^{d}	46.09^{ef}	6.67^{b}	87.65^{ab}
77.3: 5.0: 17.7	42.84^{c}	41.04^{c}	1.79^{b}	107.63^{c}	66.59^{b}	5.13^{d}	86.83^{bcd}
62.1: 20.9: 17.1	37.42^{cde}	36.55^{cde}	0.88^{def}	85.67^{d}	49.21^{e}	6.93^{a}	86.83^{bcd}
49.5: 21.4: 29.1	28.42^{fg}	27.34^{g}	1.09^{cde}	63.09^{e}	35.75^{g}	6.97^{a}	88.43^{ab}
74.9: 20.1: 17.1	52.50^{b}	51.71^{b}	0.79^{defg}	120.75^{b}	70.05^{b}	5.03^{c}	88.55^{cde}
65.0: 30.0: 5.0	51.21^{b}	50.13^{b}	1.09^{cde}	107.88^{c}	57.75^{d}	6.97^{a}	85.15^{de}
68.0: 5.0: 27.0	29.25^{fg}	28.67^{fg}	0.58^{fg}	78.33^{d}	49.68^{e}	6.93^{a}	88.75^{a}
40.0: 30.0: 30.0	24.75^{g}	23.38^{g}	1.38^{c}	52.71^{e}	29.33^{h}	6.97^{a}	88.85^{a}
71.4: 14.4: 14.3	40.59^{cd}	39.92^{cd}	0.67^{efg}	100.25^{c}	60.33^{cd}	6.87^{a}	86.90^{bc}
51.4: 30.0: 18.6	36.38^{de}	35.21^{de}	1.17^{cd}	77.09^{d}	41.88^{f}	6.97^{a}	87.25^{abc}

Mean values (n = 3) in a column with same superscripts are not significantly different ($p < 0.05$)

Sensory attributes of complementary food from sorghum-pigeonpea-soybean flour blends

All the formulated complementary blends were acceptable to the panellists since they were rated above 6.0 for overall acceptability (Table 6). The sensory scores of the complementary foods were 6.00 to 7.27 for viscosity, 5.47 to 6.80 for aroma, 5.40 to 7.0 for taste and 5.53 to 7.20 for colour. The blend prepared from 71.4 : 14.4 : 14.3 (sorghum:pigeonpea:soybean) flour blend was the most acceptable while the one obtained from 62.1 : 20.9 : 17.1 (sorghum : pigeonpea : soybean) flour blend had the least score.

Table 6 : Sensory attributes of complementary food from sorghum-pigeonpea-soybean flour blends

Attributs sensoriels des aliments de complément issus des mélanges de farine de sorgho-pois cajan- soja

Sorghum pigeonpea soybean flour blends ratio	Viscosity	Aroma	Taste	Colour	Overall acceptability
84.1: 10.9: 5.0	6.93^{abc}	6.73^{bc}	6.27^{abcd}	7.20^{abc}	7.13^{a}
58.6: 11.4: 30.0	6.60^{abc}	6.13^{abc}	5.60^{cd}	6.27^{cd}	6.73^{ab}
77.3: 5.0: 17.7	6.27^{abc}	5.93^{abc}	6.07^{abcd}	7.07^{abc}	6.60^{ab}
62.1: 20.9: 17.1	6.00^{bc}	5.47^{c}	5.40^{d}	5.53^{d}	6.00^{b}
49.5: 21.4: 29.1	6.20^{abc}	5.60^{bc}	5.67^{bcd}	6.47^{bcd}	6.53^{ab}
74.9: 20.1: 17.1	7.27^{a}	6.47^{abc}	6.40^{abcd}	7.20^{abc}	7.20^{a}
65.0: 30.0: 5.0	7.20^{ab}	6.80^{ab}	7.00^{a}	7.53^{ab}	6.93^{ab}
68.0: 5.0: 27.0	7.00^{abc}	6.73^{ab}	6.27^{abcd}	7.00^{abc}	7.00^{a}
40.0: 30.0: 30.0	6.27^{abc}	6.33^{abc}	6.33^{abcd}	6.67^{abc}	6.47^{ab}
71.4: 14.4: 14.3	7.20^{ab}	6.87^{a}	6.80^{abc}	7.20^{abc}	7.27^{a}
51.4: 30.0: 18.6	6.93^{abc}	6.67^{ab}	6.40^{abcd}	6.60^{abcd}	7.07^{a}

Mean values (n = 3) in a column with same superscripts are not significantly different ($p < 0.05$)

DISCUSSION

The moisture contents of the flour blends were within the recommended moisture level of 15 % for processed cereal-based foods for infant and young children and sorghum flour (Codex, 1989 ; 2006). This is desirable as higher moisture content of flour has been reported to accelerate lipolytic, proteolytic and fungal activities, leading to loss of nutrients and inferior sensory characteristics (Butt *et al.*, 2004). Hence, the lower the moisture content of a food product the more shelf stable it is. The high amount of protein means that 100 g of meal from the blends will supply more than 16 g of protein recommended as daily intake for infants (Shiriki *et al.*, 2015). Proteins are essential for normal growth and development of children since they help the body to synthesise new tissues and repair worn out tissues. They are also components of hormones, enzymes and other vital processes in the body. The protein and crude fibre contents of the blends were higher than those reported by Shiriki *et al.* (2015) for cereal-legume based complementary food. Crude fibre adds bulk to food to facilitate bowel movements (peristalsis) and prevent many gastrointestinal diseases in man (Shiriki *et al.*, 2015). The fact that the blends were low in fat content may imply the need to enrich them with healthy fat or appropriate food commodity. The high level of ash in the blends may indicate high amount of mineral in these blends. Minerals are vital to the functioning of many body processes and are critical players in nervous system functioning, other cellular processes, water balance, and structural (e.g. skeletal) systems (Shiriki *et al.*, 2015).

The level of tannin in the blends was lower than 0.3 % specified as maximum standard for sorghum flour by Codex (1989). The low value of tannin may be due to the processing method which removed the pericarp of the sorghum seeds and seed coats of the legumes. Tannins are located in the pericarp of sorghum (Earp *et al.*, 1981). Tannins are phenolic compounds that precipitate protein and cause reduced protein digestibility (Sulieman *et al.,* 2007). However, there are reports that phenolic compounds, tannins possess antioxidant and antimicrobial activities (Sulieman *et al.,* 2007).

The bulk density of a flour material affects its packaging requirement, and it is influenced by the particle size and density of flour (Adeleke and Odedeji, 2010). The significant differences observed in the bulk density of the blends may indicate that the blends have different bulk handling and packaging requirements (Shittu and Adedokun, 2010). Swelling power is an indication of the water absorption index of flour granules during heating (Adeleke and Odedeji, 2010).The swelling power of the blends was almost the same, and this may be due to similarity in their composition. Banu *et al.* (2012) also reported the same observation with respect to the swelling power of the multi-mixes of grains. The low solubility values may indicate low degree of starch degradation during the processing of the flour. High solubility value indicates high extent of starch degradation and vice versa (Banu *et al.*, 2012).

Water absorption capacity is an indication of the level of granular integrity which determines the weakness of associative forces between the starch granules, to allow for more molecular surfaces to be available for binding with water molecules (Shittu and Adedokun, 2010). There was insignificant difference in the water absorption capacity of the blends and even then the water solubility index among the blends did not vary widely. According to Banu *et al.* (2012), who also reported the same observation with the water absorption capacity of the blends, the polar amino acid in protein and polysaccharides are responsible to varying water absorption. Hence, the observation on the water absorption capacity may be a reflection of the protein and carbohydrate contents of the blends.

Peak viscosity is the maximum viscosity attainable during the heating cycle (or cooking) and it determines ease of handling of the paste. Peak viscosity of complementary food indicates the ability of formulations to gel and variation in starch granule swelling during heating (Usman *et al.*, 2016). It is therefore not surprising that blends containing high amount of sorghum recorded high peak viscosity. Blends with high trough viscosity will show high hot paste viscosity while those with low setback viscosity indicate low tendency to retrograde. Breakdown viscosity is a measure of the degree of paste stability or starch granule disintegration during heating (Usman *et al.*, 2016). The ability of starch to withstand heating at high temperature and shear stress is an important factor in many food preparation processes (Usman *et al.*, 2016). The breakdown viscosity of the blends being lower than the one (28.3 - 35.2 RVU) reported by Usman *et al.* (2016) is expected to have a more stable paste during heating. Final viscosity indicates the stability of the cooked paste in use (Ragaee and Abdel-Aal (2016), and it is important in the acceptability of complementary food as well as infants' energy intake (Usman *et al.*, 2016). The relatively low final viscosity of the complementary food blends when compared with Usman *et al.* (2016) is therefore desirable. Setback viscosity is an index of retrogadation tendency of pastes prepared from starchy foods, and the higher the value the greater the retrogadation and syneresis tendency (Ragaee and Abdel-Aal, 2006). Thus, the low range of seback values obtained for the complementary blends is desirable. The peak time indicates the total time taken by a food to attain its peak viscosity, and the lower the peak time the faster the cooking time (Usman *et al.,* 2016). The peak time range obtained for the flour blends is higher than the one reported by Usman *et al.* (2016). The pasting temperature provides an indication of the minimum temperature required to cook a given sample, and this could have influence on energy usage (Ragaee and Abdel-Aal, 2006). The pasting temperature range obtained for the complementary food blends is similar to the one (84.5 - 89.6 ^{o}C) reported by Usman *et al.* (2016). The gelatinization temperature which indicates the minimum energy required to initiate rapid water ingression and swelling of starch granules (Shittu and Adedokun, 2010), did not vary much among the blends. A combination of pasting temperature and time determines the amount of energy required to cook the flours' paste (Shittu and Adedokun, 2010).

CONCLUSION

The study evaluated the nutritional and functional attributes of complementary food from flour blends of sorghum, pigeonpea and soybean. The formulated complementary foods contained higher protein and lower tannin contents than Codex recommended level. The flour blends exhibited low final viscosity, setback viscosity and peak time which are desirable for complementary food formulations. All the complementary food formulations were acceptable to a sensory panel consisting of 50 nursing mothers.

ACKNOWLEDGEMENT

The authors acknowledge West Africa Agricultural Poductivity Programme for funding this work.

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