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PHYSICOCHEMICAL PROPERTIES AND CONSUMER ACCEPTABILITY OF BREAK FAST CEREAL MADE FROM SORGHUM (*Sorghum bicolor L*), SOYBEAN (*Glcyine max*), BAMBARA GROUNDNUT (*Vigna subterranean*) AND GROUND NUT (*Arachis hypogaea*)

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ABSTRACT

The changes in lifestyle and rapid urbanization in recent years have resulted in an increase in the consumption of ready-to-eat foods in most developing countries. The major objective of this research study is aimed at determining the physicochemical and consumer acceptability of breakfast cereals. Using standardized method, ten samples were formulated by mixing the flours in ratio of (Sorghum flour and 5% of malted sorghum flour) with graded levels of bambara nut flour (80:20, 70:30, 60:40); soybean flour (80:20, 70:30, 60:40) and defatted groundnut flour (80:20, 70:30, 60:40).The formulated flours were subjected to proximate, functional, sensory, vitamins, microbial analyses and consumer acceptability. The results revealed the following ranges: 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 parameters studied in this study were carried out using standard procedure. The data obtained from the study were analyzed using ANOVA while the means were separated by Duncan multiple range test. The sensory evaluation findings showed that good and acceptable breakfast cereals can be produced using blends of sorghum, soybean, bambara nut and defatted groundnut. The study provides the information about a commercially viable application of solving the problem of malnutrition among the population. The study had shown that acceptable ready-to-eat breakfast cereals meals could be produced from blends of Sorghum, Soybean, Bambara nut and defatted Groundnut and compare favorably with the commercial breakfast cereals as they have been shown to be good sources of protein, carbohydrates, fats and oil, vitamin of malted sorghum and sorghum flour. The microbial analysis of the formulated flour blends reveals that all the formulation indicated a safety of the products for consumption. The physicochemical, functional and microbial study shows that the breakfast cereals produced are safe for consumptions.

Keywords: physicochemical, break-fast cereal, defatted, malnutrition, and ready-to-eat

INTRODUCTION

Breakfast cereals are legally defined as any food obtained by swelling, roasting, grinding, rolling or flaking of any cereal. Breakfast cereals, though consumed dry in the early hours of the day, 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 (Pumlani, 2014). 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 (Nwosu, 2013)

In 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 (Ijarotimi and Keshinro, 2012) 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 in common (Anigo, Ameh, Ibrahim and Danbauchi, 2010). Availability of grains like soybean and maize may be limited by their uses as individual raw materials in many products as breakfast cereals. 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, that their uses may be deemed to have been over-diversified and therefore 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 interesting potentials to serve as good alternatives. Among such locally available alternatives are bambara nut and sorghum. Therefore, this study will attempt to investigate physicochemical properties and consumer acceptability of breakfast cereal made from sorghum, soybean, banbara groundnut and groundnut.

MATERIALS AND METHODS

Experimental Location

The experiments were carried out in the laboratory of Food Science and Technology, Modibbo Adama University of Technology, Yola, Adamawa State.

Research Materials

Grain samples

Sorghum, soybean, bambara nut and ground nut grains were purchased from Jimeta modern market. All samples were kept in a moisture free environment until when needed.

Chemicals and reagents

The chemicals and reagents used were of analytical grade and were obtained from the laboratory of Food Science and Technology, Modibbo Adama University of Technology, Yola Adamawa State.

Methods

Preparation of sorghum flour and malted sorghum flour

The sorghum flour sample was prepared as described by **Etok-Akpan and Palmer (1990)** 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.

Preparation of malted and unmalted samples

The sorghum cultivar was malted as described by Badau *et al.* (2006). The bambara nut flour samples was prepared as described by Nwosu (2013) with little modifications. The defatted groundnut flour sample was prepared as described by Juliana and Zhengxing (2008) also with little modifications while Soy flour was prepared according to the method described by Ndife *et al.* (2011).

Formulation of Breakfast Meal

The Breakfast meal was formulated using sorghum, soybean, bambara nut and defatted ground nut flours in the following ratios (Table 1). The flours were blended into fine powder using a Kenwood blender.

Table 1: The Percentage Ratio of the Breakfast Meal Formulation (%)

Sample Code	MSF+SF	BNF	SBF	GNF
A	100	-	-	-
B	80	20	-	-
C	80	-	20	-
D	80	-	-	20
E	70	30	-	-
F	70	-	30	-
G	70	-	-	30
H	60	40	-	-
I	60	-	40	-
J	60	-	-	40

KEY: MSF = 5% of malted sorghum flour, SF = Sorghum flour, BNF = Bambara nut flour, F = Soybean flour, GNF = Defatted groundnut flour, A= MSF & SF 100%, B= MSF & SF 80% + BNF 20%, C= MSF & SF 80% + SBF 20%, D= MSF & SF 80% + GNF 20%, E= MSF & SF 70% + BNF 30%, F= MSF & SF 70% + SBF 30%, G= MSF & SF 70% + GNF 30% , H= MSF & SF 60% + BNF 40% , I= MSF & SF 60% + SBF 40%, J= MSF & SF 60% + GNF 40%

Chemical Analyses

Proximate Composition

Proximate composition(moisture, crude protein, crude fat and ash)were determined following the methods described by **AOAC(1990)** The carbohydrate content in the samples were determined by difference (**AOAC, 2000**) Thus: %carbohydrates = 100 - (% Moisture + % Protein + %Fat + %Ash) The total energy was determined by the method described by Kanu *et al.* (2009). The total energy or the caloric values was estimated by calculation using the water quantification factors of 4, 9 and 4 Kcal/100g respectively for protein, fat and carbohydrate.

Functional Properties

Bulk density and water absorption capacity of flour samples were determined by the method described by Nwosu *et al.*(2011). The method of Onwuka (2005) was adopted in the determination of gelation capacity. The method modified by Okoli *et al.* (2010)was used in the determination of solubility. The gruel of the weaning formulation mix was prepared as described by Badau *et al.* (2006) for the determination of viscosity .To determine the swelling index,, the volume occupied by 1g sample was compared with the new volume after addition of 10ml distilled water and centrifugation(3000xg)for 10min) to remove excess water. Titratable acidity was determined by titrating a 10 g sample mixed with 90 ml of diluted water against 0.1N NaOH using phenolphthalein as indicator (AOAC, 1990).The pH and Titratable Acidity of the samples were determined following the method described by Sadler and Murphy (2010).

Determination of Vitamin B Group and Vitamin C

The vitamin B group was extracted and determined by the method described by AOAC (1990). Ascorbic acid was also determined according to the 2, 6 – dichlorophenol titermetric method of **AOAC (1990).**

Sensory Evaluation of Breakfast Cereal Flour

The developed breakfast flour bends was served to 10 untrained panel members who were asked to ranked the products on the basis of their quality attributes (appearance, taste, aroma and texture) using 9 points hedonic scale, where 1 = 'dislike extremely' and 9 = 'like extremely as described by (Ihekoronye and Ngoddy(1985) for consumer acceptability. Results obtained from the sensory evaluation were tested at 5% level of significance.

Microbial Analysis

The microbial analysis was carried out according to method described by Jideani and Jideani (2006).

Statistical Analysis

All the data reported in this study were carried out in triplicate. In each case, a mean value and standard error were calculated. The data were analyzed using SPSS version 20 statistical software package. Statistical parameters were estimated with analysis of means (ANOVA). Differences between means were evaluated by the Duncan multiple range test and significance was accepted at 0.05 ($p < 0.05$).

RESULTS AND DISCUSSION

Proximate Composition of Breakfast Cereals

Table 2 shows the results obtained for proximate composition (moisture, protein, fat, ash, fibre, carbohydrate and total energy) of breakfast foods prepared from the blends of Sorghum, Soybean, Bambara nut and defatted groundnut. The percentage moisture contents ranged from 6.46 to 10.46%.The highest value (10.46%)was obtained in the breakfast cereal sample containing 80% MSF+SF and 20% BNF while the lowest value (6.46%) was obtained in the breakfast cereal sample containing 60% MSF+SF and 40% defatted-GNF. This moisture content was probably due to the high 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 (Okafor and Usman, 2015). The low 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 difference ($p<0.05$) among the moisture content of all the samples, however within acceptable level recommended safe by FAO/WHO (<10%) as higher moisture may affect the storage quality of the foods(Msheliza *et al.*, 2018).

The crude protein which ranged from 10.26 to 19.64% was within the recommended minimum limit by FAO/WHO for weaning foods. The high protein content was observed in the samples with high level of defatted-GNF. This high level of protein in the products may be attributed to the presence of groundnut flour used in the formulations. Davis and Dean (2016) reported that protein of legumes such as peanut has higher contents than that of cereals proteins. Also, among the regularly consumed nuts (tree nuts and peanuts) worldwide, peanuts have the greatest protein content (Davis and Dean,2016)), which is commonly reported near 25.80%.The progressive solubilization and leaching out of the nitrogenous substances during processing of the samples may be responsible for the slight protein reduction in the samples other than these.. The generally high level of protein, however demonstrates the effect of supplementing legumes in breakfast cereals. It was also observed that as the soybean addition increased, the crude protein increased as well.

The percentage crude fat ranged from 4.06 to 11.42%. There were significant differences ($p<0.05$) between each one of the products. It was observed that the crude fat content of defatted-GNF and SBF products were relatively higher than BNF products. This could be attributed to the high content of oil in soybean and groundnut. Similar result was reported by Anigo *et al.* (2010) for nutrient composition of complementary food gruels formulated from malted cereals, soybeans and groundnut. Anigo *et al.* (2010) 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 nut flour in the formulations may be responsible for the generally low fat content of the resulting products, although most of the legumes, with the exception of groundnuts and soybeans contain higher than 3% fat except control sample which is 2.76% (Anigo, , Ameh, Ibrahim, and Danbauchi 2010). Highest fat values were recorded for breakfast cereals made from malted sorghum and soybean flour (12.35%) and breakfast cereals made from Sorghum and groundnut flour (8.23%).(Agunbiade and Ojezele, 2010)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, (2016) 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%. Similar values, 1.36% and 1.50 were recorded by other researchers. 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. Crude fibre of the samples were also significantly difference ($p>0.05$) from each other ranging from 1.94 to 3.72%.Similar values, 3.10 to 3.80% and 1.54 to 4.00% were previously recorded by Agunbiade and Ojezele, (2010) for other breakfast cereals formulation. Fiber 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 (Nwosu *et al.* 2011) Also, fibre reduces the incidence of colon cancer and eradicates some disease like obesity, diabetes, gall stone and coronary heart disease. 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 ranges from 56.09% to 72.06%, with sample A (100% MSF+SF) having the highest value and sample J (60% MSF+SF and 40% defatted-GNF) 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. Similar reports were reported by other workers for breakfast cereals formulated from malted sorghum flour and sorghum. The total energy content of the breakfast cereal samples ranges from 363.20 to 405.64 Kcal. It was observed that the samples with higher inclusions of defatted-GNF and

SBF had high energy value. Adedeji *et al.* (2015) reported that flours of high fat content supply high energy, however, food containing high fat is susceptible to both hydrolytic and oxidative/enzymatic rancidity which is responsible for off flavour and this affect both the general acceptability and storage stability of the products.

Functional Properties of Breakfast Cereals

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/ml with sample A (100% MSF+SF) having the lowest value while sample J (60% MSF+SF and 40% defatted-GNF) had the highest value. Hussein *et al.* (2016)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 (Srividya *et al.*, 2014). 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 increases.

The water absorption capacity (WAC) is important property in the development of ready to eat foods, and a high WAC may assure the flour product cohesiveness (Okafor and Usman 2015),a low WAC product assure easy digestibility of the flour (Bolarinwa *et al.*, 2015). The WAC of the breakfast samples ranges from 70.45 to 82.45 ml/g, with sample A (100% MSF+SF) having the highest value and sample J (60% MSF+SF and 40% defatted-GNF) having the lowest value. The WAC were significantly difference ($p<0.05$) from each other and decreases as the level of substitution with Bambara nut, soybean and ground nut flour increases 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 lipids 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 (60% MSF+SF and 40% defatted-GNF) showed highest swelling index (10.95) than other samples. Solubility index is related to the presence of soluble molecules in the flour. Water solubility index was also highest in sample J than other samples. The results of swelling index and solubility index in Table 3 is higher than the results obtained by Okafor and Usman (2015) which stated that sorghum flour had bulk density which falls within the range of 0.53g/ml-0.73g/ml.

The results of gelation capacity ranged between 5.87 to 10.25 ml/g. Pre-gelatinization and untreated sprouting increased the formulation and the strength of gel of the samples. The strength of the gel increased as the temperature of heating increased pregelatinization and sprouting. 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.* (2015) 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. The viscosity of the products ranged from 22.96 to 38.84 cp; with sample A (100% MSF+SF) having the lowest value and sample J (60% MSF+SF and 40% defatted-GNF) 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. Thus, increase in the viscosity was as a result of sprouting and pre-gelatinization. Also, the increase in the bulk density of other samples (from Sample B to Sample J) brought about the increase in the ability of the samples to form gel or become viscous. 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.* (2013).sprouting reduced the gel properties and the water holding capacity of gruels prepared from the flours although the reconstitubility of the flours improved. Pregelatinization also increased the bulk density of the flour blends as the viscosity increase. The increased bulk density and increase viscosity attributed to the use of the pregelatinized flours for the formulation of weaning foods according to (Ijarotimi and Keshinro, 2012).

Titratable acidity (TA) and pH are interrelated in terms of acidity, but have different impacts on food quality (Sadler and Murphy, 2010). 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 Owusu *et al.,* (2012), Sadler and Murphy (2010) 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 shows that they are neutral and safe for consumptions.

Vitamins Contents of 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, B1, B2, B3, 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(Pumlani 2014).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. 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(Pumlani 2014).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 B2 acts as a coenzyme 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 (Pumlani 2014).

Microbial Examination of 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 yeast growth (Sadler and Murphy2010). 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 (Abdulkadir and Danjuma, 2015).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. Nwokoro and Chukwu (2012) highlighted the importance of adequate hygiene during the preparation of food and also link between infection and nutrition.

Sensory Evaluation of Breakfast Cereals Flours

The results of sensory evaluation of the flours formulated for the production of breakfast cereals from 10 untrained panelists were graphically presented in Figure 2. The degree of difference among the flour samples was compared by Duncan's Multiple Range Test (DMRT) at 95% probability level. In terms of appearance, the scores ranged from 1.00 to 9.00 with sample H, 60% MSF+SF and 40% BNF having the lowest score while sample F, 70% MSF+SF and 30% SBF had the highest score thereby the most preferred by the panelists. The appearance of sample F was most preferred due to high addition of 5 % malt sorghum flour samples. This result agrees with Anigo *et al.*(2010) for gruel produced from malted sorghum,soya bean and groundnut. In term of aroma, the scores ranged from 1.80 to 9.00 with the sample C, 80% MSF+SF and 20% SBF having the lowest score while sample F, 70% MSF+SF and 30% SBF had the highest score thereby the most preferred by the panelists.The textural attributes of dried samples play a significant role in consumer appeal, buying decisions and eventual consumption (Hussein *et al.*, 2018). The scores of the texture ranges from 4.00 to 8.87 with sample I, 60% MSF+SF and 40% SBF having the lowest score while sample B, 80% MSF+SF and 20% BNF had the highest score thereby the most preferred by the panelists.

CONCLUSION

The study provides the information about a commercially viable application of solving the problem of malnutrition among the population. The study had shown that acceptable ready-to-eat breakfast cereals meals could be produced from blends of Sorghum, Soybean, Bambara nut and defatted Groundnut and compare favourably with the commercial breakfast cereals as they have been shown to be good sources of protein, carbohydrates, fats and oil and vitamin of malted and unmalted sorghum flour. The economic implication of this is that breakfast cereals of good quality could be produced at a reduced cost. Also, the breakfast producer can produce at high profit and more foreign exchange can be conserved on the importation of wheat (major ingredient in the production of breakfast cereals) from foreign countries, because soybean, sorghum, bambara nut and ground nut are easily grown in the tropical areas with high yield. Also, the flour blends have cheap source of nutrients could also play a key role in the acceptability and nutritional value of monotonous diets in the world at large.

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Table 2: Proximate Composition of the Breakfast Cereal Produced from Blends of Sorghum, Soybean, Bambara nut and defatted Groundnut

Sample	Moisture (%)	Crude Protein (%)	Crude Fat (%)	Ash (%)	Crude Fibre (%)	Carbohydrate (%)	Energy (Kcal)
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	10.46 ± 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}

Means in the same column bearing different superscripts are significantly different ($p<0.05$)

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

Sample	Bulk Density (g/ml)	WAC ml/g	Swelling Index	Gelation (g/ml)	Solubility	Viscosity (cP)	TA	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}

Means in the same column bearing different superscripts are significantly different ($p<0.05$)

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Table 4: Vitamin Contents of the Breakfast Cereal Produced from Blends of Sorghum, Soybean, Bambara nut and defatted Groundnut (mg/100g)

Sample	Vitamin C	Vitamin B1	Vitamin B2	Vitamin B3	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]

Means in the same column bearing different superscripts are significantly different ($p<0.05$)

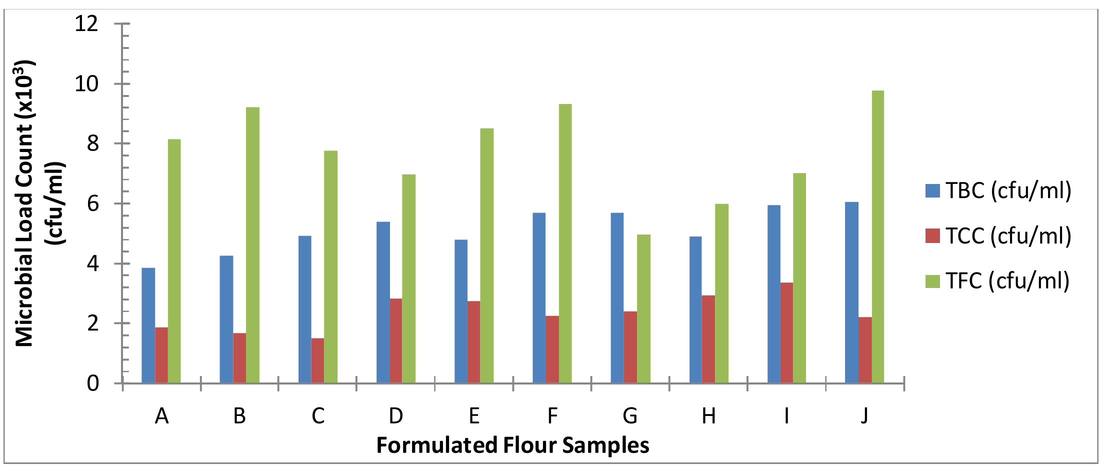

Figure 1: Microbiological Evaluation of Total Bacteria Count (TBC), Total Coliform Count (TCC), and Total Fungi Count (TFC)

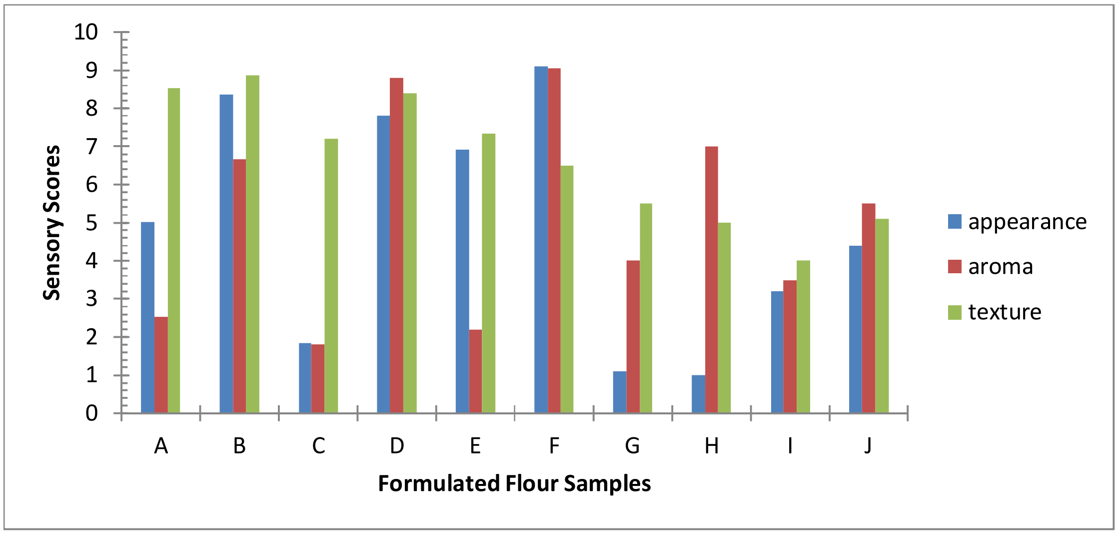

Figure 2: Sensory Evaluation of the Flours Formulated