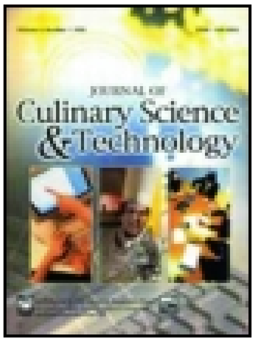

Journal of Culinary Science & Technology

ISSN: 1542-8052 (Print) 1542-8044 (Online) Journal homepage: http://www.tandfonline.com/loi/wcsc20

Effect of Co-Fermentation on Nutritional Composition, Anti-Nutritional Factors and Acceptability of Cookies from Fermented Sorghum (Sorghum bicolor) and Soybeans (Glycine max) Flour Blends

Samuel Ayofemi Olalekan Adeyeye, Abiodun Omowonuola Adebayo-Oyetoro, Olanrewanju Emmanuel Fayemi, Hussaina Kehinde Tiamiyu, Emmanuel Kehinde Oke & Ayodele Adebayo Soretire

JOURNAL OF CULINARY SCIENCE & TECHNOLOGY
https://doi.org/10.1080/15428052.2017.1404536

Effect of Co-Fermentation on Nutritional Composition, Anti-Nutritional Factors and Acceptability of Cookies from Fermented Sorghum *(Sorghum bicolor)* and Soybeans *(Glycine max)* Flour Blends

Samuel Ayofemi Olalekan Adeyeye[a], Abiodun Omowonuola Adebayo-Oyetoro[b], Olanrewanju Emmanuel Fayemi[c], Hussaina Kehinde Tiamiyu[d], Emmanuel Kehinde Oke[e], and Ayodele Adebayo Soretire[e]

[a]Department for Management of Science and Technology Development, Ton Duc Thang University, Ho Chi Minh City, Vietnam; [b]Department of Food Technology, Yaba College of Technology, Lagos, Nigeria; [c]Department of Biological Sciences, Mountain Top University, Prayer City, Nigeria; [d]College of Education, Home Economics, School of Vocational and Technology Education, College of Education, Azare, Nigeria; [e]Department of Food Science and Technology, Federal University of Agriculture, Abeokuta, Nigeria

ABSTRACT

This study evaluated the effect of co-fermentation on nutritional composition, anti-nutritional factors, and acceptability cookies from fermented sorghum *(Sorghum bicolor)* and soybean *(Glycine max)* flour blends. White sorghum and yellow soy-beans were soaked and fermented separately for 24 h, 48 h, and 72 h respectively at 27 ± 2°C with 0 h as control. Fermented sorghum and soy-beans were oven-dried at 60°C for 8 h, milled and sieved and then used for the production of cookies. Cookie samples produced from different flour blends were evaluated for nutritional (proximate and vitamins profile analyses), anti-nutritional (phytate, tannin and trypsin inhibitor activity) qualities, and sensory evaluation. Results showed that the moisture contents in percent of the cookies ranged from 9.65 ± 0.21–8.34 ± 0.16 for 0 h, 10.59 ± 0.22–10.21 ± 0.21 for 24 h, 10.46 ± 0.22–10.13 ± 0.21 for 48 h, and 10.28 ± 0.21–9.41 ± 0.19 for 72 h, respectively. The protein contents in % ranged from 10.98 ± 0.26–18.72 ± 0.32 for 0 h, 11.26 ± 0.26–20.42 ± 0.32 for 24 h, 12.01 ± 0.26–21.48 ± 0.32 for 48 h, and 12.41 ± 0.26–21.49 ± 0.32 for 72 h, respectively, while the fat contents in percent ranged from 9.73 ± 0.21–11.51 ± 0.24 for 0 h, 8.84 ± 0.16–11.42 ± 0.24 for 24 h, 8.69 ± 0.16–10.56 ± 0.22 for 48 h, and 8.31 ± 0.16–10.11 ± 0.22 for 72 h, respectively. In conclusion, fermentation of sorghum and soybeans through microbial activity led to the hydrolysis and the reduction of anti-nutritional factors, it also improves the nutritional composition of cookies from fermented sorghum and soybean flour blends, as there was an increase in protein and vitamin contents of cookies. Therefore, cookies from fermented sorghum and soybeans flour could be used as a remedy to solve the menace of protein-energy malnutrition in developing countries.

ARTICLE HISTORY
Received 22 August 2017
Revised 6 October 2017
Accepted 9 November 2017

KEYWORDS
Cookies; sorghum; soybeans; fermentation; nutritional and acceptability

CONTACT Samuel Ayofemi Olalekan Adeyeye saadeyeye@yahoo.com Mountain Top University, Department of Food Science & Technology, Yaba, Nigeria.

Introduction

Sorghum (Sorghum bicolour (L.) Moench) is an indigenous crop to Africa, with many cultivated forms now, (Adeyeye, 2016; Mutegi et al., 2010) is an important crop worldwide, used for food (as grain and in sorghum syrup or "sorghum molasses"), animal fodder, the production of alcoholic beverages, and biofuels. Most varieties are drought- and heat-tolerant, and are especially important in arid regions, where the grain is one of the staples for poor and rural people (Mutegi et al., 2010). These varieties form important components of pastures in many tropical regions. *S. bicolor* is an important food crop in Africa, Central America, and South Asia, and is the fifth-most important cereal crop grown in the world (Food and Agriculture Organization (FAO), 2012; Mutegi et al., 2010).

Sorghum is grown on about 5.6 million hectare in Nigeria and the current annual production is estimated to be only about 2.8 million tons (FAO, 2012). It has multifarious usages that span across the production of malt, beer, beer powder, sorghum meal, sorghum rice, and livestock feed, among others. The whole grain may be ground into flour, which is then used in various traditional foods (Mohammed et al., 2011).

Soybeans (*Glycine max* MERILL), first grown in Eastern Asia thousands of years ago, have long been important protein sources, complementing grain proteins in Asian countries (Yang, Va, Wong, Zhang, & Xiang, 2011). In addition to essential nutrients, soybean products, especially fermented soybean products, contain various functional components including peptides, isoflavonoids, and more (Yang et al., 2011). A number of epidemiological studies have suggested that consumption of soybeans and soy foods is associated with lowered risks for several cancers including breast, prostate, and colon, and cardiovascular diseases (Butler et al., 2010; Messina, 1999; Peterson & Barnes, 2010) and improves bone health (Yang et al., 2011). Furthermore, some studies have shown that a diet rich in soy can reduce breast cancer risk (Messina, 1999).

Global production of soybeans is forecast to be 324 million tons in 2016 (USDA, 2012), a 5% increase from the 2014 world total (FAOSTAT, 2015; USDA, 2012). The United States, Brazil, and Argentina are the world's largest soybean producers and represent more than 80% of global soybean production (FAOSTAT, 2015; USDA, 2012).

In 2014, the average worldwide yield for soybean crops was 2.6 tons per hectare (FAOSTAT, 2015). The three largest yields per hectare were in Thailand, Turkey, and Italy, having an average nationwide soybean yield of 4.9 tons. The most productive soybean farms in the world in 2014 were in Thailand, with a nationwide average farm yield of 6.2 tons per hectare (FAOSTAT, 2015).

Fermentation is one of the major processes used in the production of food from sorghum and soybeans. Obadina, Akinola, Shittu, and Bakare (2013) pointed out that the traditional fermentation of foods by microorganisms serves several functions such as enrichment of food substrate biologically with proteins, essential amino acids, essential fatty acids, and vitamins; this improves the digestibility and acceptability of foods, detoxification of toxic substances in foods, preservation of substantial amounts of food through production of anti-bacterial compounds such as lactic acid and acetic acid, a decrease in time and fuel requirement during cooking, and enrichment of the diet through the development of flavors, aroma, taste, palatability, and texture of such foods.

Cookies are nutritive snacks produced from unpalatable dough that is transformed into appetizing product through the application of heat in an oven (Anozie, China, & Beleya, 2014). They are ready-to-eat conveniences and inexpensive food products, containing digestive and dietary principles of vital importance (Olaoye, Onilude, & Idowu, 2006). Cookies contribute valuable quantities of iron, calcium, protein, calories, fiber, and some of the B-vitamins to our diet and daily food requirement. Biscuits are important baked products in the human diet, which are usually consumed with beverages and also used as a weaning foods for infants (Adeyeye, 2016; Onabanjo & Ighere, 2014). The major ingredients are flour, fat, sugar, salt, and water. These are mixed together with other minor ingredients (baking powder, skimmed milk, emulsifiers, and sodium meta-bisulphite) to form dough containing a gluten network (Adeyeye, 2016; Onabanjo & Ighere, 2014). Soft wheat flour has been the major ingredient used in the production of biscuits and other pastry products, but they can also be made with non-wheat flours such as sorghum, maize, pearl millet, plantain, acha grain, bambara-nuts, etc. One such locally available resource is soybeans (Adeyeye, Adebayo-Oyetoro, & Omoniyi, 2017).

The main objective of this study is to evaluate the effect of co-fermentation on nutritional composition, anti-nutritional factors, and acceptability cookies from fermented sorghum *(Sorghum bicolor)* and soybeans *(Glycine max)* flours.

Materials and methods

Sample collection

A bulk of healthy grains of sorghum *(Sorghum bicolor)* and seeds of soybean (*Glycine max*) used for this study was purchased from Bodija market in Ibadan, Oyo State. Other materials/ingredients such as sugar, fat, common salt, and sodium bicarbonate used in this study were also bought at Bodija market. All chemicals and reagents used were of food and analytical grade.

Fermentation of sorghum *(sorghum bicolor)* grains and soybean *(glycine max)* seeds

Sorghum (*Sorghum bicolor*) grains and soybean (*Glycine max*) seeds were fermented separately. Sorghum grains and soybean seeds were sorted manually and separately to remove stones and damaged and immature seeds. The clean sorghum grains and soybean seeds were soaked separately in different containers in tap water at room temperature (27 ±2°C) for 24 h, 48 h, and 72 h, respectively. The soaked water was drained from the sorghum grains and soybean seeds, and the grains and beans thereafter were blanched at 98°C in boiling distilled water for 2 min to deactivate the enzymes and oven-dried at 60°C for 8 h. Oven-dried fermented sorghum grains and soybean seeds were separately milled with disc attrition mill and sieved. Sorghum flour and soybean flour were sieved by using mesh size of 250 µm opening and stored in Ziploc bags before utilization.

Preparation of cookies

Cookies were prepared by the method reported by Olapade and Ogunade (2014) and Adeyeye and Akingbala (2016), with modification. Cookie dough were prepared from wheat flour (control) and composite flours combinations using flour (100%), sugar (38%), shortening (50%), salt (0.9%), and sodium bicarbonate (0.1%) for each recipe. Flour (500 g) from each sample of different flour blends was used for the experiment. Sugar (200 g) was creamed with margarine (250 g) until a light and fluffy constituency was obtained using Kenwood chef with initial minimum speed and the speed increased step wise until the mark of 6 on the chef indicator was attained. Whole egg (150 g) was added, followed by flour (500 g), powdered milk (50 g), baking powder (0.25 g), and salt (2.5 g), and mixed until a stiff paste (batter) was obtained. The batter was rolled on a floured board using rolling pin to a thickness of 0.2–0.3 cm. The rolled batter was cut into circular shapes with a cutter and arranged on a greased tray and baked at 150°C for 20 min. The cookies were brought out, cooled, and packaged in cellophane bag until used for laboratory analysis.

Chemical analysis

Proximate composition

Samples of fermented sorghum flour and soybean flour, their blends, and cookies from different flour blends were analyzed for the following parameters: fat, protein, moisture, crude fiber, and ash content, using the methods of the Association of Official Analytical Chemists (2000). The carbohydrate content was determined by difference between 100 and total sum of the percentage of moisture, protein, fat, and ash (AOAC, 2000).

Analysis of vitamin B_1 (thiamin)

Vitamin B_1 was analyzed in samples using the AOAC (2000) method. Accurately weighed 1.5 g of test sample was introduced into a 200 ml volumetric flask; 100ml of 0.1N HCL solution was added and the mixture heated in a water bath at 100°C for 30 min. After cooling, the content of the flask was made up to mark with 0.1M HCL solution and mixed thoroughly. The solution was filtered using Whatman No. 1 filter paper. The first 20 ml of the filtrate was discarded. The remaining filtrate (100 ml) was transferred into centrifuge tube containing 0.5 g frankonite powder (a flocculant which precipitate the particles faster during centrifugation) stirred for 10 min using RAM 2718 stirrer, then centrifuged at 5000 rpm for 5 min to separate layers. The supernatant liquid was discarded while 5ml of absolute alcohol and 5ml of the potassium ferric-cyanide solution in sodium hydroxide solution were added after it was previously frozen at 0°C. A pinkish coloration of mixture was observed after 10 min of mixing, and then 10 ml of toluene solution was added, stirred for 10 min and centrifuged for 10 min at 5000 rpm. A very clear pink color was transferred to the toluene layer. Thiamine standard (0.5mg) was prepared and 10ml of the thiamine standard solution was treated the same as the aforementioned sample. The standard and sample solution was read at 530 nm wavelength using the SP 30UV spectrophotometer (Pye Unican). The amount of thiamine present in each sample was calculated as thus:

$$\text{Thiamine}\,(\text{mg}/100\text{g}) = \frac{\text{Absorbance of sample}}{\text{Absorbance of Standard}} \times \frac{\text{Weight of Standard(mg)}}{\text{Weight of sample(g)}} \times 100$$

Analysis of vitamin B_2 (riboflavin)

Vitamin B_2 was analyzed in samples using the AOAC (2000) method. Accurately weighed 1.5 g of sample was introduced into 200 ml volumetric flask; 100 ml of acetic acid: water mixture (50:50) was added and heated on a boiling water bath at 100°C for 30 min. The mixture in the flask was cooled to 20°C, then made up to the mark with acetic acid–water solution. The mixture was stirred for 10 min using the stirrer and then filtered in the dark. The first 20 ml of the filtrate was discarded, 0.5 mg of riboflavin standard solution was prepared, and 10 ml of the standard solution was transferred into 200 ml volumetric flask and treated similarly as the aforementioned sample. The fluorescence of the standard and sample solutions was read using spectrophotometer at 460 nm wavelength. The amount of riboflavin in each sample was calculated as follows

$$\text{Riboflavin}(\text{mg}/100\text{g}) = \frac{sample\ Absorbance}{Standard\ Absorbance} \times \frac{Weight\ of\ Std\ (mg)}{Weight\ of\ sample} \times 100$$

Analysis of vitamin B_3 (niacin)

Vitamin B_3 was analyzed in samples using the AOAC (2000) method. Sample (1.5 g) was accurately weighed into 200 ml volumetric flask. Hydrochloric acid solution (5N; 5 ml) was added, and 5.0 ml of dichloromethane and 90 ml of deionized water were added to the mixture, stirred, and heated on a boiling water bath at 100°C for 30 min. It was then cooled and the flask content made up to the mark with distilled water, filtered using Whatman No. 1 filter paper discarding the first 20 ml of the filtrate. The niacin standard solution of 0.5 mg was prepared, and 10 ml of the stock solution was taken and treated same as the aforementioned sample. The absorbance of the standard and sample solutions were taken at 410 nm wavelength using spectrophotometer and calculation followed thus:

$$\text{Niacin}(\text{mg}/100\text{g}) = \frac{Sample\ reading}{standard\ reading} \times \frac{standard\ weight\ (mg)}{sample\ weight} \times 100$$

Anti-nutritional factors analysis

Determination of tannin

One gram of each sample was weighed into a beaker. Each was soaked with solvent mixture (80 ml of acetone and 20 ml of glacial acetic acid) for 5 h to extract tannin. The samples were filtered through a double layer filter paper to obtain the filtrates which were stored for further use. A standard solution of tannic acid was prepared ranging from 10 ppm to 30 ppm. The absorbances of the standard solution as well as that of the filtrates were read at 500 nm on a Spectronic 20, England spectrophotometer (AOAC, 1990).

Determination of phytates

Two grams of each sample was weighed into a 250 ml conical flask. One-hundred ml of 2% hydrochloric acid was used to soak each sample in a conical flask for 3 h. This was filtered through a double layer of hardened filter paper Whatman No. 3. 50 ml of each filtrate was placed in 250 ml beaker and 107 ml of distilled water was added in each case. Ten ml of 0.3% ammonium thiocyanate solution was added into each solution as indicator. This was titrated with standard iron (III) chloride solution, which contained 0.00l95 g iron per ml. The end point is slightly brownish yellow, which persisted for 5 m. The percentage phytates was calculated using the formula:

$$\%\ \text{Phytates} = \frac{\text{Xx1.19x100}}{0.00195}$$

Where X = Titre value (AOAC, 1990).

Determination of trypsin inhibitors

Two batches each of the samples (0.2 g each) were weighed into a screw-capped centrifuge tube. Ten ml of 0.1M phosphate buffer was added and shaken vigorously. The contents were left at 25°C for 1 h on a UDY 60 shaker, England. The suspension obtained was centrifuged at 5,000 rpm for 5 min and filtered through Whatman No. 42 filter paper. The volume of each was adjusted to 2 ml with phosphate buffer. The test tubes were placed in a water bath, maintained at 37°C. Six ml of 5% trichloroacetic acid (TCA) solution was added to one of the tubes to serve as a blank. Two ml of casein solution was added to all the tubes, which was previously kept at 37°C. These were incubated for 20 min. The reaction was stopped after 20 min by adding 6 ml of TCA solution to the experimental tubes and shaken. The reaction was left for 1 h at room temperature, after which it was filtered through Whatman No. 42 filter paper. Absorbance of filtrate from sample and trypsin standard solutions was read at 380 nm on a Spectronic 20, England spectrophotometer. The trypsin inhibitor in mg/g sample was calculated using the formula:

$$\text{Trypsin}(\text{mg/g}) = \frac{\text{A STD} - \text{A sample} \times \text{Dilution factor} \times 1,000}{19 \times \text{sample wt in g}}$$

(AOAC, 1990)

Determination of protease inhibitor

Egg albumin 2% solution and 0.1% solution of bromelain, both in pH 7 phosphate buffer, were prepared. 5 ml of the egg albumin substrate and 1ml of the bromelain enzyme was incubated at 55°C for 10 min. Five ml 10% TCA was added to stop the reaction. The precipitate was filtered off with Whatman No. 1 filter paper, and the absorbance of the filtrate was measured at 280 nm on the Atomic Absorption Spectrophotometer (AAS) labelled (Ai). The entire procedure was repeated but incubating with the enzyme and substrate mixture, i.e., 1 ml of the extract of the material for protease inhibitor determination labelled (As). The absorbance of the filtrate was measured at 280 nm. This was denoted Ai.

$$\%\ \text{Protease Inhibitor} = \frac{\text{As} - \text{Ai}\,\text{x}\,100}{\text{As}}$$

Where As = Absorbance of sample
Ai = Absorbance of blank/initial (Cuatrecasas and Anfisen, 1991)

Sensory evaluation

Cookie samples prepared from fermented sorghum and soybean flour with various level of substitution were compared to cookies from 0 h fermentation sample (R), and 2 = extremely inferior to R. Two different groups of 100 member (50 men and 50 women), consumer-type, untrained sensory panelists were selected (Hough et al., 2006). Each panelist was provided with separate sensory booth. Water was provided to rinse the palate between two tasting sessions. Also, quality attributes: color, texture, taste, and overall acceptability were evaluated on a nine-point Hedonic scale where 9 = Like extremely and 1 = Dislike extremely.

Statistical analysis

Five treatments were studied, and each treatment consists of 50 samples. Each sample was analyzed in triplicates. Mean values of triplicate determinations were reported with their standard deviations. Data obtained were subjected to analysis of variance (ANOVA) at $\alpha = 0.05$ level of significance with the use of the Statistical Package for Social Sciences (SPSS) version 16.0. Significant means ($p < 0.05$) were separated using Duncan multiple range test.

Results and discussion

Proximate composition

Table 1 shows the formulation of fermented sorghum and soybean flour blends used for the production of cookies for this study. There are six different combinations of flour blends with C_0 = 100% of sorghum flour and 0% of soybean flour, C_1 = 95% of sorghum flour and 5% of soybean flour, C_2 = 90% of sorghum flour and 10% of soybean flour, C_3 = 85% of sorghum flour and 15% of soybean flour, C_4 = 80% of sorghum flour and 20% of soybean flour, and C_0 = 75% of sorghum flour and 25% of soybean flour respectively.

Table 2 shows the recipe for the production of cookies from fermented sorghum and soybean flour blends. Apart from the flour formulations, the amounts of other ingredients used for the production of cookies for all categories of flour formulations were fixed and remained constant at sugar 40 g, fat 50 g, baking powder 0.05 g, milk powder 10 g, salt 0.5 g, and egg 30 g.

Table 1. Formulation of fermented sorghum and soybean flour blends.

Sample Code	Sorghum flour (%)	Soybean flour (%)
C_0	100	0
C_1	95	5
C_2	90	10
C_3	85	15
C_4	80	20
C_5	75	25

Table 2. Recipe for cookie production from fermented sorghum and soybean flour blends.

Sample Code	Sorghum flour (%)	Soybean flour (%)	Sugar (g)	Fat (g)	Baking powder (g)	Milk (g)	Salt (g)	Egg (g)
C_0	100	0	40	50	0.05	10	0.5	30
C_1	95	5	40	50	0.05	10	0.5	30
C_2	90	10	40	50	0.05	10	0.5	30
C_3	85	15	40	50	0.05	10	0.5	30
C_4	80	20	40	50	0.05	10	0.5	30
C_5	75	25	40	50	0.05	10	0.5	30

The results of nutritional composition of cookies from different ratios of fermented sorghum and soybean flour blends are presented in Table 3. The moisture contents in ranged from 9.65 ± 0.21–8.34 ± 0.16 for 0 h, 10.59 ± 0.22–10.21 ± 0.21 for 24 h, 10.46 ± 0.22–10.13 ± 0.21 for 48 h, and 10.28 ± 0.21–9.41 ± 0.19 for 72 h, respectively. The protein contents in percent ranged from 10.98 ± 0.26–18.72 ± 0.32 for 0 h, 11.26 ± 0.26–20.42 ± 0.32 for 24 h, 12.01 ± 0.26–21.48 ± 0.32 for 48 h, and 12.41 ± 0.26–21.49 ± 0.32 for 72 h, respectively, while the fat contents in percent ranged from 9.73 ± 0.21–11.51 ± 0.24 for 0 h, 8.84 ± 0.16–11.42 ± 0.24 for 24 h, 8.69 ± 0.16–10.56 ± 0.22 for 48 h, and 8.31 ± 0.16–10.11 ± 0.22 for 72 h, respectively. It was observed that there was a decrease in moisture contents of the cookies as the quantities of soybean flour increased in the samples of unfermented flour blends. This trend also continued in cookies from fermented flour blends while an increase was observed in protein and fat contents of the cookies from unfermented flour blends and fermented sorghum and soybeans flour blends. Several researchers (Adeyeye et al., 2017; Adeyeye, 2016; Adeyeye & Akingbala, 2016; Obadina et al., 2013; Adeleke and Oladeji, 2010; Akpapunam & Darbe, 1999) had reported similar results. Decrease in moisture content was also reported by (Adeyeye & Akingbala, 2016; Adeleke & Odedeji, 2010; Akpapunam & Darbe, 1999) in cookies from composite flour as this might affect the water retention capacity of the flour blends. Obadina et al. (2013) reported improvement in protein content of fermented soy-nono, which was attributed to some anabolic processes leading to polymer build-up or due to microbial cell proliferation.

The crude fiber contents in % ranged from 2.41 ± 0.01–3.34 ± 0.01 for 0 h, 2.33 ± 0.01–3.18 ± 0.01 for 24 h, 2.14 ± 0.01–2.98 ± 0.01 for 48 h, and 2.06 ± 0.01–2.73 ± 0.01 for 72 h, respectively, while the ash contents ranged from 3.26 ± 0.01–3.81 ± 0.01 for 0 h, 3.07 ± 0.01–3.60 ± 0.01 for 24 h, 2.76 ± 0.01–3.20 ± 0.01 for 48 h, and 2.41 ± 0.01–2.93 ± 0.01 for 72 h, respectively. Fermentation of sorghum and soybeans from 24 h to 72 h reduced the crude fiber and ash contents of the cookies as the period of fermentation increases. This may be due to biodegradation of crude fiber by microorganisms involved in the fermentation process. This report is similar to that of Obadina et al. (2013) for fermented soy-nono. The thiamine contents in mg/100g ranged from 0.38 ± 0.01–0.73 ± 0.01 for 0 h, 0.46 ±

Table 3. Nutritional profile of cookies from different blends of fermented sorghum and soybean flour.

Time (h)	Ratios of SF:SBF	Moisture (%)	Protein (%)	Fat (%)	Crude Fiber (%)	Ash (%)	Thiamin (mg)	Niacin (mg)	Riboflavin (mg)
0 h	SF (100%)	9.65 ± 0.21^{d}	10.98 ± 0.26^{e}	9.73 ± 0.21^{d}	2.41 ± 0.01^{b}	3.26 ± 0.01^{c}	0.38 ± 0.01^{a}	3.02 ± 0.01^{c}	0.14 ± 0.01^{a}
	95:5	8.95 ± 0.18^{d}	11.00 ± 0.26^{e}	9.94 ± 0.21^{d}	2.63 ± 0.01^{b}	3.30 ± 0.01^{c}	0.47 ± 0.01^{a}	3.36 ± 0.01^{c}	0.21 ± 0.01^{a}
	90:10	8.68 ± 0.16^{d}	14.31 ± 0.28^{f}	10.16 ± 0.22^{d}	2.85 ± 0.01^{b}	3.38 ± 0.01^{c}	0.54 ± 0.01^{a}	3.61 ± 0.01^{c}	0.33 ± 0.01^{a}
	85:15	8.43 ± 0.16^{d}	15.86 ± 0.28^{f}	10.98 ± 0.22^{d}	2.91 ± 0.01^{b}	3.44 ± 0.01^{c}	0.66 ± 0.01^{a}	3.78 ± 0.01^{c}	0.41 ± 0.01^{a}
	80:20	8.41 ± 0.16^{d}	17.34 ± 0.30^{f}	11.30 ± 0.24^{d}	3.16 ± 0.01^{b}	3.63 ± 0.01^{c}	0.68 ± 0.01^{a}	3.90 ± 0.01^{c}	0.60 ± 0.01^{a}
	75:25	8.34 ± 0.16^{d}	18.72 ± 0.31^{f}	11.51 ± 0.24^{d}	3.34 ± 0.01^{b}	3.81 ± 0.01^{c}	0.73 ± 0.01^{a}	4.06 ± 0.01^{c}	0.83 ± 0.01^{a}
24 h	SF (100%)	10.59 ± 0.22^{d}	11.26 ± 0.26^{e}	8.84 ± 0.16^{d}	2.33 ± 0.01^{b}	3.07 ± 0.01^{c}	0.46 ± 0.01^{a}	3.81 ± 0.01^{c}	0.29 ± 0.01^{a}
	95:5	10.48 ± 0.22^{d}	12.08 ± 0.28^{e}	9.63 ± 0.21^{d}	2.48 ± 0.01^{b}	3.12 ± 0.01^{c}	0.68 ± 0.01^{a}	3.94 ± 0.01^{c}	0.36 ± 0.01^{a}
	90:10	10.43 ± 0.22^{d}	14.00 ± 0.28^{f}	9.88 ± 0.021^{d}	2.62 ± 0.01^{b}	3.29 ± 0.01^{c}	0.71 ± 0.01^{a}	4.17 ± 0.01^{c}	0.51 ± 0.01^{a}
	85:15	10.37 ± 0.21^{d}	16.33 ± 0.29^{f}	10.21 ± 0.22^{d}	2.80 ± 0.01^{b}	3.41 ± 0.01^{c}	0.83 ± 0.01^{a}	4.32 ± 0.01^{c}	0.64 ± 0.01^{a}
	80:20	10.30 ± 0.21^{d}	18.16 ± 0.31^{f}	10.67 ± 0.22^{d}	2.97 ± 0.01^{b}	3.53 ± 0.01^{c}	0.92 ± 0.01^{a}	4.51 ± 0.01^{c}	0.86 ± 0.01^{a}
	75:25	10.21 ± 0.21^{d}	20.42 ± 0.32^{f}	11.42 ± 0.24^{d}	3.18 ± 0.01^{b}	3.60 ± 0.01^{c}	0.98 ± 0.01^{a}	4.83 ± 0.01^{c}	0.99 ± 0.01^{a}
48 h	SF (100%)	10.46 ± 0.22^{d}	12.01 ± 0.26^{e}	8.69 ± 0.16^{d}	2.14 ± 0.01^{b}	2.76 ± 0.01^{c}	0.69 ± 0.01^{a}	4.22 ± 0.01^{c}	0.38 ± 0.01^{a}
	95:5	10.39 ± 0.22^{d}	14.24 ± 0.28^{f}	8.92 ± 0.16^{d}	2.26 ± 0.01^{b}	2.81 ± 0.01^{c}	0.72 ± 0.01^{a}	4.51 ± 0.01^{c}	0.49 ± 0.01^{a}
	90:10	10.31 ± 0.22^{d}	15.09 ± 0.28^{f}	9.33 ± 0.21^{d}	2.43 ± 0.01^{b}	2.98 ± 0.01^{c}	0.81 ± 0.01^{a}	4.74 ± 0.01^{c}	0.63 ± 0.01^{a}
	85:15	10.24 ± 0.21^{d}	18.33 ± 0.31^{f}	9.71 ± 0.21^{d}	2.58 ± 0.01^{b}	3.07 ± 0.01^{b}	0.90 ± 0.01^{a}	4.89 ± 0.01^{c}	0.88 ± 0.01^{a}
	80:20	10.20 ± 0.21^{d}	20.52 ± 0.32^{f}	10.12 ± 0.22^{d}	2.71 ± 0.01^{b}	3.11 ± 0.01^{c}	0.98 ± 0.01^{a}	5.03 ± 0.01^{c}	0.98 ± 0.01^{a}
	75:25	10.13 ± 0.21^{d}	21.48 ± 0.32^{f}	10.56 ± 0.22^{d}	2.98 ± 0.01^{b}	3.20 ± 0.01^{c}	1.12 ± 0.01^{a}	5.11 ± 0.01^{c}	1.24 ± 0.01^{a}
72 h	SF (100%)	10.28 ± 0.21^{d}	12.41 ± 0.26^{e}	8.31 ± 0.16^{d}	2.06 ± 0.01^{b}	2.41 ± 0.01^{c}	0.82 ± 0.01^{a}	4.52 ± 0.01^{c}	0.48 ± 0.01^{a}
	95:5	10.11 ± 0.21^{d}	14.23 ± 0.28^{f}	8.66 ± 0.16^{d}	2.15 ± 0.01^{b}	2.49 ± 0.01^{c}	0.89 ± 0.01^{a}	4.86 ± 0.01^{c}	0.61 ± 0.01^{a}
	90:10	9.96 ± 0.21^{d}	16.11 ± 0.29^{f}	8.93 ± 0.16^{d}	2.32 ± 0.01^{b}	2.64 ± 0.01^{c}	0.94 ± 0.01^{a}	4.98 ± 0.01^{c}	0.82 ± 0.01^{a}
	85:15	9.89 ± 0.21^{d}	18.06 ± 0.31^{f}	9.47 ± 0.21^{d}	2.49 ± 0.01^{b}	2.71 ± 0.01^{c}	1.06 ± 0.01^{a}	5.12 ± 0.01^{c}	0.96 ± 0.01^{a}
	80:20	9.68 ± 0.21^{d}	20.53 ± 0.32^{f}	9.86 ± 0.21^{d}	2.61 ± 0.01^{b}	2.86 ± 0.01^{c}	1.33 ± 0.01^{a}	5.36 ± 0.01^{c}	1.11 ± 0.01^{a}
	75:25	9.41 ± 0.19^{d}	21.49 ± 0.32^{f}	10.11 ± 0.22^{d}	2.73 ± 0.01^{b}	2.93 ± 0.01^{c}	1.57 ± 0.01^{a}	5.61 ± 0.01^{c}	1.36 ± 0.01^{a}

Values are mean ± standard deviation of triplicate determinations. Means on the same row with different sets of superscripts are statistically different ($p \leq 0.05$).
Note: SF = Fermented sorghum flour. SBF = Fermented soybean flour

Table 4. Anti-nutritional and mineral of cookies from different blends of fermented sorghum and soybean flour.

Time (h)	Ratios of SF:SBF	Tannin (mg/100 g)	Phytates (mg/100 g)	Trypsin inhibitors (mg/100 g)	Protease inhibitors (mg/100 g)
0 h	SF (100%)	186.92 ± 0.30^{i}	210.18 ± 0.32^{j}	74.63 ± 0.20^{d}	72.46 ± 0.20^{d}
	95:5	180.37 ± 0.30^{i}	203.48 ± 0.32^{j}	76.39 ± 0.20^{d}	75.11 ± 0.20^{d}
	90:10	176.66 ± 0.30^{i}	194.91 ± 0.31^{j}	77.93 ± 0.20^{d}	76.68 ± 0.20^{d}
	85:15	171.82 ± 0.30^{i}	189.82 ± 0.30^{i}	79.64 ± 0.20^{d}	78.39 ± 0.20^{d}
	80:20	168.99 ± 0.30^{h}	183.47 ± 0.30^{i}	84.37 ± 0.21^{d}	82.68 ± 0.21^{d}
	75:25	165.81 ± 0.30^{h}	188.62 ± 0.30^{i}	88.53 ± 0.21^{d}	86.22 ± 0.21^{d}
24 h	SF (100%)	172.59 ± 0.30^{i}	193.28 ± 0.31^{j}	61.82 ± 0.19^{c}	62.03 ± 0.19^{c}
	95:5	158.31 ± 0.29^{h}	174.11 ± 0.30^{i}	64.46 ± 0.19^{c}	65.48 ± 0.19^{c}
	90:10	151.43 ± 0.28^{h}	166.73 ± 0.30^{h}	67.38 ± 0.19^{c}	68.41 ± 0.19^{c}
	85:15	142.60 ± 0.27^{g}	158.92 ± 0.29^{h}	72.86 ± 0.20^{d}	73.22 ± 0.20^{b}
	80:20	135.84 ± 0.26^{g}	149.11 ± 0.27^{g}	76.33 ± 0.20^{d}	77.58 ± 0.20^{b}
	75:25	122.47 ± 0.25^{f}	138.69 ± 0.26^{g}	79.32 ± 0.20^{d}	79.96 ± 0.20^{b}
48 h	SF (100%)	138.68 ± 0.26^{g}	158.61 ± 0.29^{h}	43.52 ± 0.17^{b}	40.24 ± 0.17^{b}
	95:5	133.19 ± 0.26^{g}	137.56 ± 0.26^{g}	46.24 ± 0.17^{b}	42.06 ± 0.17^{b}
	90:10	126.48 ± 0.25^{f}	130.24 ± 0.26^{g}	49.11 ± 0.17^{b}	46.83 ± 0.17^{b}
	85:15	117.69 ± 0.24^{f}	122.71 ± 0.25^{f}	51.92 ± 0.18^{c}	49.42 ± 0.17^{b}
	80:20	104.82 ± 0.23^{e}	109.94 ± 0.32^{e}	57.36 ± 0.18^{c}	55.69 ± 0.18^{c}
	75:25	89.11 ± 0.21^{d}	94.26 ± 0.22^{e}	62.22 ± 0.19^{c}	60.48 ± 0.19^{c}
72 h	SF (100%)	114.61 ± 0.24^{f}	124.36 ± 0.25^{f}	18.65 ± 0.14^{a}	15.97 ± 0.14^{a}
	95:5	98.52 ± 0.22^{e}	119.08 ± 0.24^{f}	21.18 ± 0.15^{a}	18.63 ± 0.14^{a}
	90:10	91.84 ± 0.22^{e}	106.58 ± 0.23^{f}	22.96 ± 0.15^{a}	20.13 ± 0.15^{a}
	85:15	86.21 ± 0.21^{d}	90.31 ± 0.22^{e}	26.30 ± 0.15^{a}	24.71 ± 0.15^{a}
	80:20	78.68 ± 0.20^{d}	81.79 ± 0.21^{d}	29.11 ± 0.15^{a}	25.99 ± 0.15^{a}
	75:25	51.26 ± 0.18^{c}	58.33 ± 0.18^{c}	31.82 ± 0.16^{a}	28.56 ± 0.15^{a}

Values are mean ± standard deviation of triplicate determinations. Means on the same row with different sets of superscripts are statistically different ($p \leq 0.05$).
Note: SF = Fermented sorghum flour. SBF = Fermented soybean flour

0.01–0.98 ± 0.01 for 24 h, 0.69 ± 0.01–1.12 ± 0.01 for 48 h, and 0.82 ± 0.01–1.57 ± 0.01 for 72 h, respectively, while the niacin contents ranged from 3.02 ± 0.01–4.06 ± 0.01 for 0 h, 3.81 ± 0.01–4.83 ± 0.01 for 24 h, 4.33 ± 0.01–5.11 ± 0.01 for 48 h, and 4.52 ± 0.01–5.61 ± 0.01 for 72 h, respectively. The riboflavin contents ranged from 0.14 ± 0.01–0.83 ± 0.01 for 0 h, 0.29 ± 0.01–0.99 ± 0.01 for 24 h, 0.38 ± 0.01–1.24 ± 0.01 for 48 h, and 0.48 ± 0.01–1.36 ± 0.01 for 72 h, respectively. Fermentation of sorghum and soybeans from 24 h to 72 h also increased the thiamine, niacin, and riboflavin contents of the cookies, as fermentation had been found to help in the production of vitamin B-complex. Most of the B vitamins have been recognized as coenzymes (substances that participate with enzymes in accelerating the interconversion of chemical compounds), and they all appear to be essential in facilitating the metabolic processes of all forms of animal life. The increase in values of vitamin B such as thiamine, riboflavin, and niacin in the cookies from fermented sorghum and soybean flour blends could be as a result of biological and enzymatic activities during soaking and fermentation processes. This agreed with the works of (Adeyemi and Onilude, 2013; Obadina et al., 2013).

Table 5 shows the composition of anti-nutrients in cookies from fermented sorghum and soybean flour. Legumes and some cereals contain some

Table 5. Sensory properties of cookies from different blends of fermented sorghum and soybean flour.

Time (h)	Ratios of SF:SBF	Crispiness	Flavor	Texture	Taste	Color	Appearance	Overall Acceptability
0 h	SF (100%)	6.6 ± 0.02^{b}	7.2 ± 0.03^{c}	7.7 ± 0.03^{c}	6.6 ± 0.02^{b}	6.9 ± 0.02^{b}	7.8 ± 0.03^{c}	7.7 ± 0.03^{c}
	95:5	6.2 ± 0.02^{b}	6.7 ± 0.02^{b}	7.4 ± 0.03^{c}	6.3 ± 0.02^{b}	6.6 ± 0.02^{b}	7.4 ± 0.03^{c}	7.3 ± 0.03^{c}
	90:10	6.0 ± 0.02^{b}	6.3 ± 0.02^{b}	6.8 ± 0.02^{b}	5.8 ± 0.02^{b}	6.4 ± 0.02^{b}	7.5 ± 0.03^{c}	6.6 ± 0.02^{b}
	85:15	5.7 ± 0.02^{b}	6.0 ± 0.02^{b}	6.5 ± 0.02^{b}	5.7 ± 0.02^{b}	6.4 ± 0.02^{b}	8.6 ± 0.03^{c}	6.2 ± 0.02^{b}
	80:20	5.4 ± 0.02^{b}	5.9 ± 0.02^{b}	6.3 ± 0.02^{b}	5.5 ± 0.02^{b}	7.6 ± 0.03^{c}	8.6 ± 0.03^{c}	5.9 ± 0.02^{b}
	75:25	4.9 ± 0.01^{a}	5.7 ± 0.02^{b}	5.5 ± 0.02^{b}	5.3 ± 0.02^{b}	7.8 ± 0.03^{c}	8.7 ± 0.03^{c}	5.6 ± 0.02^{b}
24 h	SF (100%)	6.5 ± 0.02^{b}	8.2 ± 0.03^{c}	6.8 ± 0.02^{b}	6.3 ± 0.02^{b}	5.8 ± 0.02^{b}	7.6 ± 0.03^{c}	7.1 ± 0.03^{c}
	95:5	5.8 ± 0.02^{b}	8.0 ± 0.03^{c}	6.6 ± 0.02^{b}	5.8 ± 0.02^{b}	5.5 ± 0.02^{b}	7.2 ± 0.03^{c}	6.9 ± 0.02^{b}
	90:10	5.5 ± 0.02^{b}	7.6 ± 0.03^{c}	5.8 ± 0.02^{b}	5.6 ± 0.02^{b}	5.2 ± 0.02^{b}	6.8 ± 0.02^{b}	6.7 ± 0.02^{b}
	85:15	5.3 ± 0.02^{b}	7.3 ± 0.03^{c}	5.2 ± 0.02^{b}	5.3 ± 0.02^{b}	4.9 ± 0.01^{a}	6.3 ± 0.02^{b}	6.3 ± 0.02^{b}
	80:20	4.8 ± 0.01^{a}	6.6 ± 0.02^{b}	4.7 ± 0.01^{a}	5.0 ± 0.02^{b}	4.5 ± 0.01^{a}	5.9 ± 0.02^{b}	5.5 ± 0.02^{b}
	75:25	4.2 ± 0.01^{a}	6.4 ± 0.02^{b}	4.4 ± 0.01^{a}	4.5 ± 0.01^{a}	4.3 ± 0.01^{a}	5.6 ± 0.02^{b}	6.8 ± 0.02^{b}
48 h	SF (100%)	5.6 ± 0.02^{b}	7.5 ± 0.03^{c}	7.1 ± 0.03^{c}	6.1 ± 0.02^{b}	5.7 ± 0.02^{b}	7.9 ± 0.03^{c}	6.2 ± 0.02^{b}
	95:5	5.3 ± 0.02^{b}	7.2 ± 0.03^{c}	6.9 ± 0.02^{b}	5.6 ± 0.02^{b}	4.8 ± 0.01^{a}	7.7 ± 0.03^{c}	5.9 ± 0.02^{b}
	90:10	4.7 ± 0.01^{a}	6.9 ± 0.02^{b}	6.3 ± 0.02^{b}	5.3 ± 0.02^{b}	4.7 ± 0.01^{a}	7.3 ± 0.03^{c}	5.7 ± 0.02^{b}
	85:15	4.4 ± 0.01^{a}	6.3 ± 0.02^{b}	5.7 ± 0.02^{b}	5.1 ± 0.02^{b}	4.4 ± 0.01^{a}	6.9 ± 0.02^{b}	5.6 ± 0.02^{b}
	80:20	4.2 ± 0.01^{a}	5.5 ± 0.02^{b}	5.2 ± 0.02^{b}	4.7 ± 0.01^{a}	4.1 ± 0.01^{a}	6.6 ± 0.02^{b}	5.5 ± 0.02^{b}
	75:25	3.8 ± 0.01^{a}	5.4 ± 0.02^{b}	4.6 ± 0.01^{a}	4.4 ± 0.01^{a}	3.2 ± 0.01^{a}	5.2 ± 0.02^{b}	5.3 ± 0.02^{b}
72 h	SF (100%)	5.2 ± 0.02^{b}	6.4 ± 0.02^{b}	5.6 ± 0.02^{b}	5.6 ± 0.02^{b}	5.4 ± 0.02^{b}	7.8 ± 0.03^{b}	5.0 ± 0.02^{b}
	95:5	4.9 ± 0.01^{a}	6.2 ± 0.02^{b}	5.3 ± 0.02^{b}	5.1 ± 0.02^{b}	4.9 ± 0.01^{a}	6.9 ± 0.02^{b}	4.8 ± 0.01^{a}
	90:10	4.6 ± 0.01^{a}	5.9 ± 0.02^{b}	4.9 ± 0.01^{a}	4.8 ± 0.01^{a}	4.6 ± 0.01^{a}	6.4 ± 0.02^{b}	4.5 ± 0.01^{a}
	85:15	4.3 ± 0.01^{a}	5.6 ± 0.02^{b}	4.7 ± 0.01^{a}	4.4 ± 0.01^{a}	4.4 ± 0.01^{a}	5.6 ± 0.02^{b}	4.2 ± 0.01^{a}
	80:20	3.8 ± 0.01^{a}	5.3 ± 0.02^{b}	4.6 ± 0.01^{a}	4.1 ± 0.01^{a}	4.3 ± 0.01^{a}	5.3 ± 0.02^{b}	4.0 ± 0.01^{a}
	75:25	3.4 ± 0.01^{a}	4.9 ± 0.01^{a}	3.9 ± 0.01^{a}	3.7 ± 0.01^{a}	4.0 ± 0.01^{a}	5.0 ± 0.02^{b}	3.6 ± 0.01^{a}

Values are mean ± standard deviation of triplicate determinations. Means on the same row with different sets of superscripts are statistically different ($p \leq 0.05$).
Note: SF = Fermented sorghum flour. SBF = Fermented soybean flour

natural toxicants which include tannins, phytic acid, protease and trypsin inhibitors, saponins, metal chelates, cyanogens, isoflavonoids, phytoalexins, flatus factors, etc. (Pariza & Johnson, 1996). Some of these substances reduce the nutritional value of the food by interfering with mineral bioavailability and digestibility of proteins and carbohydrates (Salunkhe et al., 1990; Haard, 1999; MacDonald et al., 2012). Since legumes are usually consumed along with cereals in form of additives, or as protein sources, proper processing of these food substances should therefore be encouraged to eliminate these anti-nutrients before they are consumed (Reddy & Pierson, 1994).

The tannin contents in mg/100g ranged from 186.92 ± 0.30–165.81 ± 0.30 for 0 h, 172.59 ± 0.30–122.47 ± 0.25 for 24 h, 138.68 ± 0.26–89.11 ± 0.21 for 48 h, and 114.61 ± 0.24–51.26 ± 0.18 for 72 h, respectively, while the phytate contents ranged from 210.18 ± 0.32–188.62 ± 0.30 for 0 h, 193.28 ± 0.31–138.69 ± 0.26 for 24 h, 158.61 ± 0.29–94.26 ± 0.22 for 48 h, and 124.36 ± 0.25–58.33 ±0.18 for 72 h, respectively. The trypsin inhibitors contents in mg/100g ranged from 74.63 ± 0.20–88.53 ± 0.21 for 0 h, 61.82 ± 0.19–79.32 ± 0.20 for 24 h, 43.52 ± 0.17–62.22 ± 0.19 for 48 h, and 18.65 ± 0.14–31.82 ± 0.16 for 72 h, respectively, while the protease inhibitors contents ranged from 72.46 ± 0.20–86.22 ± 0.21 for 0 h, 62.03 ± 0.19–79.96 ± 0.20 for 24 h, 40.24 ± 0.17–60.48 ± 0.19 for 48 h, and 15.97 ± 0.14–28.56 ± 0.15 for 72 h, respectively.

Sorghum and soybeans contain appreciable amounts of anti-nutritional factors like tannin, phytates, trypsin, and protease inhibitors. It was observed that soaking and fermentation reduced the different anti-nutritional factors in sorghum and soybeans. Soaking and fermentation reduced the quantity of tannin, phytates, trypsin inhibitors, and protease inhibitors in the sorghum and soybeans. The results and the values of the anti-nutrients in the cookies agreed with the works of Adeyemo and Onilude (2013) and Obadina et al. (2013).

The results of sensory evaluation are shown in Table 6. The cookies from the control samples C_0 (100% sorghum flour) without fermentation had the highest ratings by the panelists for crispiness (6.6 ± 0.02), taste (6.6 ± 0.02), and appearance (7.8 ± 0.03), while cookies from C_1 (100% sorghum flour) with 24 h fermentation had the highest flavor (8.2 ± 0.03) rating.

Cookies from C_0 (100% sorghum flour) without fermentation had the highest value of overall acceptability (7.7 ± 0.03). The results showed that as the quantity of soybean flour increases as the overall acceptability decreases. Similar results were also observed in the cookies from fermented sorghum and soybean flour blends. This implies that the inclusion of soybean flour and fermentation affected all the sensory properties as well as overall acceptability of the cookie samples.

Cookie samples from C_5 (75% sorghum flour and 25% soybean flour) fermented for 72 h had the least values for crispiness, flavor, texture, taste, color, appearance, and overall acceptability. However, all cookie samples from C_0 to C_4 had high overall acceptability, which means that cookies from fermented sorghum and soybean flour with up to 48 h fermentation and 25% soybean flour substitution were still acceptable to the consumers.

Conclusion

In conclusion, fermentation of sorghum and soybeans through microbial activities led to the hydrolysis and the reduction of anti-nutritional factors and also improves the nutrient composition of cookies from fermented sorghum and soybeans flour blends, as there was an increase in protein and vitamin contents of the cookies at the end of fermentation. This is a good product, rich in substantial amounts of proteins that are important to poor nursing mothers, children, and adolescents. Therefore, cookies from fermented sorghum and soybean flour blends could be used as a remedy to solve the menace of protein-energy malnutrition in developing countries.

Implications of the study to culinary science

Baking had been an important culinary practice for a long time. Baked products are very common among all tribes and nations of the world. However, there is need to streamline the production of baked products based on the health needs of the people and economic reality especially among the developing nations. The usual raw material for the baking industry is wheat. The problem of celiac disease and the cost of importation of wheat by developing nations as necessitated the need to look inward in using available local cereals and legumes in producing novel and cheap products such as cookies of acceptable quality attributes and sensory properties. This product could be produced in commercial quantity with the conventional method which will meet the taste and preferences of the consumers. This product if careful executed could alleviate the problem of celiac disease among those that could not tolerate gluten as the product is gluten free and also gives economic succour to these nations.

ORCID

Abiodun Omowonuola Adebayo-Oyetoro http://orcid.org/0000-0002-3604-1440

References

Adeleke, R. O., & Odedeji, J. O. (2010). Functional properties of wheat and sweet potato flour blends. *Pakistan Journal of Nutrition*, *9*, 535–538. doi:10.3923/pjn.2010.535.538

Adeyemo, S. M., & Onilude, A. A. (2013). Enzymatic reduction of anti-nutritional factors in fermenting soybeans by *lactobacillus plantarum* isolates from fermenting cereals. *Nigerian Food Journal*, *31*(2), 84–90. doi:10.1016/S0189-7241(15)30080-1

Adeyeye, S. A., & Akingbala, J. O. (2016). Quality, functional and sensory properties of cookies from sweet potato-maize flour blends. *Journal of Culinary Science and Technology*, *14*(4), 363–376. doi:10.11080/15428052:2015.1160016

Adeyeye, S. A. O. (2016). Assessment of quality and sensory properties of sorghum-wheat flour cookies. *Cogent Food and Agriculture*, *2*, 1245059. Taylor and Francis Online. doi: 10.1080/23311932.2016.1245059

Adeyeye, S. A. O., Adebayo-Oyetoro, A. O., & Omoniyi, S. A. (2017). Quality and sensory properties of maize flour cookies enriched with soy protein isolate. *Cogent Food and Agriculture*, *3*, 1278827. Taylor and Francis Online.

Akpapunam, M. A., & Darbe, J. W. (1999). Chemical composition and functional properties of blend of maize barbara groundnuts flours for cookie production. *Plants Food for Human Nutrition*, *46*, 147–155. doi:10.1007/BF01088767

Anozie, G. O., China, M. A., & Beleya, E. A. (2014). Sensory evaluation and proximate composition of snacks produced from campsite flour of *dioscorea alata* and *telfairia occidentalis* seeds flours. *Journal of Home Economic Research*, *20*, 100–108.

AOAC. (2000). *Official methods of analysis* (17th ed.). Washington, DC: Association of Official Analytical Chemists.

Association of Official Analytical Chemists (AOAC). (1990). *Official methods of analysis* (16th ed.). Washington, DC: Author.

Barnes, S. (2010, March). The biochemistry, chemistry and physiology of the isoflavones in soybeans and their food products. *Lymphatic Research and Biology*, *8*(1), 89–98. doi:10.1089/lrb.2009.0030

Butler, L. M., Wu, A. H., Wang, R., Koh, W.-P., Yuan, J.-M., & Yu, M. C. (2010, April). A vegetable-fruit-soy dietary pattern protects against breast cancer among postmenopausal Singapore Chinese women. *The American Journal of Clinical Nutrition*, *91*(4), 1013–1019. doi:10.3945/ajcn.2009.28572

FAOSTAT. (2015). *Soybeans, production/crops/world for 2014*. Rome: Author.

Food and Agriculture Organization (FAO). (2012). *Trade data base, Production data base*. http://faostat.fao.org

Haard, N.F. (1999). Haard Cereals: Rational for fermentation Fermented Cereals — A Global Perspective. FAO, Agricultural Sciences Bulletin, Rome, Italy (1999) No. 138 FAO/UN.

Hough, G., Van Hout, D. & Kilcast, D. (2006). "Workshop summary: sensory shelf-life testing". Food Quality and Preference, *17*(7–8), 640–650.

MacDonald, A., Evans, S., Cochrane, B & Wildgoose, J. (2012). Weaning infants with phenylketonuria: A review. Journal of Human Nutrition and Dietetics, *25*(2012), 103–110.

Messina, M. J. (1999). Legumes and soybeans: Overview of their nutritional profiles and health effects1, 2. *American Society for Clinical Nutrition*, *70*(3), 439s–450s.

Mohammed, B. T.,Aduba, J. J., Jilasaya, I., Ozumba, I.C., (2011). Farmers resource use efficiency in sorghum production in Nigeria. Continental J. Agricultural Economics *5*(2), 21–30, 2011.

Mutegi, E., Sagnard, F., Muraya, M., Kanyenji, B., Rono, B., Mwongera, C., … Labuschagne, M. (2010, Febuary 1). Ecogeographical distribution of wild, weedy and cultivated Sorghum bicolor (L.) Moench in Kenya: Implications for conservation and crop-to-wild gene flow. *Genetic Resources and Crop Evolution*, *57*(2), 243–253. doi:10.1007/s10722-009-9466-7

Obadina, A. O., Akinola, O. J., Shittu, T. A., & Bakare, H. A. (2013). Effect of natural fermentation on the chemical and nutritional composition of fermented Soymilk Nono. *Nigerian Food Journal*, *31*(2), 91–97. doi:10.1016/S0189-7241(15)30081-3

Olaoye, O. A., Onilude, A. A., & Idowu, O. A. (2006). Quality characteristics of bread produced from composite flours of wheat, plantain and soybeans. *African Journal Biotechnology*, *11*, 1102–1106.

Onabanjo, O. O., & Ighere, D. A. (2014). Nutritional, functional and sensory properties of bread biscuit produced from wheat-sweet potato composite. *Journal of Food Technology Research*, *1*(3), 111–121. doi:10.18488/journal.58/2014.1.2/58.2.111.121

Pariza, M. W., & Johnson, E. A. (1996). Evaluating the Safety of Microbial Enzyme Preparations Used in Food Processing: Update for a New Century. Regulatory Toxicology and Pharmacology, *33*, 173–186, 2001.

Reddy, N.R. & Pierson, M.D. (1994). Reduction in antinutritional and toxic components in plant foods by fermentation. Food Research International, *27*(1994), 281–285.

Salunkhe, D. K., Chavan, J. K., & Kadam, S. S. (1990). Dietary tannins: Consequences and remedies. CRC Press, Boca Raton, Florida, USA.

USDA. (2012). National Agricultural Statistics Services. Washington, DC 20250–9410. www.nass.usda.gov.

Yang, W. S., Va, P., Wong, M. Y., Zhang, H.-L., & Xiang, Y.-B. (2011, December). Soy intake is associated with lower lung cancer risk: Results from a meta-analysis of epidemiologic studies. *The American Journal of Clinical Nutrition*, *94*(6), 1575–1583. doi:10.3945/ajcn.111.020966