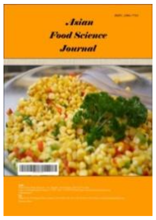

Asian Food Science Journal

20(5): 25-37, 2021; Article no.AFSJ.66644
ISSN: 2581-7752

Physicochemical Properties and Consumer Acceptability of Break Fast Cereal Made from Sorghum (*Sorghum bicolor L*) Soybean (*Glycine max*), Bambara Groundnut (*Vigna subterranean*) and Groundnut (*Arachis hypogaea*)

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/AFSJ/2021/v20i530296
Editor(s):
(1) Dr. Chouitah Ourida, University of Mascara, Algeria.
Reviewers:
(1) Bracacescu Carmen, Romania.
(2) Abdul Manab, Brawijaya University, Indonesia.
Complete Peer review History: http://www.sdiarticle4.com/review-history/66644

Received 27 January 2021
Accepted 02 April 2021
Published 17 April 2021

Original Research Article

ABSTRACT

The present study was aimed at the assessment of physicochemical and consumer acceptability of breakfast cereals developed from locally-sourced materials (sorghum, soybean, Bambara groundnut and groundnut). Ten samples were formulated by mixing the flours in different ratios while the formulated flours were subjected to various analyses including proximate composition, functional properties, vitamins and microbial evaluation and consumer acceptability. The results revealed the following ranges in the proximate parameters: moisture (6.45 – 10.46%), protein (10.26 –19.64%), fat (3.89–11.42%), ash (1.48 – 2.69%), crude fiber (1.94–3.72%), carbohydrates (56.09 – 72.06%), and energy (363.52 – 405.64 Kcal). The functional properties of the formulated breakfast cereal were bulk density (0.65-1.14 g/cm^3), water absorption capacity (70.45-82.45 ml/g), swelling index (7.05-10.95%), solubility (73.55-88.84%), and viscosity (22.96-38.84 cP). Appreciable quantities of vitamins were present in the formulated breakfast cereal including vitamins C, B_1, B_2, B_3, and folic acid. The sensory evaluation on the formulated breakfast cereal revealed that sample F (5% Malted sorghum flour + 65% Unmalted Sorghum flour + 30% Soybean

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flour) was rated the highest in terms of appearance, taste, and overall acceptability. The comparative advantage of this formulated cereal meal is that the ingredients used (soybean, sorghum, Bambara groundnut and groundnut) are easily grown in the tropical areas with high yield and are locally available.

Keywords: Breakfast; cereals; sorghum; bambara groundnut; soybean.

1. INTRODUCTION

Breakfast cereals are usually defined as foods prepared by swelling and roasting cereals or cereal products, e.g. corn flakes, puffed rice; cereals or maize, in grain form, precooked or otherwise prepared [1]. Breakfast cereals, usually consumed in the early part of the morning, serve as a good source of strength which is a vital requirement of the human body. They are not usually consumed alone but supplemented with other food classes. For instance, cereals are known to be deficient in lysine and sometimes tryptophan, which are the essential amino acids for body maintenance for both infants and adults. Lysine, which is limiting in cereals, is supplemented when cereals are combined with legumes rich in lysine. Some legumes that have been experimented upon include soya bean, bambara groundnut, groundnut, pigeon, pea, African yam bean, among others [2]. Cereal-legume blends are found to be employed in producing weaning food for 'infant formula' (complementary foods) for both infants and small children less than five year [3].

In the developing countries such as Nigeria, malnutrition is a common dietary problem that is said to be endemic. It is characterized by micro-nutrient deficiency and protein-energy malnutrition. Over the last few years, efforts have been made to reduce or eliminate the problem worldwide [4]. Dietary diversification has been suggested by many workers as the ultimate solution to malnutrition. The diversification involves the use of commonly known or consumed grains and/or legumes in more than one form and still meeting the dietary nutritional need of the target consumers. A diversification that may be effective in rural communities may entail evolving additional uses of some locally available grains [5]. Availability of grains like soybean and maize may be limited as their uses in many products as individual raw materials are so diversified. These raw materials have found so much use in a number of products, mainly industrial products (cottage and multi-national products) as well as household purposes [6], that their uses may be deemed to have been over-diversified and therefore presenting a tough competition for the raw materials.

However, there exist a lot of other locally available cereals and legumes that can serve as good alternatives to these highly-sought-after conventional raw materials in use. Consequently, there is the need to have some baseline study on the use of these raw materials to identify and evaluate their characteristics and potentiality in serving as good alternatives. Among such locally available alternatives are Bambara groundnut and sorghum. Therefore, this study was aimed at investigating the physicochemical properties and consumer acceptability of breakfast cereal made from sorghum, soybean, Bambara groundnut and groundnut.

2. MATERIALS AND METHODS

2.1 Materials

The sorghum, soybean, Bambara groundnut and groundnut used in this study were purchased from Jimeta Modern Market, Jimeta-Yola, Nigeria. All samples were kept in a moisture-free environment until when needed.

2.2 Production of Flour from the Cereals and Legumes

The sorghum flour sample was prepared as described by [7] with little modifications. The sorghum was sorted to remove extraneous materials and damaged seeds. Thereafter, one kilogram (1kg) of the grains was steeped, dehulled, dried and milled to fine powder. A local sieve of about 250 μm was used to sieve the flour in order to obtain a fine particle size. The flour was packaged in a plastic container and sealed until when needed. The sorghum grains were also malted as described by [8] from where malted sorghum flour was produced.. The bambara groundnut flour samples was prepared as described by [3] with little modifications. The defatted groundnut flour sample was prepared as described by [9] also with little modifications while soybean flour was prepared according to the method described by [10].

2.3 Formulation of Breakfast Cereal Meal

The breakfast cereal meal was formulated using sorghum, soybean, Bambara groundnut and defatted ground nut flours in the ratios as stated in Table 1. The flours were thoroughly blended into homogenous mixture using a Kenwood blender.

2.4 Determination of Proximate Composition of Meal Samples

The proximate composition (moisture, crude protein, crude fat and ash) were determined following the methods as described by AOAC [11]. The carbohydrate content in the samples was determined by difference. The total energy of each sample meal was estimated by calculation using the Atwater quantification factors of 4, 9 and 4 Kcal/100g for protein, fat and carbohydrate respectively [12].

2.5 Assessment of the Functional Properties of Meal Samples

The bulk density and water absorption capacity of flour samples were determined by the method described by [13]. The method of [14] was adopted in the determination of gelation capacity. The method modified by Okoli et al. was used in the determination of solubility. The gruel of the meal formulation mix was prepared as described by [8] for the determination of viscosity. To determine the swelling index, the volume occupied by 1 g sample was compared with the new volume after addition of 10 ml distilled water and centrifugation (3000 x g) for 10 min to remove excess water. Titratable acidity was determined by titrating a 10 g sample mixed with 90 ml of distilled water against 0.1N NaOH using phenolphthalein as indicator [11]. The pH of the samples was determined following the method described by Sadler and Murphy [15].

2.6 Determination of Vitamin B Group and Vitamin C of Meal Samples

The vitamin B group was extracted and determined by the method described by AOAC [11]. Ascorbic acid was also determined according to the 2, 6 – dichlorophenol titrimetric method of.

2.7 Microbial Analysis

The microbial analysis was carried out according to method described by [16].

Table 1. The percentage formulation of the breakfast cereal meal

Sample Code	Percent combination (%)				
	MSF	**SF**	**BNF**	**SBF**	**GNF**
A	5	95	-	-	-
B	5	75	20	-	-
C	5	75	-	20	-
D	5	75	-	-	20
E	5	65	30	-	-
F	5	65	-	30	-
G	5	65	-	-	30
H	5	55	40	-	-
I	5	55	-	40	-
J	5	55	-	-	40

MSF = (Malted sorghum flour); SF = (Non-malted Sorghum flour); BNF = (Bambara groundnut flour); SBF = (Soybean flour); GNF = (Defatted groundnut flour)
A= (5% Malted sorghum flour + 95% Non-malted Sorghum flour);
B= (5% Malted sorghum flour + 75% Non-malted Sorghum flour + 20% Bambara groundnut flour);
C= (5% Malted sorghum flour + 75% Non-malted Sorghum flour + 20% Soybean flour);
D= (5% Malted sorghum flour + 75% Non-malted Sorghum flour + 20% Defatted groundnut flour);
E= (5% Malted sorghum flour + 65% Non-malted Sorghum flour + 30% Bambara groundnut flour);
F= (5% Malted sorghum flour + 65% Non-malted Sorghum flour + 30% Soybean flour);
G= (5% Malted sorghum flour + 65% Non-malted Sorghum flour + 30% Defatted groundnut flour); H= (5% Malted sorghum flour + 55% Non-malted Sorghum flour + 40% Bambara groundnut flour);
I= (5% Malted sorghum flour + 55% Non-malted Sorghum flour + 40% Soybean flour);
J= (5% Malted sorghum flour + 55% Non-malted Sorghum flour + 40% Defatted groundnut flour)

2.8 Sensory Quality Rating of Breakfast Cereal Meal

The developed breakfast cereal meals were subjected to sensory evaluation by serving them to 30 untrained panel members who were asked to ranked the products on the basis of their quality attributes (appearance, taste, aroma, consistency and overall acceptability) using a 9-point Hedonic scale (where 1 = 'dislike extremely' and 9 = 'like extremely) as described by Ihekoronye and Ngoddy [17]. Results obtained from the sensory evaluation were tested at 5% level of significance.

2.9 Statistical Analysis

All the data reported in this study were carried out in triplicate. In each case, a mean value and standard deviation were calculated. The data were analyzed using SPSS version 20 statistical software package. Differences between means were evaluated by the Duncan multiple range test and significance was accepted at 95% confidence level.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition of the Breakfast Cereal Meals

Table 2 shows the proximate composition (moisture, protein, fat, ash, fibre, carbohydrate and total energy) of breakfast foods prepared from the blends of sorghum, soybean, Bambara groundnut and defatted groundnut. The crude protein which ranged from 10.26 to 19.64% was within the recommended minimum limit by FAO/WHO for cereal meals. The higher protein content was observed in the samples with high level of defatted-GNF (samples G and J). This high level of protein in the products may be attributed to the presence of groundnut flour used in the formulations [18]. reported that protein of legumes such as peanut has higher contents than that of cereals proteins. The generally high level of protein, however, demonstrates the effect of legume supplementation in breakfast cereals. It was also observed that as the soybean addition increased, the crude protein increased as well.

The percentage moisture contents ranged from 6.46 to 10.46%. The highest value (10.46%) was obtained in the breakfast cereal sample B (5% Malted sorghum flour + 75% Non-malted Sorghum flour + 20% Bambara groundnut flour) while the lowest value (6.46%) was obtained in the breakfast cereal sample J (5% Malted sorghum flour + 55% Non-malted Sorghum flour + 40% Defatted groundnut flour). This moisture content was probably due to the higher content of sorghum flour that has the ability to imbibe moisture from the environment and swell. Sorghum has been shown to have hygroscopic or water-absorbing properties [19]. The lower moisture content generally observed in other samples may add the advantage of prolonging the shelf life of the products, if properly packaged. There were significant differences ($P<0.05$) among the moisture content of all the samples and were within acceptable safe level recommended by FAO/WHO (<10%) as higher moisture may affect the storage quality of the foods [20].

The percentage crude fat ranged from 4.06 to 11.42%. There were significant differences ($P<0.05$) among the samples. It was observed that the crude fat content of meals containing defatted-GNF and SBF products were relatively higher than that of BNF products. This could be attributed to the higher content of oil in soybean and groundnut. Similar result was reported by [5] for nutrient composition of complementary food gruels formulated from malted cereals, soybeans and groundnut [5]. reported that the inclusion of oil-dense soya beans in the complementary diets will not only increase the energy density but also be a transport vehicle for fat soluble vitamins. The presence of malted sorghum and Bambara groundnut flour in the formulations may be responsible for the generally low fat content of the resulting products. The low fat content of the sample A with 100% malted sorghum flour and sorghum flour would be suitable for weight watchers and lower enough to allow for good storage if packaged properly.

Ash content is an indication of the mineral content of a food sample. Davis and Dean [18] reported that peanuts are considered valuable sources of minerals to the human diet. The ash content of the formulated breakfast food ranged from 1.48 to 2.69%. The high ash values recorded in this work may be attributed to the presence of groundnut flour used as part of the ingredients in this study.

Table 2. Proximate composition (%) of the breakfast cereal produced from blends of sorghum, soybean, Bambara nut and defatted groundnut

Sample	Proximate composition (%)						Energy (Kcal)
	Moisture	Crude Protein	Crude Fat	Ash	Crude fibre	Carbohydrate	
A	10.39 ± 0.06^{a}	10.26 ± 0.06^{i}	3.89 ± 0.06^{g}	1.48 ± 0.06^{e}	1.94 ± 0.06^{f}	72.06 ± 0.30^{a}	364.23 ± 0.42^{fg}
B	10.46 ± 0.10^{a}	11.28 ± 0.10^{h}	4.06 ± 0.10^{fg}	1.74 ± 0.10^{de}	2.08 ± 0.10^{ef}	70.40 ± 0.48^{b}	363.20 ± 0.67^{f}
C	9.71 ± 0.05^{b}	12.41 ± 0.29^{f}	4.33 ± 0.05^{ef}	1.93 ± 0.05^{bcd}	2.53 ± 0.05^{d}	69.10 ± 0.16^{bc}	364.99 ± 0.34^{fg}
D	9.58 ± 0.04^{bc}	15.06 ± 0.04^{c}	7.76 ± 0.04^{e}	2.19 ± 0.04^{c}	2.94 ± 0.04^{c}	62.49 ± 0.22^{d}	379.98 ± 0.30^{c}
E	10.45 ± 0.13^{a}	11.76 ± 0.13^{g}	4.24 ± 0.13^{ef}	1.84 ± 0.13^{cd}	2.12 ± 0.13^{ef}	69.58 ± 0.64^{b}	363.52 ± 0.89^{f}
F	9.38 ± 0.04^{cd}	13.16 ± 0.17^{e}	4.69 ± 0.04^{d}	2.16 ± 0.04^{bc}	2.84 ± 0.04^{c}	67.78 ± 0.26^{c}	365.95 ± 0.26^{f}
G	9.13 ± 0.07^{d}	17.40 ± 0.07^{b}	9.78 ± 0.07^{b}	2.50 ± 0.07^{b}	3.39 ± 0.07^{b}	57.82 ± 0.33^{e}	388.84 ± 0.47^{b}
H	8.56 ± 0.05^{e}	12.44 ± 0.05^{f}	4.36 ± 0.05^{ef}	2.16 ± 0.05^{bc}	2.36 ± 0.05^{de}	70.15 ± 0.25^{b}	369.54 ± 0.34^{e}
I	6.67 ± 0.19^{f}	13.65 ± 0.19^{d}	4.49 ± 0.19^{de}	2.11 ± 0.19^{bc}	2.85 ± 0.19^{c}	70.23 ± 0.95^{b}	375.93 ± 1.33^{d}
J	6.46 ± 0.15^{f}	19.64 ± 0.15^{a}	11.42 ± 0.15^{a}	2.69 ± 0.15^{a}	3.72 ± 0.15^{a}	56.09 ± 0.77^{f}	405.64 ± 1.07^{a}

Mean values in the same column bearing different superscripts are significantly different (P<0.05)
A= (5% Malted sorghum flour + 95% Unmalted Sorghum flour);
B= (5% Malted sorghum flour + 75% Unmalted Sorghum flour + 20% Bambara groundnut flour);
C= (5% Malted sorghum flour + 75% Unmalted Sorghum flour + 20% Soybean flour);
D= (5% Malted sorghum flour + 75% Unmalted Sorghum flour + 20% Defatted groundnut flour);
E= (5% Malted sorghum flour + 65% Unmalted Sorghum flour + 30% Bambara groundnut flour);
F= (5% Malted sorghum flour + 65% Unmalted Sorghum flour + 30% Soybean flour);
G= (5% Malted sorghum flour + 65% Unmalted Sorghum flour + 30% Defatted groundnut flour);
H= (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Bambara groundnut flour);
I= (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Soybean flour);
J= (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Defatted groundnut flour)

Crude fibre of the samples were also significantly different (P<0.05) from each other ranging from 1.94 to 3.72%. Similar values of 3.10 to 3.80% and 1.54 to 4.00% were previously recorded by [21] for other breakfast cereals formulation. Fibre is needed to assist in digestion and keep the gastrointestinal tract healthy and can also help to keep the blood sugar stable. It slows down the release of glucose during digestion, so cells require less insulin to absorb that glucose. High fibre foods are reported to enhance gastrointestinal tract functions [13]. Also, fibre reduces the incidence of colon cancer and prevents some diseases like obesity, diabetes, gall stone and coronary heart disease [13]. Thus, consumption of this breakfast cereal products could help in normal bowel movements and aid food digestion.

The carbohydrates content of the breakfast cereal samples ranged from 56.09% to 72.06%, with sample A (5% Malted sorghum flour + 95% Unmalted Sorghum flour) having the highest value and sample J (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Defatted groundnut flour) having the lowest value. The higher carbohydrate values recorded for sample A may be attributed to the high content of the cereals than legumes used as the principal ingredients in the formulations.

The total energy content of the breakfast cereal samples ranged from 363.20 to 405.64 Kcal. It was observed that the samples with higher inclusions of defatted-GNF and SBF (sample J) had the highest energy value. [22] reported that flours of higher fat content supply higher energy, however, food containing higher fat contentis susceptible to both hydrolytic and oxidative/enzymatic rancidity which is responsible for off flavour and this affects both the general acceptability and storage stability of the products.

3.2 Functional Properties of Breakfast Cereal Meals

The result of the functional properties of the developed breakfast cereals is shown in Table 3. The bulk density ranged from 0.65 to 1.14 g/cm^3 with sample A (5% Malted sorghum flour + 95% Unmalted Sorghum flour) having the lowest value while sample J (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Defatted groundnut flour) had the highest value. Hussein et al. [23] reported that the bulk density is an important property that has a direct impact on the packaging and storage space requirement, which is equally important in transportation requirement for products generally. Bulk density also provides indication of physical properties like cohesion and porosity and may affect flow behaviour and storage stability of powder materials [24]. Thus, the reduction in the bulk densities observed in this study is an indication of a lesser packaging requirement as the sorghum-soy flour substitution increased.

The water absorption capacity (WAC) is an important property in the development of ready-to-eat foods, and a high WAC may assure the flour product cohesiveness [19]. A low WAC product assures easy digestibility of the flour [25]. The WAC of the breakfast samples ranged from 70.45 to 82.45 ml/g, with sample A (5% Malted sorghum flour + 95% Unmalted Sorghum flour) having the highest value and sample J (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Defatted groundnut flour) having the lowest value. The WAC were significantly different (P<0.05) from each other and decreased as the level of substitution with Bambara nut, soybean and ground nut flour increased in the breakfast produced. The differences in the water absorption capacities may be explained by their respective content of hydrophilic constituents such as carbohydrates which bind more water than either protein or lipids. Both carbohydrates and proteins 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).

Swelling index is an important functional property that indicates the ability of flour to associate with water. The swelling index of the products ranged from 7.05 to 10.95%. Sample J (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Defatted groundnut flour) showed the highest swelling index (10.95%) than other samples.

Solubility index is related to the presence of soluble molecules in the flour. Solubility index was also highest in sample J (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Defatted groundnut flour) than other samples.

The results of gelation capacity ranged between 5.87 to 10.25 g/ml. Pre-gelatinization and untreated sprouting increased the formation and the strength of gel of the samples. Thus, the least gelation concentration of the samples increased as the starch broke down into high amount of amylose and amylopectin molecules. Similar results were obtained by Adedeji et al. [22] 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.

Viscosity of food is one of the important determinants of food acceptability to both mothers and young children. Viscosity is the measure of the resistance to fluid flow. Food is visco-elastic in nature. Weaning or complementary food of high viscosity is usually unacceptable to growing infants as it makes feeding difficult and causes suffocation [26]. The viscosity of the products ranged from 22.96 to 38.84 cP; with sample A (5% Malted sorghum flour + 95% Unmalted Sorghum flour) having the lowest value and sample J (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Defatted groundnut flour) had the highest value. The lower viscosity value of Sample A could probably be attributed to the starch moiety which was not ruptured by preprocessing to release assimilable sugars (amylose and amylopectin) for gelation and in turn increase the viscosity. During sprouting of the sorghum, there was increased activity of the alpha beta amylases in the sprouts. There was digestion of the starch by these amylases to dextrin and mattose. The amylases degrade the starch moiety and breakdown the starch leading to formation of gel network. According to Mabhaudhi et al. [26], sprouting reduced the gel properties and the water holding capacity of gruels prepared from the flours although the reconstitutionability of the flours improved.

The titratable acidity (TA) and pH are interrelated in terms of acidity, but have different impacts on food quality [15]. The total acid available to react with sodium hydroxide solution during titration is the titratable acidity(TA) whiles the pH gives a measure of the strength of the acid in food [27,15]. reported that the impact of an acid on food flavour is much more determined by TA than pH. The pH value obtained for the breakfast cereals produced showed that they are neutral and safe for consumptions.

3.3 Vitamins Contents of the Breakfast Cereals

The vitamin contents of the formulated breakfast cereals are shown in Table 4. Significant differences ($P<0.05$) were observed between most of the products in the vitamins evaluated. The vitamins C, B_1, B_2, B_3, and folic acids contents of the produced breakfast cereals ranged from 0.01 – 12.32, 0.01 – 0.25, 0.03 – 0.29, 0.02 – 0.15 and 0.02 – 0.23 mg/100g respectively. It was observed that the vitamin contents of these developed breakfast cereals were generally low when compared to vitamin contents of some commonly consumed food substances which are established dietary sources of vitamins. Vitamins are generally needed daily in small amounts from foods. They yield no energy directly but may contribute to energy yielding chemical reactions in the body and promote growth and development [2]. Vitamin C is mainly used for synthesizing collagen, a major protein for building connective tissues. It is a general antioxidant, enhances iron absorption, and is needed for synthesizing some hormones and neurotransmitters [28]. Vitamin C maintains blood vessels flexibility and improves circulation in the arteries of smokers. It also acts as an antioxidant in the body system where it scavenges oxygen-free radicals which are bye-products of many of the normal metabolic processes in the body [2]. Vitamin C deficiency results in scurvy, which is evidenced in poor wound healing, pinpoint hemorrhages in the skin, and bleeding of gum. Like thiamin, vitamin B_2 acts as a co-enzyme in the breakdown of fats, proteins, carbohydrate, and other nutrients. It also helps fatty acid reduction and also necessary for catabolism of nutrients in the liver. Furthermore, it assists eye and skin maintenance [2].

3.4 Microbial Status of the Breakfast Cereals

The microbial examination of the products revealed different values for total bacteria count (TBC), total coliform count (TCC), and total fungi count (TFC) as shown in Figure 1. The TBC ranged from 3.85×10^5 to 6.06×10^5 cfu/ml, while the TCC ranged between 1.50×10^5 to 3.36×10^5 cfu/ml and the TFC ranged from 4.98×10^5 to 9.77×10^5. The contamination could have occurred during cooling and before packaging. Yeasts are commonly present as contaminants in cereals and can probably be attributed to the low value of the pH which creates ideal conditions for

Table 3. Functional Properties of the Breakfast Cereal Produced from Blends of Sorghum, Soybean, Bambara nut and defatted Groundnut

Sample	Bulk Density (g/cm^3)	WAC (ml/g)	Swelling Index (%)	Gelation (g/ml)	Solubility index (%)	Viscosity (cP)	Titratable acidity	pH
A	0.65 ± 0.17^{g}	82.45 ± 0.12^{a}	7.05 ± 0.15^{j}	5.87 ± 0.11^{j}	73.55 ± 0.55^{j}	22.96 ± 2.91^{j}	0.06 ± 0.06^{b}	6.39 ± 0.32^{d}
B	0.79 ± 0.29^{f}	80.46 ± 0.23^{b}	7.43 ± 0.32^{i}	6.16 ± 0.17^{i}	74.86 ± 0.32^{i}	24.00 ± 3.99^{i}	0.08 ± 0.04^{a}	6.38 ± 0.33^{d}
C	0.84 ± 0.12^{e}	78.43 ± 0.12^{c}	8.45 ± 0.11^{h}	7.23 ± 0.23^{h}	77.15 ± 0.32^{h}	26.26 ± 2.26^{h}	0.06 ± 0.05^{bc}	6.42 ± 0.37^{cd}
D	0.85 ± 0.12^{e}	78.06 ± 0.11^{d}	8.50 ± 0.12^{g}	7.50 ± 0.08^{g}	80.16 ± 0.32^{g}	26.85 ± 2.68^{g}	0.08 ± 0.06^{a}	6.52 ± 0.47^{b}
E	0.91 ± 0.12^{d}	77.83 ± 0.17^{e}	8.96 ± 0.32^{f}	8.63 ± 0.32^{f}	83.16 ± 0.55^{f}	28.77 ± 2.87^{f}	0.05 ± 0.05^{c}	6.44 ± 0.37^{c}
F	0.96 ± 0.12^{c}	75.85 ± 0.11^{f}	9.38 ± 0.17^{e}	8.76 ± 0.10^{e}	85.96 ± 0.23^{e}	30.59 ± 3.06^{e}	0.08 ± 0.07^{a}	6.10 ± 0.50^{f}
G	0.98 ± 0.12^{c}	75.20 ± 0.13^{g}	9.55 ± 0.12^{d}	9.87 ± 0.32^{d}	86.16 ± 0.55^{d}	31.75 ± 3.17^{d}	0.06 ± 0.05^{bc}	6.38 ± 0.31^{d}
H	1.00 ± 0.12^{bc}	73.15 ± 0.17^{h}	9.80 ± 0.11^{c}	10.01 ± 0.17^{c}	87.24 ± 0.32^{c}	34.27 ± 3.42^{c}	0.06 ± 0.02^{bc}	6.31 ± 0.26^{e}
I	1.04 ± 0.12^{b}	71.43 ± 0.12^{i}	10.49 ± 0.23^{b}	10.12 ± 0.11^{b}	88.13 ± 0.32^{b}	35.65 ± 3.03^{b}	0.07 ± 0.05^{b}	6.60 ± 0.55^{a}
J	1.14 ± 0.12^{a}	70.45 ± 0.17^{j}	10.95 ± 0.09^{a}	10.25 ± 0.23^{a}	88.76 ± 0.55^{a}	38.84 ± 3.05^{a}	0.06 ± 0.03^{b}	6.29 ± 0.22^{e}

Mean values in the same column bearing different superscripts are significantly different (P<0.05).
A= (5% Malted sorghum flour + 95% Unmalted Sorghum flour);
B= (5% Malted sorghum flour + 75% Unmalted Sorghum flour + 20% Bambara groundnut flour);
C= (5% Malted sorghum flour + 75% Unmalted Sorghum flour + 20% Soybean flour);
D= (5% Malted sorghum flour + 75% Unmalted Sorghum flour + 20% Defatted groundnut flour);
E= (5% Malted sorghum flour + 65% Unmalted Sorghum flour + 30% Bambara groundnut flour);
F= (5% Malted sorghum flour + 65% Unmalted Sorghum flour + 30% Soybean flour);
G= (5% Malted sorghum flour + 65% Unmalted Sorghum flour + 30% Defatted groundnut flour);
H= (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Bambara groundnut flour);
I= (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Soybean flour);
J= (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Defatted groundnut flour)

Table 4. Vitamin contents (mg/100g) of the breakfast cereal produced from blends of sorghum, soybean, Bambara nut and defatted groundnut

Sample	Vitamin concentration (mg/100g)				
	Vitamin C	Vitamin B_1	Vitamin B_2	Vitamin B_3	Folic Acid
A	0.01 ± 0.05^{i}	0.01 ± 0.10^{d}	0.03 ± 0.02^{e}	0.02 ± 0.10^{e}	0.02 ± 0.03^{f}
B	2.70 ± 0.12^{h}	0.02 ± 0.21^{d}	0.03 ± 0.01^{e}	0.03 ± 0.05^{e}	0.03 ± 0.05^{ef}
C	5.31 ± 0.11^{g}	0.03 ± 0.06^{d}	0.05 ± 0.04^{d}	0.04 ± 0.03^{d}	0.13 ± 0.11^{c}
D	5.91 ± 0.14^{f}	0.03 ± 0.11^{d}	0.03 ± 0.02^{de}	0.04 ± 0.09^{de}	0.04 ± 0.14^{e}
E	6.23 ± 0.17^{c}	0.04 ± 0.06^{d}	0.03 ± 0.07^{e}	0.04 ± 0.04^{e}	0.05 ± 0.06^{e}
F	7.91 ± 0.12^{d}	0.04 ± 0.05^{d}	0.07 ± 0.04^{c}	0.06 ± 0.05^{c}	0.16 ± 0.12^{b}
G	8.52 ± 0.11^{c}	0.16 ± 0.17^{c}	0.05 ± 0.06^{de}	0.05 ± 0.03^{de}	0.08 ± 0.06^{d}
H	7.71 ± 0.15^{d}	0.16 ± 0.15^{c}	0.29 ± 0.23^{a}	0.05 ± 0.09^{a}	0.11 ± 0.05^{c}
I	12.32 ± 0.14^{a}	0.25 ± 0.11^{a}	0.16 ± 0.09^{b}	0.15 ± 0.10^{b}	0.23 ± 0.15^{a}
J	11.54 ± 0.23^{b}	0.19 ± 0.12^{b}	0.09 ± 0.11^{c}	0.08 ± 0.07^{c}	0.16 ± 0.11^{b}

Mean values in the same column bearing different superscripts are significantly different (P<0.05)
A= (5% Malted sorghum flour + 95% Unmalted Sorghum flour);
B= (5% Malted sorghum flour + 75% Unmalted Sorghum flour + 20% Bambara groundnut flour);
C= (5% Malted sorghum flour + 75% Unmalted Sorghum flour + 20% Soybean flour);
D= (5% Malted sorghum flour + 75% Unmalted Sorghum flour + 20% Defatted groundnut flour);
E= (5% Malted sorghum flour + 65% Unmalted Sorghum flour + 30% Bambara groundnut flour);
F= (5% Malted sorghum flour + 65% Unmalted Sorghum flour + 30% Soybean flour);
G= (5% Malted sorghum flour + 65% Unmalted Sorghum flour + 30% Defatted groundnut flour);
H= (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Bambara groundnut flour);
I= (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Soybean flour);
J= (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Defatted groundnut flour).

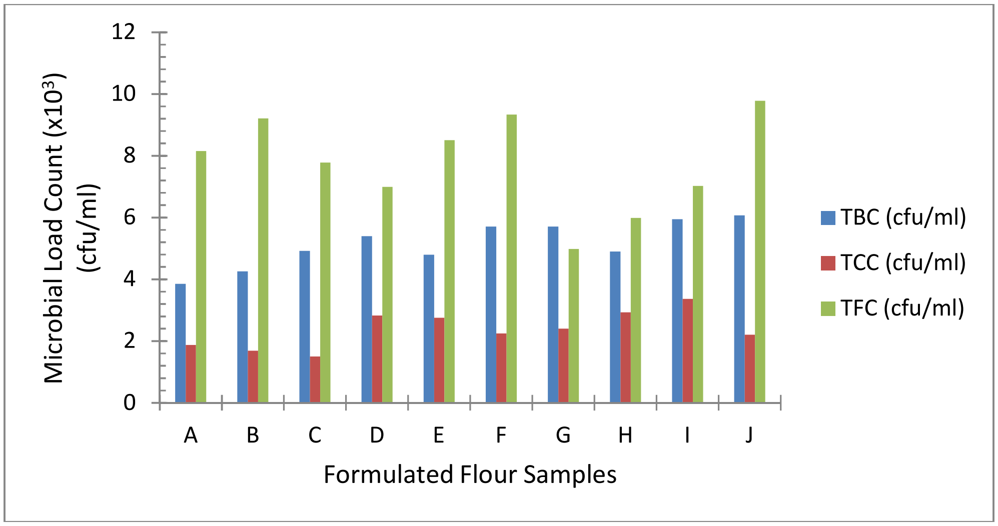

Fig. 1. Microbiological status of the formulated flour samples

TBC= Total bacteria count (TBC), total coliform count
TCC= Total coliform count
TFC= Total fungi count
A= (5% Malted sorghum flour + 95% Unmalted Sorghum flour);
B= (5% Malted sorghum flour + 75% Unmalted Sorghum flour + 20% Bambara groundnut flour);
C= (5% Malted sorghum flour + 75% Unmalted Sorghum flour + 20% Soybean flour);
D= (5% Malted sorghum flour + 75% Unmalted Sorghum flour + 20% Defatted groundnut flour);
E= (5% Malted sorghum flour + 65% Unmalted Sorghum flour + 30% Bambara groundnut flour);
F= (5% Malted sorghum flour + 65% Unmalted Sorghum flour + 30% Soybean flour);
G= (5% Malted sorghum flour + 65% Unmalted Sorghum flour + 30% Defatted groundnut flour);
H= (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Bambara groundnut flour);
I= (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Soybean flour);
J= (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Defatted groundnut flour).

yeast growth [15]. The presence of microflora may also be due to availability of more nutrients for microbial proliferation and enhanced metabolic activities. These results are much lower than the FAO/WHO limits of 10^4 to 10^6cfu/g for bacteria and 10^2 to 10^4 cfu/g for moulds in weaning foods [29].

Thus, the microbial analysis of the formulated flour blends reveals that all the formulation indicated a safety of the products for consumption and this could be due to higher standard of personal hygiene and quality maintenance of manufacturing practice observed during the preparation [27].Highlighted the importance of adequate hygiene during the preparation of food and also link between infection and nutrition.

3.5 Sensory Evaluation of the Reconstituted Breakfast Cereal Meal

The results of sensory evaluation of the reconstituted breakfast cereal meal from 30 untrained panelists are presented in Table 5. Sample F (5% Malted sorghum flour + 65% Unmalted Sorghum flour + 30% Soybean flour) was rated the highest in terms of appearance followed by sample B (5% Malted sorghum flour + 75% Unmalted Sorghum flour + 20% Bambara groundnut flour). In terms of taste, sample F (5% Malted sorghum flour + 65% Unmalted Sorghum flour + 30% Soybean flour) was equally rated the highest followed by sample D (5% Malted sorghum flour + 75% Unmalted Sorghum flour + 20% Defatted groundnut flour). The highest ratings for aroma and consistency were allotted to sample D (5% Malted sorghum flour + 75% Unmalted Sorghum flour + 20% Defatted groundnut flour) and sample B (5% Malted sorghum flour + 75% Unmalted Sorghum flour + 20% Bambara groundnut flour) respectively while the highest overall acceptability rating was allotted to sample F (5% Malted sorghum flour + 65% Unmalted Sorghum flour + 30% Soybean flour) followed by sample D (5% Malted sorghum flour + 75% Unmalted Sorghum flour + 20% Defatted groundnut flour).

Table 5. Sensory quality rating of the formulated cereal meal

Sample	Sensory factor[1]				
	Appearance	Taste	Aroma	Consistency	Overall acceptability
A	5.0^{d}	4.4^{e}	2.5^{f}	8.4^{a}	6.1^{d}
B	8.2^{b}	6.3^{c}	6.7^{b}	8.6^{a}	7.5^{c}
C	1.9^{f}	2.1^{g}	2.1^{f}	7.2^{b}	3.2^{f}
D	7.9^{b}	7.2^{b}	8.7^{a}	8.4^{a}	8.1^{b}
E	6.8^{c}	5.2^{d}	2.2^{f}	7.2^{b}	4.2^{e}
F	8.7^{a}	8.2^{a}	8.5^{a}	6.8^{c}	8.8^{a}
G	1.3^{f}	3.3^{f}	4.1^{d}	5.2^{d}	2.8^{g}
H	1.2^{f}	2.8^{g}	7.1^{b}	4.8^{e}	2.9^{g}
I	3.4^{e}	4.1^{e}	3.7^{e}	4.2^{f}	3.3^{f}
J	4.8^{d}	5.2^{d}	5.4^{c}	5.3^{d}	3.5^{f}

[1]Mean values in the same column bearing different superscripts are significantly different at P<0.05.
A= (5% Malted sorghum flour + 95% Unmalted Sorghum flour);
B= (5% Malted sorghum flour + 75% Unmalted Sorghum flour + 20% Bambara groundnut flour);
C= (5% Malted sorghum flour + 75% Unmalted Sorghum flour + 20% Soybean flour);
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H= (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Bambara groundnut flour);
I= (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Soybean flour);
J= (5% Malted sorghum flour + 55% Unmalted Sorghum flour + 40% Defatted groundnut flour).

4. CONCLUSION

The study had shown that acceptable ready-to-eat breakfast cereals meals could be produced from the blends of sorghum, soybean, Bambara groundnut and defatted groundnut. Specifically, sample F (5% Malted sorghum flour + 65% Unmalted Sorghum flour + 30% Soybean flour) gave the most acceptable cereal meal followed by sample D (5% Malted sorghum flour + 75% Unmalted Sorghum flour + 20% Defatted groundnut flour). The comparative advantage of this formulated cereal meal is that the ingredients used (soybean, sorghum, Bambara groundnut and groundnut) are easily grown in the tropical areas with high yield and are locally available. The implication of this is that more foreign exchange can be conserved on the importation of wheat (major ingredient in the production of breakfast cereals) from foreign countries.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/66644