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Production and Evaluation of the Quality Characteristics of Pearl Millet-based *Kunun Tsamiya* (A Northern Nigeria Cereal-based Gruel) as Affected by Bambara Groundnut Flour Fortification

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ABSTRACT

Pearl millet flour was fortified with Bambara groundnut flour (0-20%) to form blends used in Kunun tsamiya preparation. Functional and microbiological profiles of the flours and modified kunu samples as well as proximate and sensory properties were evaluated. Fortification had raised the nutritional value of the foods. Swelling power and water absorption capacity had increased with an increase in the level of bambara groundnut flour addition whereas bulk density and viscosity had decreased, the results were as follows- swelling power (23.512-27.654%), water absorption capacity (3.300-4.650 g/g), bulk density (0.791-0.779 g/cm^3), viscosity (48.625-56.555 mPa-s). The moisture content, ash, fat, protein, fiber, carbohydrate and total energy levels were found as follows- 78.90-83.64%, 0.24-0.35%, 1.88-3.95%, 3.52-6.02%, 0.70-0.78%, 5.27-14.77% and 80.69-90.02 kcal/100g respectively. The concentration of anti-nutritional factors, alkaloids, flavonoids, phytic acids and tannins ranged from 0.03 to 0.07g/100g, 0.12 to 0.19g/100g, 2.21 to 4.29g/100g and 0.04 to 0.07g/100g respectively. The minerals contents were found to be significant as follows Ca (21.82 to 26.53 mg/100g), Fe (5.19 to 6.24 mg/100g), Zn (1.71 to 2.11 mg/100g), P (83.39 to 93.28 mg/100g), Mg (1.04 to 1.08 mg/100g), K (65.84 to 81.34 mg/100g), Na (8.60 to 10.59 mg/100g). In-vitro protein digestibility at 1h ranged between 66.86 to 68.76% and 68.17 to 69.17% at 6hrs; starch digestibility ranged between 68.99 and 72.17%. Microbial findings generally revealed moderate counts with a total microbial load of 1.41x103cfu/g in the K0MfB (100:00) formulation. Salmonella and Escherichia coli were not detected in Kunun tsamiya samples made from an 80:20% millet-bambara nut flour blend. *Staphylococcus aureus*, *Staphylococcus epidemidis*, *Salmonella spp*, *Klebsiella spp*, *Pseudomonas spp* and *Escherichia coli* were isolated with the following percentage occurrences 27.92%, 20.13%, 12.34%, 16.88%, 17.86% and 4.87% respectively. Sensory evaluation results revealed that Kunun tsamiya from 80:20% millet-bambara groundnut nut flour blends had better taste, aroma and general acceptability and as such the food formulation was the most liked, nutritious and as well most preferred by the test panelists. Therefore it's concluded that fortification of pearl millet with bambara groundnut at 20% level enhanced the nutrient density of the resulting kunu tsamiya without adversely affecting its well-known organoleptic properties.

Keywords: Pearl millet; Bambara groundnut; Supplementation; Kunun tsamiya; Invitro-digestibility; Antinutrients; Minerals; Bacteria prevalence; Functional properties; Food fortification.

1.0. Introduction

Kunu can be referred to as a non alcoholic cereal beverage that is commonly produced from millet. It is the most common beverage used by the people of northern Nigeria, though it is consumed in all other parts of the country too. Kunu is produced all year round with the peak production during the dry season by different households. *Kunun tsamiya* is specifically, a local food of the Hausa/Fulani tribe that dwells in Northern Nigeria and some other West African countries commodity produce from Pearl millet.

Millet is a general term used for a wide range of small-seeded cereal grains that describes several taxonomically divergent species of grass. Millet is thought to be among the first cultivated crops and has been a staple food ingredient in Central and Eastern Asia, Europe (mainly Russia), China, India, and some parts of Africa since ancient times (Baltensperger, 1996). It is an important food in many developing countries because of its ability to grow under adverse weather conditions such as limited rainfall. In addition, millet has many nutritious and medicinal properties (Obilana and Manyasa, 2002).

Pearl millet is an important food for millions of people inhabiting the semi-arid tropics and is a major source of calories and vital component of food security in the semi-arid areas of the developing world (FAO and ICRISAT, 1996). The grain is processed in so many ways for preparation of various food products. Some of the products include cooked whole grain, thin and thick porridges, steamed or cooked grits (couscous, burabusko), *Kunun zaki*, *Tuwo* and *Fura* (Nkama and Ikwelle, 1997; Jideani *et al*., 1999; 2001). Other traditionally processed pearl millet-based foods in North-Eastern Nigeria include Yartsala, Shinkafan tudu (dehulled boiled millet), *Fura*, *Gumba, Kunun tsamiya, Tuwo*, and *Nyauri* etc.

Enrichment of cereal-based food with other protein sources has received considerable attention. *Kunun tsamiya* is solely a cereal-based food which will require the use of a grain legume as a supplement in order to complement the limiting nutrients in millet. Addition of Bambara nut will help to enhance the quantity and quality of nutrients in millet-based foods especially improving the essential amino acids profile of *Kunun tsamiya* because Bambara groundnut is a good source of of high quality protein. It will also help to reduce the incidence of protein-energy malnutrition in people who consume essentially a starchy staple.

Bambara nut (*Vigna subterranea* (*L.*) *Verdc*.) is a leguminous plant of African origin, the cultivation of which predates that of groundnut(Arachis hypogeae). However, it's occasionally grown in Asia and elsewhere but African continent specifically West Africa is the main belt of cultivation and consumption. The distribution of wild Bambara groundnut is also known to extend from Jos Plateau and Yola in northern Nigeria, to Garoua in Cameroon (Goli, 1997). It is in West Africa that most of the world's Bambara groundnut is grown and where the crop is most prominent in the traditional cuisines of rural communities. Bambara nut plays a key role in the traditional food and culture of peoples of the North-Eastern part of Nigeria. Bambara nut is now widely distributed in the semi-arid zone of sub-Saharan Africa (SSA) and is the third most important food legume after cowpea *(Vigna unguiculata)* and groundnut (Mkandawire, 2007).

Consumption of a single cereal may cause deficiency diseases because of the lower concentration of essential amino acids, minerals and vitamins. Therefore value addition to millet grains is another strategic approach to enhance nutritive value of these millet based foods. Nutritive value and health benefits of millet grains are comparable to major cereals such as wheat, rice, and maize. Utilization of millet grain through processing technologies such as fermentation, soaking/malting, and decortification, fortification are adopted to improve the nutritional characteristics of millet grain is limited and is still mainly limited to populations in rural areas and at the household level. This is due to lack of innovative millet processing technologies to provide easy-to-handle, ready-to-cook or ready-to-eat safe products and meals at a commercial scale that can be used to feed large populations in urban areas.

Legumes are good sources of complex carbohydrates including fibre, both soluble and insoluble, legumes are a low-fat, high protein, vitamins, minerals and antioxidant components, and highly satiating. It is important to note that multi grain blends are nutritionally superior to single grain flour or food (Malik *et al*., 2015). Supplementing millet flour with Bambara nut flour which is a good source of fibre and a low glycemic index food would result to nutritionally enhanced composite flour which that can be used for the production of nutritionally enhanced foods such as *Kunun tsamiya*.

Adu-Dapaah and Sangwan (2004) reported that Bambara nut seed is regarded as a complete food because it is rich in iron 4.9-48 mg/100g, compared to a range of 2.0-10.0 mg/100g for most food legumes, protein 18.0-24.0% with high lysine and methionine contents, ash 3.0-5.0%, fat 5.0-7.0%, fibre 5.0-12.0%, potassium 1144-1935 mg/100 g, sodium 2.9-12.0 mg/100 g, calcium 95.8-99 mg/ 100 g, carbohydrate 51-70%, oil 6-12% and energy 367-414 kcal/100 mg. Due to the high price of meat and fish, much importance is now placed on grain legumes as significant sources of protein in resource-poor countries. Legumes are rich not only in proteins, but in other nutrients such as starch (Yagoub and Abdalla, 2007).

1.1. Study Objectives

The study fortified millet flour with Barbara groundnut flour at two levels (10 & 20%). The formulations were used to produce kunun tsamiya. Thereafter, evaluated the physicochemical properties and mineral contents of the modified and controled kunun tsamiya as well as determined the effects of processing on antinutrient contents and microbiological status of the products. Finally, the study evaluated the invitro-digestibilities of the tsamiya and the effects of fortification on consumer acceptability of the the gruels.

The aim of this present study therefore was to investigate the effect of Bambara nut flour inclusion on the quality and acceptability of *Kunun tsamiya*, a cereal-based gruel consumed in Northern Nigeria.

2.0. Materials and Methods

2.1. Collection of Materials

Spices (cloves, ginger), Bambara groundnut grains were purchased from a local and Pearl millet grains obtained from Lake Chad Research Institute Maiduguri, Nigeria. Chemical analyses were carried out at Food Processing Laboratory of the Kano University of Science and Technology (KUST) Wudil in the month of January 2022.

2.2. Processing of Bambara groundnut

The method of Nkama (1993) was used for Bambara groundnut flour production with a slight modification as shown in Figure 1.

2.3. Blend Formulation and *Kunun tsamiya* Preparation

The Pearl millet (M) and Bambara groundnut (B) flours were blended in the ratios of 90:10 and 80:20, while 100% Pearl millet served as the experimental control. The blends were thoroughly blended in a kitchen mixer and used to prepare the *Kunun tsamiya* using the traditional method as shown below.Bambara g/nut grains

Table 1. Formulation Table for Millet-Bambara Groundnut *Kunun tsamiya* (K) Blends

Ingredients	**K_0M_f (100:00)**	**K_1M_fB (90:10)**	**K_2M_fB (80:20)**
Millet flour (%)	100	90	80
Bambara nut flour (%)	-	10	20
Cloves (g)	0.6	0.6	0.6
Ginger (g)	1.5	1.5	1.5
Water (ml)	100	100	100
Tamarind (g)	1.0	1.0	1.0
Sugar (g)	2.5	2.5	2.5

K_0M_f = 100% millet flour, K_1**M_fB**= Millet flour (90%) & Bambara groundnut (10%), K_2**M_fB** = Millet flour (80%) & Bambara groundnut (20%).

Three formulations of *Kunun tsamiya* blends were produced after using sound pearl millet grains. These were first cleaned to remove debris and sorted to remove unsound grains and other foreign matter, the grains were then de-hulled using the commercial mill, and winnowed to remove the chaff, and later washed, and finally sun-dried which reduced moisture content sufficiently, and spices were added to improve nutrition and sensory property. The flow chart is shown in Figure 1 below.

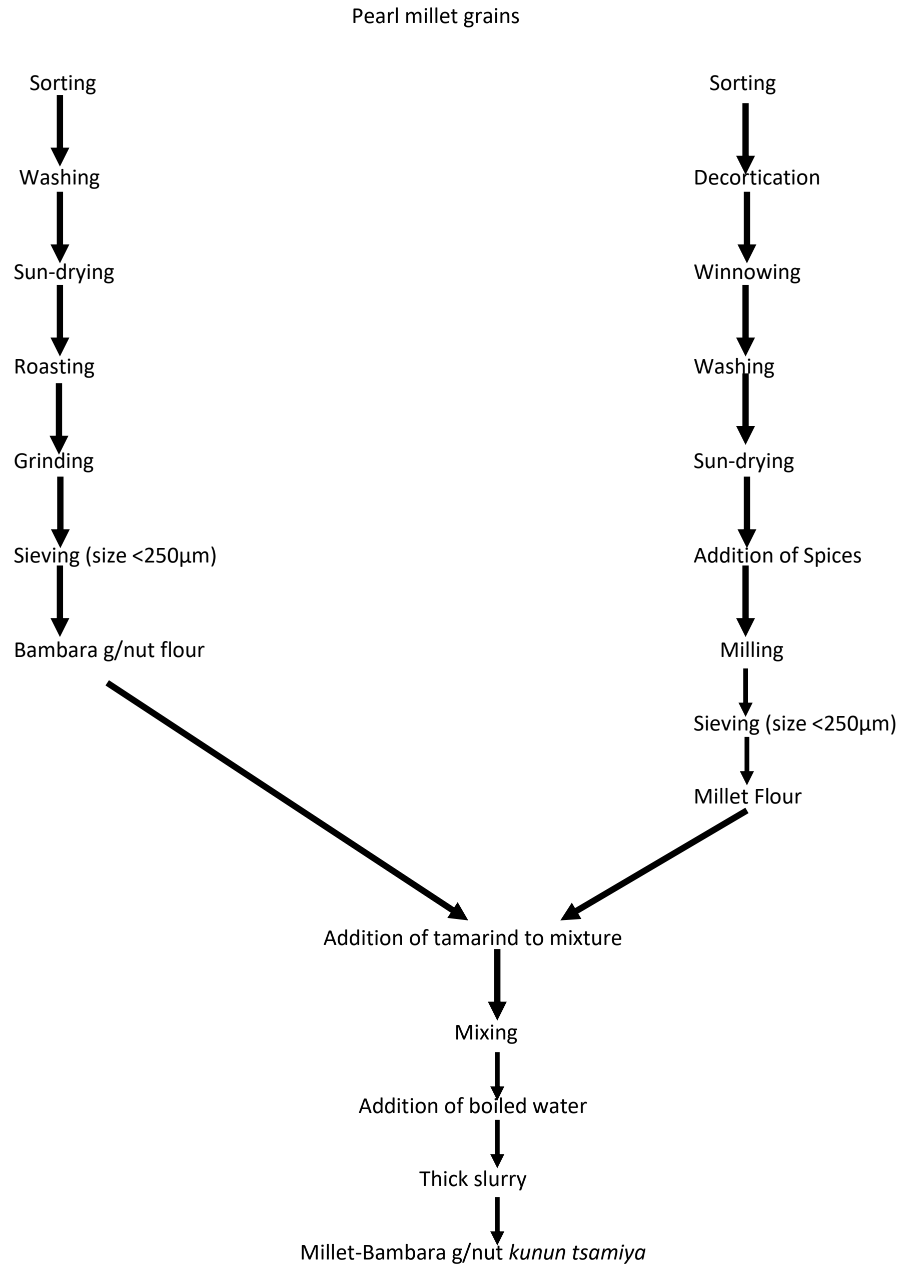

Figure 1. Flowchart for the production of *kunun tsamiya* from Pearlmillet-Bambara groundnut flour

3.0. Physicofunctional Chemical Analysis

3.1. Functional Properties Analysis

Determination of water absorption capacity

A gram (1g) of the sample was placed into a graduated centrifuge tube and 10 ml of distilled water was added and mixed thoroughly for 30 seconds. The sample was allowed to stand for 30 minutes at room temperature and then centrifuged at 5,000 rpm for 30 minutes. The volume of the free water was read directly from the graduated centrifuge tube. The water absorption capacity was expressed as grams of water absorbed per gram of sample (Onwuka, 2005).

Determination of bulk density(BD)

This was determined according to the method of Onwuka (2005). A 10ml capacity measuring cylinder was weighed. The cylinder was gently filled with the sample. The bottom of the cylinder was gently tapped on the laboratory bench several times until there was no further diminution of the sample level after filling to the 10ml mark. BD was taken as the ratio of mass to volume.

Determination of solubility and swelling power

This was determined according to the method of AOAC (1990). 1g of the sample was placed into a cleaned weighed graduated centrifuge tube and 40 ml of distilled water added and mixed thoroughly. The mixture was placed on a water bath thermostatically controlled at 85 ^{0}C with continuous stirring for 30 minutes. The sample was allowed to cool to room temperature and then centrifuged at 2,200 rpm for 15 minutes. The supernatant was poured into a pre-weighed crucible and then placed in an oven to evaporate. The solid residue in the crucible was weighed again and the difference in weight calculated as percentage solubility. The paste in the tube was then weighed and the swelling power (SP) determined by the following equation:

$$\% \text{ Sp} = \frac{\text{Weight of paste}}{\text{Weight of sample}} \times 100 \qquad (1)$$

Viscosity

NDJ-5S Digital Rotary Viscometer equipped with set of spindles 1-4, beakers and samples. About 100ml of the flours for the different *Kunun tsamiya* food samples was put in a glass beaker taking care of the temperature. The rotor protection bracket was mounted on the instrument, turning right for mounting and left for removing. The selected rotor was screwed into connecting bolt rod, taking care while slightly lifting the connecting rod when mounting or removing rotors. The rotor was put into the measured liquid till the level mark on the rotor reached the liquid surface. The samples were allowed to stand for two minutes under stable temperature before taking result. After putting on the machine the rotor was selected by pressing left and right while velocity was selected by pressing the down key. The return key was then pressed and the measurement started and finally the result was recorded when the data was within 10% - 100% of the chosen scale ensuring the given precision, taking care of the appropriate unit, results expressed in milliPascal second (mPa-s) (AOAC 1990).

3.2. Proximate composition of Raw materials, flour blends and *Kunun tsamiya* Samples

For the determination of proximate composition of *Kunun tsamiya,* raw material (millet , bambara groundnut nut and flour blends of raw materials were determined using procedures of AOAC (1990). Moisture content was determined by drying the sample at 105 ^{0}C for about 3 hours. Ash content was determined by introducing the samples in the crucibles using a pair of tongs into a muffle furnace at 500 ^{0}C until fully ashed (grey color ash). Protein content (%N x 6.25) was determined by the Kjeldhal method. Crude fat was determined using the Soxhlet extraction with petroleum ether. Crude fiber was determined using 5 grams of the sample and defatted by ether extraction with soxhlet apparatus and dried. The sample was transferred quantitatively by brushing in a 600ml beaker of the fiber digestion apparatus, 200 ml of 1.25% sulphuric acid was added. The beaker was placed on digestion block with pre adjusted heater and boiled for exactly 30 minutes. The beaker was removed and the contents filtered through California Buchner funnel, dried and finally ashed. Carbohydrate was determined by 'difference'. Energy (E) values (Kcal) was determined according to the method described by Chinma and Gernah (2007). Energy values were determined using Atwater conversion factors {4x(protein) + 4x(carbohydrate) + 9x(fat)}.

3.3. Microbial Analysis

The total bacterial count, the serial dilution method as described by the American Public Health Association (APHA 1992) was employed, 5g of the sample was mixed with 225 ml of 0.1% peptone water. The sample was shaken thoroughly to make a homogenate solution, this gave the dilution of 10^{-1}. 1ml of this prepared solution was transferred into 9ml of the diluent (0.1% peptone water), this gave the dilution of 10^{-2}. This procedure was repeated up to the fifth dilution which gave the dilution of 10^{-5}. Common bacterial pathogens associated with the foods are E*scherichia coli*- Eosin Methylene Blue (EMB), *Pseudomonas aeruginosa*- MacConkey (MA), *Klebsiella spp*- MacConkey (MA),, *salmonella spp*- De-oxycitrate Agar (DCA), *Staphylococcus epidermidis* and *Staphylococcus aureus*- Mannitol Salt Agar (MSA). These organisms were isolated from the prepared foods and identified by colony morphology on selective media in addition y Gram-staining and standard biochemical tests. Colonies were enumerated using digital colony counter and results expressed in colony forming unit per gram (cfu/g).

3.4. Sensory Evaluation

The sensory evaluation of *Kunun tsamiya* samples were carried out by 20 respondents which comprised of students from the Department of Food Science and Technology, Kano University of Food Science and Technology (KUST) Wudil who are very familiar with the product some of them were residents of the North-East sub region of Nigeria. The samples were ranked on a 9 point hedonic scale with 1 representing dislike extremely and 9 like extremely as described by Ihekoronyi and Ngoddy (1985). The samples were prepared and served immediately after preparation. Individual samples were presented in a random pattern and judged based on attributes such as: aroma, texture, taste, appearance, and overall acceptability. A glass of clean water was given to the respondents to rinse their mouth in between each determination to avoid discrepancies in taste.

3.5. Statistical analysis

Determinations were done in duplicates except otherwise stated and the data generated were subjected to one-way analysis of variance (ANOVA) at 5% ($p<0.05$) and the means separated using the Least Significance Difference (LSD) method (Gomez and Gomez, 1984). The statistical analysis was carried out using MINITAB version 17.

4.0. Results and Discussion

Functional properties of *Kunun tsamiya* Supplemented with Bambara Groundnut Flour and the Unfortified Control

There were significant variations ($p<0.05$) in the functional properties of the flours and blends (Table 2). The values obtained generally decreased as pearl millet flour was being substituted with bambara groundnut flour. Bulk density ranged from 0.779 to 0.791 g/cm^3, starchy pearl millet flour had the highest bulk density and whole bambara groundnut flour the least. The decrease might be attributed to the lower density of bambara groundnut flour compared with millet flour.

Plaami., (1997) reported that bulk density is influenced by the structure of the starch polymers and the loose structure of the starch polymers could result in low bulk density. The results obtained in this study is higher compared with the report of James et al. (2018) who reported a bulk density range of 0.33 to 0.43 g/cm^3 for bambara groundnut fortified millet-based infant formula, and also higher than bulk density of bambara groundnut fortified millet based fura powder (Adebayo-oyetoro *et al*., 2017). Bulk density is the measure of the heaviness of flour and is important in determining the packaging requirement and material handling during processing (Karuna *et al*., 1996). Greater quantity of flour in a unit volume translates to greater nutritive value and, therefore calorific value.

For the water absorption capacity (WAC), the obtained values ranged from 3.300 to 4.650g/g, bambara groundnut flour had the highest,v and the least was recorded for whole millet flour. WAC of fine millet and whole millet flours were not significantly different ($p>0.05$) but were significantly different from the rest of the formulations. The higher water absorption capacity might be attributed to the higher dry matter content of B_f (100:00). In this study WAC increased with an increase in the level of bambara groundnut flour inclusion (0-20%) and this implies addition of bambara groundnut increased the water absorption capacity of the resulting blends, a sure indication that increase in protein content was responsible for higher WAC of the blends. Moreover, dietary fibers are known to have higher water holding capacity as seen in B_f (100:00). Low water absorption capacity could be an advantage in long term storage stability as the rate of moisture absorption could be relatively low hence reduced moisture availability for microbial growth and deleterious biochemical reactions. Proper mixing and consistency of *Kunun tsamiya* requires high water absorption of the blends which impact positively on the *Kunun tsamiya* sensory attributes.

Swelling power(SP) values ranged from 23.512% in whole millet flour to 27.654% in whole bambara groundnut flour. No significant difference was observed between SP of fine millet and whole grain flours. The swelling power increased with an increase in the level of bambara groundnut inclusion to the pearl millet flour. The swelling power results agreed with the report by Agbara *et al.* (2018) on yartsala production.

The viscosity of the flours ranged from 48.625 mPa-s in bambara groundnut flour to 56.555 mPa-s for whole millet grain flour, the highest. The result revealed that increasing the level of bambara groundnut marginally reduced the viscosity of the flours for the *Kunun tsamiya* production because starchy millet flour is a better thickener than protein-rich bambara groundnut flour.

As results in Table 2 show, all the parameters determined were related to one another, the lower the bulk density with addition of bambara groundnut, the higher the flours ability to absorb water and the more the swelling power as well as the less the viscosity of the flours. Agbara *et al.* (2018) similarly observed for blends of *Yartsala* production.

Table 2. Functional properties of the Millet- Bambara groundnut blends for *Kunun tsamiya* preparation

Sample code	Bulk density (g/cm^3)	Water absorption (g/g)	Swelling power (%)	Viscosity (mPa/s)
M_f (100:00)	0.791±0.000[a]	3.350±0.071[e]	23.616±0.187[c]	52.965±0.290[b]
M_{wf} (100:00)	0.787±0.000[b]	3.300±0.000[e]	23.512±0.021[c]	56.555±0.629[a]
B_f (100:00)	0.782±0.000[d]	4.650±0.071[a]	27.589±0.713[a]	48.625±0.884[d]
B_{wf} (100:00)	0.779±0.001[e]	4.450±0.071[b]	27.654±0.066[a]	50.175±0.050[c]
M_fB_f (90:10)	0.787±0.000[b]	3.500±0.000[d]	23.783±0.033[bc]	51.315±0.205[c]
M_fB_f (80:20)	0.785±0.000[c]	3.650±0.071[c]	24.203±0.301[b]	50.210±0.028[c]

M_f=Fine millet flour B_f= Bambara groundnut flour M_{wf}=whole millet flour B_{wf}=wholr bambara groundnut flour; Mean values in the column bearing the identical superscripts are significantly not different (P>0.05).

Proximate composition (%) of the Millet, Bambara groundnut flours and the blends

Table 3 shows the proximate composition of whole millet and bambara groundnut flours, fine and the flour blends used for the preparation of millet-bambara groundnut blends for *Kunun tsamiya*. The results shows that ash, protein and crude fiber contents increased as the level of Bambara groundnut flour increased (0-20%). This redefines the true state of legume grains as good sources of protein, fat, ash and crude fiber than in most cereals (Ruth *et al*., 2018). Bambara groundnut has been reported by several authors as being a complete food. The results obtained in this study were found to be higher than the report by Olaleye *et al.* (2013) regarding the chemical composition of bambara groundnut (2.46-4.36%, 15.2-22.2%, 2.47-6.99% and 51.66-61.9% for ash, protein, fat and carbohydrate respectively). The high content of ash, protein and fiber are important because protein is an important nutrient that plays a role in human metabolism, the fiber which indicates the indigestible cellulose was higher in Bambara groundnut. Also fiber is needed for bowel health and play vital role in metabolism of glucose and fat for healthy adults, 38 grams for men and 25 grams for women are recommended daily, 30 and 21 grams are recommended for adults over the age of 50 (Holly, Larsson, 2017).

The moisture(water), ash, fat, protein, crude fiber and carbohydrate contents of different samples of the processed *Kunun tsamiya* are shown in Table 4 is as follows: 78.90-83.64%, 0.24-0.35%, 1.88-3.95%, 3.52-6.02%, 0.70-0.78% and 5.27-14.77% respectively. There was an increase in all the nutrients determined other than carbohydrate and total energy which decreased as millet flour was increasingly substituted with bambara groundnut flour, the increase in ash, fat, protein and crude fiber level was expected since bambara groundnut is reported to contain high level of ash, protein and crude fiber (Igbalul *et al.*, 2013). Kunu is a local beverage, a vital thirst quenching product and the raw materials for its preparation are readily available and cheap, therefore kunu is an inexpensive beverage for many resource poor households but it's noted for being having potential chemical and microbial deterioration.

Table 3. Proximate composition (%) of the Millet, Bambara groundnut flours and the blends

Sample code	Moisture	Ash	Fat	Protein	Crude fiber	Carbohydrate	Energy-Kcal/100g
M_f(100:00)	12.120±0.057[b]	1.090±0.071[e]	5.800±0.354[d]	11.880±0.000[c]	1.060±0.071[d]	68.055±0.438[a]	371.920±1.43[d]
M_{wf}(100:00)	13.140±0.099[a]	1.250±0.014[de]	4.350±0.071[e]	11.407±0.663[c]	1.225±035[bc]	68.629±0.599[a]	359.290±0.382[e]

B_f(100:00)	7.610± 0.099^{d}	3.090±0.127^{b}	11.725±0.247^{a}	15.314±0.001^{a}	1.310±0.014^{b}	60.951±0.461^{c}	409.370±2.11^{a}
B_{wf}(100:00)	6.630±0.806^{e}	4.400±0.057^{a}	9.550±0.212^{b}	16.410±0.000^{a}	1.460±0.028^{a}	61.554±0.622^{c}	397.790±4.40^{b}
M_fB(90:10)	10.210±0.042^{c}	1.300±0.028^{d}	6.900±0.141^{c}	12.500±0.884^{bc}	1.135±0.021^{cd}	67.955±0.778^{ab}	383.920±0.849^{c}
M_fB(80:20)	9.620±0.085^{c}	1.640±0.028^{c}	7.350±0.071^{c}	13.688±0.795^{b}	1.205±0.078^{bc}	66.498±0.746^{b}	

M_f=Fine millet flour B_f= Bambara groundnut flour M_{wf}=whole millet flour B_{wf}=wholr bambara groundnut flour; Mean values in the column bearing the identical superscripts are significantly not different (P>0.05).

Table 4. Proximate Composition (%) of *Kunun tsamiya* Supplemented with Bambara Groundnut Flour and the Control

Sample	Moisture	Ash	Fat	Protein	Crude Fiber	Carbohydrate	E-(kcal/100g)
K_0M_f(100:00)	78.90±0.68^{c}	0.24±0.06^{a}	1.88±0.04^{c}	3.52±0.33^{b}	0.70±0.07^{a}	14.77±1.00^{a}	90.02±2.95^{a}
K_1M_fB(90:10)	81.72±0.11^{b}	0.31±0.01^{a}	2.83±0.04^{b}	3.75±0.00^{b}	0.70±0.00^{a}	10.70±0.09^{b}	83.21±0.69^{b}
K_2M_fB(80:20)	83.64±0.40^{a}	0.35±0.01^{a}	3.95±0.07^{a}	6.02±0.77^{a}	0.78±0.04^{a}	5.27 ±1.22^{c}	80.69±1.15^{b}

K= *Kunun tsamiya* Subscripts 1 and 2 denote for supplementation with Bambara groundnut flour at 10%& 20% levels, whereas 0 denotes for the control, M_f= Millet flour, B_f=Bambara groundnut flour;

Mean values in the column bearing the identical superscripts are significantly not different (P>0.05) of duplicate determinations.

Table 5a. Mineral Contents (mg/100g) of the Flours and Flour Blends for *Kunun tsamiya* Production

Sample code	Ca	Mg	Fe	K	Na
M_f(100:00)	17.80±0.28^{d}	271.75±0.07^{b}	7.65±0.00^{d}	178.85±0.07^{a}	38.25±0.21^{a}
B_f(100:00)	22.30±0.14^{b}	379.00±0.14^{a}	11.00±0.14^{c}	86.75±0.21^{d}	29.35±0.21^{b}
M_fB(90:10)	18.50±0.00^{c}	263.45±0.07^{c}	15.05±0.07^{b}	140.30±0.14^{b}	28.70±0.14^{c}
M_fB(80:20)	23.00±0.14^{a}	220.25±0.21^{d}	17.00±0.00^{a}	123.15±0.21^{c}	21.45±0.21^{d}

M_f=Fine millet flour B_f= Bambara groundnut flour;

Mean values in the column bearing the identical superscripts are significantly not different (p>0.05) of duplicate determinations.

The mineral contents of the flours and the blends are presented in Table 5a. The concentrations(mg/100) of the elements (Mg, K, and Na) other than Ca and Fe were found to have decreased in the flour blends. The variations were significant and as follows: Ca 17.80 to 23.00, Mg 220.25 to 379.00, Fe 7.65 to 17.00, Na 21.45 to 38.25. The highest concentrations of Ca, Fe, were in the blend of M_fB(80:20), and Mg, K and Na were found to be higher in M_f(100:00). The high content of Ca and Fe in B_f (100:00) might be attributed to the grain's own composition, being a calcium rich grain, Amarteifio *et al.*, (2006) reported that Ca levels ranged from 95.8 to 99.0 mg/100g. Fe content was higher than 7.49 mg/100 reported by Léder (2004) and 2.08-8.12 mg/100gthe reported by Kulthe *et al.* (2016) for millet cultivars. Ca and P are very important in bones and teeth formation and growth, blood clothing, heart function and cell metabolism (Roth and Townsend, 2003; Rolfe *et al.*, 2009. Inadequate Ca intake results in rickets and increase risk of osteoporosis as well as hypertension and stroke.

Fe results were found higher in this study than earlier reported. Fe is required for oxygen carrying capacity of haemoglobin and myglobin and as a co-factor for several other enzymes (NHS Direct online, 2017). Deficiency in Fe may lead to anaemia. Ca and Fe levels increased with an increase in the levels of bambara groundnut inclusion.

The high content of Mg, K and Na could be linked to the high contents of these minerals in millets. Ca and Mg both plays important role in bone structure, muscles contraction, nerve impulse contraction, blood clothing, cell signaling (FAO (2002)). Mg has been linked to lower risk of type 2 diabetes. Potassium (K) is important in nerves and muscles function, it helps to offset some of the sodium harmful effects on blood pressure. Sodium is added to foods for better sensory attributes and to maintain water balance in cells. Nkama, and Malleshi (1998) reported higher Na contents in millet flour (1596ppm (159.6 mg/100g) and results obtained by Hillrocks *et al.* (2012) on bambara groundnut utilization were comparable.

Mineral Contents of Bambara Groundnut fortified pearl Millet-Based *Kunun tsamiya* and Control

Mineral contents of bambara groundnut supplemented pearl millet-based Kunun tsamiya and control are presented in Table 5b, All the elements analyzed generally decreased in the bambara groundnut fortified Kunun tsamiya. The variations were found to be significant as follows Ca (21.82 to 26.53, Fe 5.19 to 6.24, Zn 1.71 to 2.11, P 83.39 to 93.28 but the decrease were pronounced for Na, K and Mg, Na, K and Mg decreased greatly in fortified kunun tsamiya samples, this could be attributed to higher levels of these elements in millet grain. Millet flour was reported to contain more K than bambara groundnut. K content ranged from 11.44 to 19.35 mg/100g (Amarteifio et al., 2006, Fasoyiro et al., 2006). Potassium (K) is important in nerves and muscles function, it helps to offset some of the sodium harmful effects on blood pressure. The high Mg content might be linked to higher Mg in foods made from millet than in bambara groundnut foods. Ayo and Aba (2020) reported that millet based Madidi decreased in Mg content as more bambara groundnut was added. Magnesium is important for healthy bone. Higher intake of magnesium results in higher bone mineral density which is important in reducing the risk of bone fractures and osteoporosis. Olaleye et al. (2013) reported a range between 11.2 to 40.2 mg/100g higher than the concentration of zinc in pearl millet which is 46.9 ppm equivalent to 4.69 mg/100g (Nkama, and Malleshi 1998) on Masa. This might be the reason for the increased zinc content within the different kunun tsamiya food samples as Bambara groundnut was added. Zinc is important for the body's defense (immune) system and is important in the synthesis, storage and secretion of insulin (Chausmer, 1998).

Table 5b. Mineral Contents (mg/00g) of Bambara Groundnut Fortified Pearl Millet-Based *Kunun tsamiya* and Control

Sample code	Ca	Fe	Na	K	Zn	Mg	P
K_0M_f(100:00)	21.82±2.36^c	5.19±0.55^b	10.59±0.36^a	81.34±4.49^a	1.71±0.03^b	1.08±0.02^a	83.39±2.50^c
K_1M_fB(90:10)	24.38±2.36^b	5.73±0.55^b	8.70±0.25^b	73.49±4.66^b	1.83±0.08^b	1.06±0.06^a	88.17±10.26^b
K_2M_fB(80:20)	26.53±2.36^a	6.24±0.55^a	8.60±0.83^b	65.84±7.46^c	2.11±0.13^a	1.04±0.05^a	93.28±5.62^a

K= *Kunun tsamiya* subscripts 1 and 2 denote for supplementation with Bambara groundnut flour at 10% & 20% levels, where as 0 indicates the unfortified control, M_f= Millet flour, B_f=Bambara groundnut flour;

Mean values in the column bearing the identical superscripts are significantly not different (P>0.05) of duplicate determinations.

Microbiological status fortified tsamiya

The whole investigation as shown in Table 6a, shows microbiological status of 3-day-old *Kunun tsamiya.* Generally, counts were moderate. The extent to which a product is contaminated by microorganisms depends on the level of hygiene and sanitary status of handlers and materials used in the production as well as the nature of product. Traditionally, low moisture foods contain no more than 25% moisture and water activity of 0.00 to 0.60 Jones *et al.* (2001). Bacteria require relatively high level of moisture for growth. Highest total microbial load was $1.41x10^3$cfu/g. *Salmonella and Escherichia coli* were not detected in *Kunun tsamiya* made from 90:10 millet:bambara nut flour blend. *Staphylococcus aureus, Staphylococcus epidemidis, Salmonella* spp, *Klebsiella spp*, *Pseudomonas* and *Escherichia coli* were isolated with the following percentage of occurrences 27.92%, 20.13%, 12.34%, 16.88%, 17.86% and 4.87% respectively. The occurrence of such bacteria as *Staphylococcus aureus* and *E. coli* in the *Kunun tsamiya* food samples should be of public health concerns; due to the facts that they have been implicated in various diseases of man (Gilbert and Arrison, 2001; Reiman and Cliver 2006; Ogbonna *et al*., 2012; Falegan *et al*., 2017). *Staphylococcus aureus* recorded the highest frequency in the *Kunun tsamiya* samples. Moreover, the total bacterial counts recorded in different *Kunun tsamiyas* did not exceed the limits for ready-to-eat foods at level of 10^2 to < 10^4 cfu/g prescribed by the Food Standards (2002), and Centre for Food Safety (2007). The food samples from *kunun tsamiya* studied here contain greater moisture content level which indicates higher susceptibility to microbial attack if not kept refrigerated.

Table 6a. Total bacterial count of the processed *Kunun tsamiya* food samples under a 3-day room temperature

Formulation	**TVC x 10^3 (cfu/g)**
K_0M_f (100:00)	$1.41{\pm}0.00^a$
K_1M_fB (90:10)	$1.32{\pm}0.00^b$
K_2M_fB (80:20)	1.17 ± 0.00^c

K= *Kunun tsamiya* Subscripts 1 and 2 denote for supplementation with Bambara groundnut flour at 10%& 20% levels, M_f= Millet flour, B_f=Bambara groundnut flour;

Mean values in the column bearing the identical superscripts are significantly not different (P>0.05);

TVC=Total viable count, cfu/g= coliform forming unit per gram, of the food sample.

Table 6b. Prevalence of bacteria associated with the Bambara groundnut Fortified Pearl Mllet-based *Kunun tsamiya* and the Control.

Sample code	**Bacterial isolates of the foods**					
	S. aureus	***S. epidemidis***	***Salmonella spp***	***Klebsiella spp***	***Pseudomonas spp***	***E. coli***
K_0M_f(100:00)	34	15	22	13	24	9
K_1M_fB(90:10)	28	18	ND	17	9	ND
K_2M_fB(80:20)	24	29	16	22	22	6
Total	86	62	38	52	55	15
Mean	28.67	20.67	12.67	17.33	18.33	5.00
% Occurrence	**27.92**	**20.13**	**12.34**	**16.88**	**17.86**	**4.87**

K= *Kunun tsamiya* Subscripts 1 and 2 denote for supplementation with Bambara groundnut flour at 10%& 20% levels, whereas 0 denotes for the control, M_f= Millet flour, B_f=Bambara groundnut flour, ND= Not determined.

Millet flour, B_f=Bambara groundnut flour, **S.=*Staphyllococcus***, Spp=*Specie*, E= *Escherichia*, ND= Not Detected.

Anti-nutrients Composition of the Flours and the Blends

The anti-nutritional factors of the raw material flours and the blends for *Kunun tsamiya* formulations are presented in Table 7a. Tannin, Alkaloid and Phytic acids contents ranged from 0.18 to 0.25g/100g, 2.75 to 3.50g/100g. and 8.93 to 13.81mg/100g respectively. Tannin, alkaloid and phytic decreased with bambara groundnut flour inclusion (0-20%). This is as a result of the low content of anti-nutrients in the bambara groundnut and to its high concentration in the millet flour. The results obtained agreed with the report by Kulthe *et al*. (2016) who characterized millet cultivars on the basis of some physical and chemical properties, and the report by Gull *et al*. (2015) on Fura evaluation. Tannin binds to both exogenous and endogenous proteins including enzymes of the digestive tract affecting the utilization of proteins (Griffiths, 1985). Alkaloids are secondary metabolites and show strong effects on animal and human organism on very small dozes. Alkaloids are not only present in daily human life in food but also as stimulant drugs, they are anti-inflammatory, anti-cancer, analgesics in nature. Phytic acids was lower compared to the report from Kulthe *et al*. (2016) on anti-nutritional contents of some pearl millet cultivars and the work of Florence and Asna (2014) on influence of germination on bio-accessible iron and calcium in pearl millet. Kheterpaul and Chauhan (1991) reported 990 mg/100g of phytic acid in pearl millet and Kumar and Chauhan (1993) reported value of 825.7 mg/100g, while El-Hag *et al*. (2002) reported 943 and 1076 mg/100g of phytic acid in two Sudanese wheat cultivars. The low phytic acid content could be due to varietal differences and also the effect of processing. Many processing techniques such as cooking, germination, soaking reduces the contents of anti-nutrients for many grains or their flours.

Table 7a. Anti-nutrient Composition of the Flours and the Blends

Formulation	Tannin (g/100g)	Alkaloid (g/100g)	Phytic Acid (mg/100g)
M_f(100:00)	0.25 ± 0.01^{a}	3.50 ± 0.28^{a}	13.81 ± 0.16^{a}
B_f(100:00)	0.18 ± 0.00^{c}	2.75 ± 0.07^{b}	8.93 ± 0.16^{c}
M_fB(90:10)	0.21 ± 0.01^{b}	2.92 ± 0.02^{b}	12.65 ± 0.16^{b}
M_fB(80:20)	0.20 ± 0.01^{bc}	2.86 ± 0.01^{b}	12.18 ± 0.16^{b}

M_f=Fine millet flour B_f= Bambara groundnut flour;

Mean values in the column bearing the identical superscripts are significantly not different (P>0.05).

Anti-nutrient Content in Fortified Pearl Millet-Based *Kunun tsamiya* and Unfortified Control

The anti-nutritional contents of the bambara groundnut supplemented pearl millet-based food *Kunun tsamiya* is presented in Table 7b. The concentration of alkaloids, flavonoids, phytic acids and tannins ranged from 0.03 to 0.07g/100g, 0.12 to 0.12g/100g, 2.21 to 4.29g/100g and 0.04 to 0.07g/100g. There was general decrease in the anti-nutritional factors as bambara groundnut was added. Alkaloid are active component of stimulants, tranquilizers and are not only in food systems but in also in medicine because they can act quickly in specific areas of the nervous system. The results obtained indicate *kunun tsamiya* may have medicinal properties. Flavonoids, phytic acids and tannins contents were similar to the report by Owheruo *et al*. (2018) on the physicochemical properties of malted finger and pearl millets wherein he reported the phytic acid content of pearl millet as 910mg/100g, tannin content of pearl millet as 0.10g/100g. Tannin have been reported to lower digestibility of most nutrients especially protein (Ali *et al.*, 2003). Flavonoid has been reported to exhibit anti-oxidant activity, the presence of flavonoid in foods, a phenolic compound may contribute to health potential of that food. There was a general decrease in the anti-nutritional content of the foods of *Kunun tsamiya* when compared with their higher levels in theraw materials. This might be attributed to processing through which the flours were obtained involving soaking, de-hulling, cooking, etc., which have been found to reduce anti-nutrient levels in grains.

Table 7b. Anti-nutrients Contents of the Bambara Groundnut Supplemented Pearl Millet-Based *Kunun tsamiya* and Control

Sample code	Alkaloid (g/100g)	Flavonoid (g/100g)	Phytic acid (mg/100g)	Tannin (g/100g)
K_0M_f(100:00)	0.07 ± 0.01^a	0.19 ± 0.01^a	4.29 ± 0.16^a	0.07 ± 0.01^a
K_1M_fB(90:10)	0.06 ± 0.00^a	0.15 ± 0.01^b	2.90 ± 0.17^b	0.05 ± 0.00^b
K_2M_fB(80:20)	0.03 ± 0.00^b	0.12 ± 0.00^c	2.21 ± 0.17^c	0.04 ± 0.00^b

K= *Kunun tsamiya* Subscripts 1 and 2 denote for supplementation with Bambara groundnut flour at 10%& 20% levels, whereas 0 denotes for the control, M_f= Millet flour, B_f=Bambara groundnut flour;

Mean values in the column bearing the identical superscripts are significantly not different (P>0.05) of duplicate determinations.

In-vitro Protein and Starch Digestibility of the Bambara Groundnut Fortified Pearl Millet-Based *Kunun tsamiya* and the Unfortified Control

The i*n-vitro* protein and starch digestibility of the bambara groundnut fortified pearl millet-based *Kunun tsamiya* and the control are presented in Table 8. At 1hr the *in-vitro* protein digestibility ranged from 66.86 to 68.76%, K_2M_fB (80:20) being highly digestible greater than the other formulations and K_0M_f (100:00) being the least with 66.86%. After 6 h formulations K_2M_fB (80:20) and K_0M_f (100:00) maintained being the highly and less digestible respectively. *In*-vitro-starch digestibility ranged from 68.99% to 72.17% with K_0M_f (100:00) being the highly digestible (72.17%) greater than the other food formulations and K_2M_fB (80:20) being the least digestible (68.99%). *In-vitro* protein digestibility increased with an increase in bambara groundnut flour inclusion (0-20%) to the pearl millet-based *Kunun tsamiya*. The increase in *in-vitro* protein digestibility at 1 & 6hrs might be attributed to the bambara groundnut flour inclusion as it's a grain rich in protein. Mohammed *et al.* (2018) reported that supplementation of millet flour with 15% moringa seed flour significantly (p<0.05) increased the *in-vitro* protein digestibility of the supplemented flour to 79.42%. The increment in *in-vitro* protein digestibility could also be due to anti-nutrients degradation by microorganisms and to partial degradation of complex storage proteins into simple and soluble products. Boiling was also found to improve *in-vitro* protein digestibility (Aremu *et al.*, (2016)) on effect of processing on *in-vitro* protein digestibility of underutilized legumes grown in Nigeria. The present findings is inline with the report by El Hag *et al.* (2013) and Taylor and Taylor (2002) that combination of fermentation and cooking significantly improved the digestibility of sorghum. The improvement in protein digestibility after boiling was due to the reduction in anti-nutritional factors such as saponins, alkaloids, tannins and cyanide. The starch digestibility decreased with an increase in the level of bambara groundnut grain flour supplementation to the pearl milled-based *Kunun tsamiya*. This might be attributed to the high amylase content since high amylase content may increase starch digestibility (Annor *et al.*, 2017). In general, millet protein digestibility can be reduced by several factors, notably the presence of tannin and dietary fiber (Annor *et al.*, 2017) but these tsamiya were found to be low in dietary fiber.

Table 8. *In-vitro* Protein Digestibility of the Bambara Groundnut Supplemented Pearl Millet-Based Foods and the Controls

Sample code	Protein Digestibility @1hr	Protein Digestibility @6hrs	Starch Digestibility
K_0M_f(100:00)	66.86±0.01[c]	68.17±0.01[c]	72.17±0.01[a]
K_1M_fB(90:10)	67.92±0.01[b]	68.78±0.01[b]	70.85±0.01[b]
K_2M_fB(80:20)	68.76±0.01[a]	69.17±0.01[a]	68.99±0.00[c]

K= *Kunun tsamiya* Subscripts 1 and 2 denote for supplementation with Bambara groundnut flour at 10%& 20% levels, whereas 0 denotes for the control, M_f= Millet flour, B_f=Bambara groundnut flour;

Mean values in the column bearing the identical superscripts are significantly not different (P>0.05) of duplicate determinations.

Sensory evaluation Results

Table 9 displays the sensory evaluation results of the bambara groundnut fortified pearl millet-based *Kunun tsamiya* samples. There is significant difference (p<0.05) in terms of appearance and mouth feel in all the *kunun tsamiya* food samples. There was no significant difference (p>0.05) in *kunun tsamiya* from K_0M_f (100:00) and K_2M_fB (80:20), K_1M_fB (90:10) and K_2M_fB (80:20), K_0M_f (100:00) and K_1M_fB (90:10) for aroma, texture and general acceptability respectisvely. *Kunun tsamiya* from 80:20 blend had the best attributes and therefore the most preferred.

Table 9. Sensory evaluation Results

Sample code	Appearance	Aroma	Texture	Mouth feel	General acceptability
K_0M_f (100:00)	7.00±0.80[a]	6.10±0.97[a]	7.00±0.800[a]	6.00±0.46[b]	4.60±0.94[b]
K_1M_fB (90:10)	4.10±0.72[c]	4.60±1.05[b]	5.30±0.80[b]	4.40±1.14[c]	5.00±0.80[b]
K_2M_fB (80:20)	5.50±1.54[b]	6.70±0.80[a]	5.40±0.68[b]	7.30±0.92[a]	7.40±0.68[a]

K= *Kunun tsamiya* Subscripts 1 and 2 denote for supplementation with Bambara groundnut flour at 10%& 20% levels, whereas 0 denotes for the control, M_f= Millet flour, B_f=Bambara groundnut flour;

Mean values in the column bearing the identical superscripts are significantly not different (P>0.05) of twenty (20) respondents.

5.0. Conclusion

In conclusion, fortification of the millet-based *Kunun tsamiya*, with Bambara groundnut flour (0-20%) had improved the ash, fat, protein and energy contents of *Kunun tsamiya*. The microbial load in the processed *Kunun tsamiya* foods samples revealed moderate counts which meant that the foods were safe for consumption even at ambient storage for less than three days. Finally, the study had succeeded in improving the functional, nutritional quality without altering sensory properties of the millet-bambara groundnut *Kunun tsamiya*. The modified tsamiya can be considered an alternative source of good quality food for resource-poor families with reduced antinutrients.

It is recommended that further studies should target higher level of bambara groundnut inclusion and use of chemical preservatives to lengthen kunun tsamiya shelf life as well as the further enhancement of the nutritive value considering the consumers worldwide are now nutrition conscious and for greater acceptability outside the shores of its origin. Aseptic packaging is avocated which will ensure wider distribution and acceptability.

Declarations

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Competing Interests Statement

The authors declare having no competing interest with any party concerned during this publication.

Consent for Publication

The authors declare that they consented to the publication of this study.

Authors' contributions

All the authors made full contribution starting from proposal writing, visualization, methodology, data analysis, first draft writing, review and editing.

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