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Assessment of the nutritional quality of weaning food prepared from fermented blends of sorghum (Ogi) and soybean

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Abstract

This study investigated the nutritional quality of weaning food prepared from fermented blends of sorghum (ogi) and soybean. The raw samples were processed into flour and were mixed in ratio of 60:40 and 70:30 respectively. Lactic acid bacteria (LAB) were isolated from fermented ogi and were accessed for their technological properties. The pH and total titratable acidity of the ogi was accessed, proximate composition and shelf-life of the weaning blends were determined by standard methods. A total of 10 LAB isolates were obtained, characterized and identified as *L. plantarum* (50%), *L. fermentum* (30%), *L. delbrueckii* (10%), and *L. brevi* (10%). Lactic acid, diacetyl and hydrogen peroxide produced by the LAB isolates ranged from 1.203 ± 0.006 - 3.410 ± 0.010, 1.21 ± 0.02 - 3.63 ± 0.05 and 0.650 ± 0.060 - 1.910 ± 0.040 (mg/mL) respectively. The fermentation of the ogi resulted in pH reduction from 4.5 ± 0.01- 2.40 ± 0.01 and increased titratable acidity 12.49 ± 0.01 - 23.00±0.01 g/L. The 60:40 weaning blend of sorghum ogi flour and soybean improved protein, ash, crude fiber, moisture, fat, vitamin A, ascorbic acid, riboflavin, and beta carotene content compared to a 70:30 blend. The blend also showed improvements in mineral content, with a significantly higher overall nutritional value compared to the 70:30 blend. Coliforms were not observed during the shelf-life monitoring. This study concluded that these blends meet daily nutritional requirements, provide health benefits, and meet recommended standards for weaning.

Keywords: Complementary foods; Lactic acid bacteria; Nutritional quality; Ogi; Sorghum; Soybean; Weaning

1. Introduction

Weaning involves gradually introducing foods other than breast milk into a baby's diet to provide basic nutrients and support the transition to adult diets. Breast milk is often insufficient for rapid growth after six months, so appropriate weaning foods are introduced to supplement it and support the child's development [1,2]. Complementary feeding is recommended between 6-24 months of age [3], containing balanced nutrients like 25-50% protein, copper, riboflavin, thiamine, calcium, manganese, and 75-100% phosphorus, zinc, and iron [4, 5].

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Commercial complementary foods, often associated with exclusivity and luxury, are popular among high-income groups, perpetuating inequality and marginalizing lower-income individuals, hindering true food equality for all by focusing on brand names and price tags [6]. To address this, weaning foods from local, readily available raw materials can be adopted to meet nutritional requirements and promote food equality.

Ogi is a popular meal commonly used as a complementary food for infant in Nigeria. It is prepared from cereal grains such as (*Sorghum bicolor*), millet (*Pennisetum americanum*) and maize (*Zea mays*). The traditional preparation of ogi involves soaking grains in water for 72 h at 28 ± 2°C and milling into a smooth paste. The slurry obtained is then sieved using a muslin cloth to remove the bran, germ and hull. The filtrate undergoes secondary fermentation for 24-72 hours to develop its sour taste [7, 8], aided by lactic acid bacteria and yeasts, which improves nutritional value, organoleptic properties, shelf life, and food preservation [9]. However, ogi is low in nutritional quality due to the absence of essential amino acid such as lysine, threonine, and tryptophan, crucial for infant growth and development [10]. This loss is attributed to processing techniques during preparation. [11]. To improve its nutritional value, studies have focused on enriching ogi gruel with legumes like soy-beans, as a strategy to enhance the cereal meal's nutritional requirements [12, 13, 14].

Soyabean, a popular protein source, is expected to become the primary protein source in the future to address Protein Calorie Malnutrition (PCM), as animal-based protein is too expensive for many people, and to bridge the growing gap between protein demand and availability [15]. Soybean, a nutritious staple food, is gaining popularity due to its health benefits, including plant-based protein, essential amino acids, fiber, antioxidants, and phytochemicals, making it a beneficial addition to a balanced diet used in milk, oil production, livestock feeds, and industrial applications [16, 17].

Sorghum and soybean combination prevents malnutrition during weaning, as cereals lack essential nutrients. Sorghum provides carbohydrates and energy, creating a balanced diet for children transitioning from breastfeeding to solid foods, establishing healthy eating habits early and reducing long-term malnutrition risk [18]. The study aimed to develop affordable, nutritious complementary foods using processed sorghum and soybeans through fermentation and roasting techniques, enhancing nutrient availability and making these foods easily prepared in rural areas.

2. Material and methods

2.1. Collection of samples

Sorghum (*Sorghum bicolor L*), and brown soybean (*Glycine max*) were purchased from Oja-Oba market, Ibadan, Oyo state, Nigeria. The samples were collected in a separate sterile polythene bag and transported to the Microbiology and Biotechnology Laboratory of First Technical University, Ibadan.

2.2. Preparation of samples

2.2.1. Preparation of soybean

Two hundred grams (200 g) of soybean were roasted in an oven (3606 Thermo Oven Lab-line Vacuum) at 100 ^{o}C for two hours. The roasted soybean seeds were dehulled by hand to remove the seed coat and milled into powder using a clean electric grinder (VTCL Excella Grinder-1000W), sieved through a fine mesh of 0.5mm pore size, and stored at room temperature in an airtight plastic bucket (Figure 1) [19]

2.2.2. Preparation of sorghum

Two hundred grams (200g) of sorghum was steeped in 5 liters of distilled water at room temperature (28 ± 2 ^{o}C) for 96 hours. The steeped sorghum was wet-milled to remove bran, hulls, and germ (Electric Grain Grinder 3000W) and sieved with a clean muslin and allow to ferment for 48 hours at (28 ± 2 ^{o}C). The steep corn water was decanted, and the sorghum ogi was packed in a clean muslin bag, tied to release residual water, and left to drain for about 18-24 hours. The drained sorghum ogi was collected and oven dried at 55 ^{o}C for 72 hours (3606 Thermo Oven Lab-line Vacuum), dried milled into ogi powder using an electric grinder (VTCL Excella Grinder-1000W), sieved through a sieve a fine mesh of 0.5mm pore size, and stored in an airtight plastic bucket at temperature 4 ^{o}C (Figure 1) [19].

2.2.3. pH and titratable acidity (TTA) of the fermented sorghum ogi

The pH and titratable acidity were determined using the AOAC [20] method, with samples taken at intervals of 24 hours to 96 hours using a digital pH meter (HANNA INSTRUMENT 8021). The total titratable acidity of 25 mL of ogi samples

was determined by titrating them with 0.1N NaOH until a pink color appeared with three drops of phenolphthalein (1 % w/v) as an indicator.

2.3. Isolation of lactic acid bacteria

One gramme (1 g) of the sorghum ogi slurry was aseptically taken and subjected to microbiological analysis added to 90 ml sterile 0.1% peptone water (Oxoid, UK) and homogenized by using vortex machine (CM-101 Remi Cyclo Mixture, 1000 RPM) for 10 seconds. The homogenate was further diluted to ten-fold serial dilution. Dilution 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6} were pour-plated in sterile De Man Rogosa Sharpe (MRS) agar plates (Oxoid, UK) in duplicates and incubated anaerobically in Gas Pak jars (GasPak System, BBL) at 30 °C for 48 hours. Representative colonies were randomly picked and purified by repeated streaking on MRS agar plates. Pure cultures were grown on MRS agar slants and kept at 4 °C for further use [21].

2.4. Physiological and biochemical characterization of lactic acid bacteria isolates

Lactic acid bacteria were examined for physiological and biochemical characteristics, including Gram staining, catalase, indole, oxidase, methyl red, Voges-Proskauer, citrate, nitrate reduction, starch hydrolysis, gelatin liquefaction, casein hydrolysis, bile tolerance, sugar fermentation, ammonia production from arginine and gas production from MRS broth [22, 23, 24, 25, 26). Probable lactic acid bacteria were identified and confirmed using Bergey's Manual of Systematic Bacteriology [27] and Automated Biometric Identification System (ABIS online).

2.5. Technological properties of the lactic acid bacteria

2.5.1. Lactic acid production

The AOAC [20] method was used to estimate lactic acid production by titrating 25 ml of 24-hour-old broth cultures with 0.1 N NaOH, using phenolphthalein as an indicator. The titratable acidity was calculated using the provided formula.

$$\textbf{Titratable acidity} = \frac{\textbf{Volume(ml)of NaOH} \times \textbf{Normality of NaOH} \times \textbf{Lactic acid equivalent}}{\textbf{Volume of sample used}} \ldots . \textbf{Equation 1}$$

Normality of NaOH= 0.1, Lactic acid equivalent = 90.08mg, Volume of sample used = 25mL

2.5.2. Diacetyl production

The LAB isolates' diacetyl production was estimated using the AOAC [20] method. A 7.5ml hydroxyl amine solution was added to 25ml of 24-hour old MRS broth culture, and the flasks were titrated with 0.1N HCl to a green-yellow end-point using bromophenol blue as an indicator. Diacetyl was calculated using the formula as provided:

$$AK = \frac{(B - S)(100 - E)}{W} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . . \textbf{Equation 2}$$

AK=Percentage of diacetyl, B=ml of 0.1N HCl consumed in titration of the sample, E=Equivalent factor of 1 mL of 0.1N HCl to diacetyl=21.52mg, W=Volume of sample used, S= Volume of ml 0.1N HCl consumed in titration of 7.5 mL Hydroxyl amine.

2.5.3. Hydrogen peroxide production

Twenty milliliters (20 mL) of 0.1 M H_2SO_4 were added to 25 mL of the MRS broth cultures of the test isolates (24 h). Titration was carried out with 0.1 N potassium permanganate. Each mL of 0.1 M H_2SO_4 is equivalent to 1.70 mg of Hydrogen peroxide and decolorization of the sample was regarded as an endpoint [20].

$$Hydrogen\ Peroxide\ Concentration = \frac{mL\ KMnO4\ x\ NKMnO4\ x\ M.E}{mL\ H2SO4\ x\ Volume\ of\ sample\ used}\ x\ 100 \ldots . . \textbf{Equation 3}$$

ml $KMnO_4$=Volume of $KMNO_4$ used $NKMNO_4$=Normality of $KMNO_4$ mL H_2SO_4=Volume of H_2SO_4 added, M. E=Equivalence factor of H_2O_2=1.701mg

2.5.4. Growth at different pH and salt concentration (4% NaCl)

De Man Rogosa Sharpe (MRS, Oxoid) broth was adjusted to pH 3, 7 and 12 using 1N HCl and 5N NaOH and 4 % NaCl, and sterilized by autoclaving at 121 °C for 15 minutes. The LAB isolates were inoculated into the MRS broth and

incubated anaerobically in Gas Pak jars (GasPak System, BBL) at 30 °C for 48 hours The medium's turbidity was measured at 600nm, while uninoculated broth served as a control.

2.6. Formulation of the weaning foods

Two composite weaning blends were formulated using varying ratios of sorghum ogi flour and soy-bean flour in 60:40 and 70:30 (Figure 1). This combination was chosen based on each ingredient's predicted nutrient content, protein content, and energy density in order to meet the acceptable WHO-recommended nutrient intake for infants.

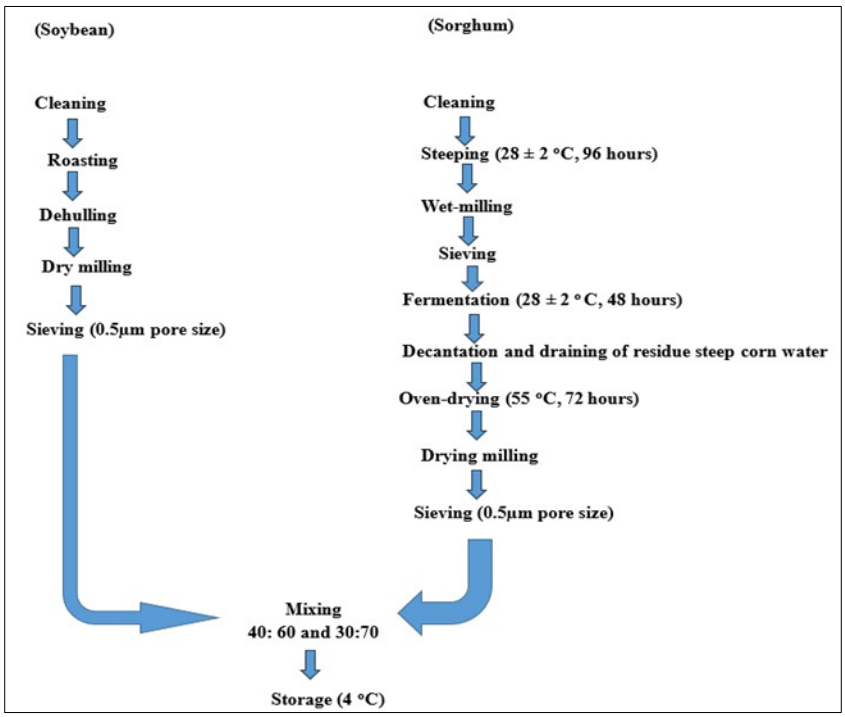

Figure 1 Process flowchart of the weaning blends (Adeyemo *et al.,* 2019)

2.7. Proximate composition of the weaning blends

2.7.1. Determination of moisture content

The moisture content of the weaning blend samples was determined by drying clean crucibles in a hot air oven at 100 °C for 1 hour, then cooling in a desiccator. Two grams of each sample were then weighed and dried at 100°C until a constant weight was obtained [28].

$$\%\ moisture\ content = W2 - W3\ \times 100\ \div W2 - W1 \ldots\ldots\ldots\ldots \textbf{Equation 4}$$

W1 = Initial weight of the empty crucible; W2 = weight of dish + sample before drying; W3 = weight of dish + sample after drying

2.7.2. Determination of fat

The Soxhlet extraction method was used to determine fat content of the weaning blend samples, following AOAC's guidelines [28]. A Soxhlet extractor with a reflux condenser and a 500 mL round bottom flask was used. Two grams of sample were weighed into a labelled thimble, and 300 ml of petroleum ether was filled into the flask. The extractor thimble was sealed, refluxed for 6 hours, and collected. Petroleum ether was dried at 105 °C for 1 hour and oven-cooled before weighing.

$$\%\ Fat = Weight\ of\ fat\ \times 100\ \div Weight\ of\ sample \ldots\ldots \textbf{Equation 5}$$

2.7.3. Determination of crude protein

The micro-Kjeldahl method was used to determine protein percentage in the weaning blend samples. A gram of each sample was weighed into a Kjeldahl flask, and 2.5 g of anhydrous Na_2S0_4, 0.5 g of $CUSO_4$, and 5 mL concentrated H_2S0_4 were added. The flask was heated in a flame chamber, then transferred to a volumetric flask. The digest was distilled, mixed with 5 mL boric acid indicator and 3 drops methyl red, and titrated against 0.01 N HC1, resulting in a purple-colored endpoint. [28]. The percentage protein was calculated using the following expression.

$$\%\ Nitrogen = T \times 14.01\ \times 0.01 \times 20 \times 100\ \div 1.0\ \times 100 \ldots\ldots \textbf{Equation 6}$$

T = Titer value; 1.0 g = Weight of the sample 20 = Dilution factor (i.e. from 10,015) 0.01 = Normality of HCl 14.01 = Atomic mass of nitrogen

2.7.4. Determination of total ash

The AOAC [28] procedure was used to determine ash content in the weaning blend samples. Two grams of each sample were weighed, ignited, and cooled before being transferred to a muffle furnace at 550°C. After 8 hours, the sample was moistened, dried, and re-ashed at 550 °C for an additional hour. The percentage of ash was calculated using the following expression.

$$\%\ Ash = Weight\ of\ Ash\ \times 100\ \div Weight\ of\ sample\ used \ldots\ldots \textbf{Equation 7}$$

2.7.5. Determination of crude fiber

The AOAC [28] method was used to determine crude fiber in the weaning blend samples by boiling two grams of each sample in 200 mL 1.25 % H_2SO_4 for 30 minutes, filtering through cloth, washing with water, returning to 200 mL NaOH, washing with 1% HCl, draining, and drying. The residue was then transferred to a silica ash crucible, dried, and cooled. Percent crude fiber was calculated using this method.

$$\%\ Crude\ fiber = Loss\ in\ weight\ on\ ignition\ \times 100\ \div Weight\ of\ the\ sample.. \textbf{Equation 8}$$

2.7.6. Determination of carbohydrate

The total carbohydrate content was estimated as the difference between 100 and the total sum of moisture, fat, protein, crude fiber, and ash as described by AOAC [28]

2.8. Determination of minerals and Vitamins

The mineral contents including sodium, potassium, iron, zinc and phosphorus content of the weaning blends were analyzed using an X-ray spectrometer (XRS) using a MiniPal 4 Version PW 4030 X-Ray Spectrometer (Perkin Elmer, Inc., USA). The samples were dried at 110°C, weighed, and mixed with a binder (PVC dissolved in Toluene) to absorb the primary beam. A turbulent mixer was used to homogenize the samples. Pellets of 1.5g were produced using a turbulent mixer at a pressure of 7182 mmHg. The pellets were loaded into the X-ray spectrometer chamber at a maximum voltage of 30 kV and a maximum current of 1 mA. A preset time of 10 minutes was used for each sample, and an inbuilt Si (Li) detector was used to count secondary X-rays. The X-ray spectrum was analyzed using a computer running a dedicated MiniPal Analytical Software**.** Riboflavin, thiamine, niacin and ascorbic acid were determined using standard procedures as described by AOAC [28].

2.9. Shelf-life evaluation of the weaning blends

Shelf-life monitoring was evaluated for three months, with one gram (1g) of each weaning blend taken aseptically and subjected to microbiological analysis added to 9 mL sterile 0.1 % peptone water. Total bacteria and coliform count were examined by inoculating the dilution $10^{-2,}$ 10^{-4} and 10^{-6} into Nutrient agar and MacConkey agar plate respectively, and incubated at 37 ^{o}C for 24-48 hours. The plates were observed and colonies were enumerated and expressed as cfu/mL.

2.10. Statistical analysis

Results were obtained in triplicates and presented as means with standard deviation and was subjected to one-way analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS version 16.0]. Significant differences between means were determined at 95 % confident limit ($p< 0.05$) and were compared using Duncan multiple range test.

3. Results and discussion

3.1. Identification and Technological properties of lactic acid bacteria isolates

Ten (10) lactic acid bacteria isolates were obtained, characterized and identified as *L. plantarum* (50%), *L. fermentum* (30%), *L. delbrueckii* (10%), and *L. brevis* (10%) **(Figure 2).** *L. plantarum* was found to be the predominant isolates obtained in this study. The predominance of *L. plantarum* among the LAB species has also been reported in previous studies on spontaneously fermenting of cereals (Adeyemo and Onilude, 2014; Sharma *et al.,* 2020). This may be due to the limited nutritional requirement of *L. plantarum*, which is advantageous for metabolism of several substrates compared to most other species of Lactobacillus [29].

The amounts of lactic acid, diacetyl, and hydrogen peroxide produced by lactic acid bacteria isolates ranged from 1.203 ± 0.006 - 3.410 ± 0.010, 1.21 ± 0.020 - 3.63 ± 0.050 and 0.650 ± 0.060 - 1.910 ± 0.040 (mg/mL), respectively (Table 1**)**. The highest amounts of lactic acid, diacetyl, and hydrogen peroxide were produced by *L. plantarum* SS3 and *L. plantarum* SS6. The production of lactic acid lowers the pH of the fermenting medium and produces bioactive inhibitors like diacetyl and hydrogen peroxide, which are primarily responsible for the antimicrobial activity [30]. Tannock [31] linked production level and proportion to strains, medium compounds, and physical parameters, so the different antimicrobial compound concentrations observed could be the result of different LAB strains producing them.

The optical densities of the LAB isolates at pH 3, 7, and 12 as well as growth at 4% NaCl at 600 nm were revealed in table 2. The highest absorbance was recorded by *L. plantarum* SS3 at pH 3 (0.580 ± 0.0005), pH 12. (0.960 ± 0.0005) and 4% NaCl (0.24 to 0.66). The LAB isolates' growth at pH 3 is consistent with Cotter's findings, [32], who attributed this growth to the relative ATPase activities of microorganisms at various pH levels, particularly at low pH. The prophylactic effects of these organisms and the probiotic benefits of LAB were both enhanced by LAB's capacity to grow at low pH [33].

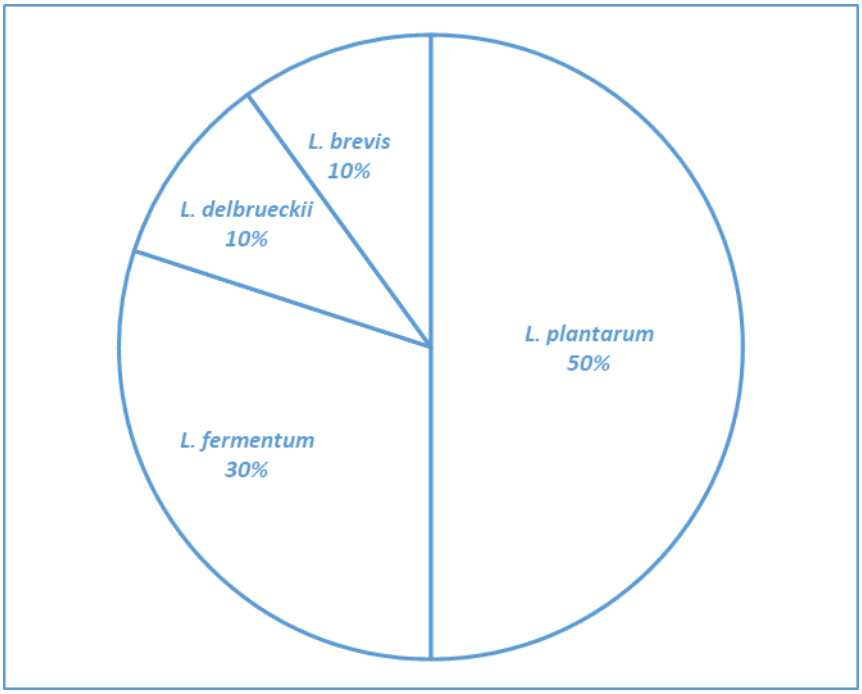

Figure 2 Percentage occurrences of the LAB isolates

Table 1 Technological properties of the LAB isolates (Antimicrobial productions (mg/mL))

Probable LAB identity	Lactic acid	Diacetyl	Hydrogen peroxide
L. plantarum SS1	1.407±0.012	2.03±0.03	0.93±0.03
L. fermentum SS2	2.707±0.012	1.91±0.02	0.94±0.04
L. plantarum SS3	3.410±0.010	3.63±0.05	1.83±0.03
L. delbrueckii SS4	1.215±0.013	2.22±0.02	1.33±0.04
L. plantarum SS5	1.307±0.012	1.84±0.05	1.64±0.05
L. plantarum SS6	1.203±0.006	2.74±0.04	1.91±0.04
L. brevis SS7	1.510±0.010	2.05±0.07	1.81±0.04
L. brevis SS8	1.410±0.010	1.21±0.02	1.38±0.09
L. plantarum SS9	1.316±0.014	2.10±0.10	0.65±0.06
L. fermentum SS10	1.707±0.012	2.64±0.04	1.57±0.09

Table 2 Optical density at 600nm of the LAB isolates of different pH and 4% NaCl

Probable LAB identity	pH 3	pH 7	pH 12	4% NaCl
L. plantarum SS1	0.24 ± 0.0003	0.47 ± 0.0003	0.70 ± 0.0012	0.27 ± 0.0006
L. fermentum SS2	0.28 ± 0.0005	0.52 ± 0.0010	0.98 ± 0.0005	0.54 ± 0.0005
L. plantarum SS3	0.58 ± 0.0005	0.42 ± 0.0012	0.96 ± 0.0005	0.25 ± 0.0010
L. delbrueckii SS4	0.22 ± 0.0005	0.45 ± 0.0010	0.86 ± 0.0011	0.65 ± 0.0012
L. plantarum SS5	0.27 ± 0.0004	0.48 ± 0.0012	0.98 ± 0.0012	0.66 ± 0.0005
L. plantarum SS6	0.38 ± 0.0002	0.63 ± 0.0010	0.84 ± 0.0010	0.24 ± 0.0010
L. brevis SS7	0.24 ± 0.0010	0.69 ± 0.0010	0.69 ± 0.0012	0.25 ± 0.0012
L. brevis SS8	0.28 ± 0.0010	0.57 ± 0.0004	0.72 ± 0.0010	0.36 ± 0.0002
L. plantarum SS9	0.24 ± 0.0010	0.62 ± 0.0008	0.60 ± 0.0012	0.25 ± 0.0010
L. fermentum SS10	0.29 ± 0.0010	0.34 ± 0.0010	0.93 ± 0.0005	0.66 ± 0.0005

3.2. pH and TTA of the fermented sorghum ogi

The fermentation of sorghum ogi over 96 hours resulted in a pH reduction of 4.50 ± 0.01 - 2.40 ± 0.01 and an increase in Total Titratable Acidity (TTA) from 12.49 ± 0.01- 23.00 ± 0.01 (Figure 3). This decrease in pH values is likely due to the production of organic acids by lactic acid bacteria [34], which eliminate undesirable microorganisms; a desirable quality of a weaning food. The degree of acidification observed is comparable to the values reported by Adeyemo *et al.* (19).

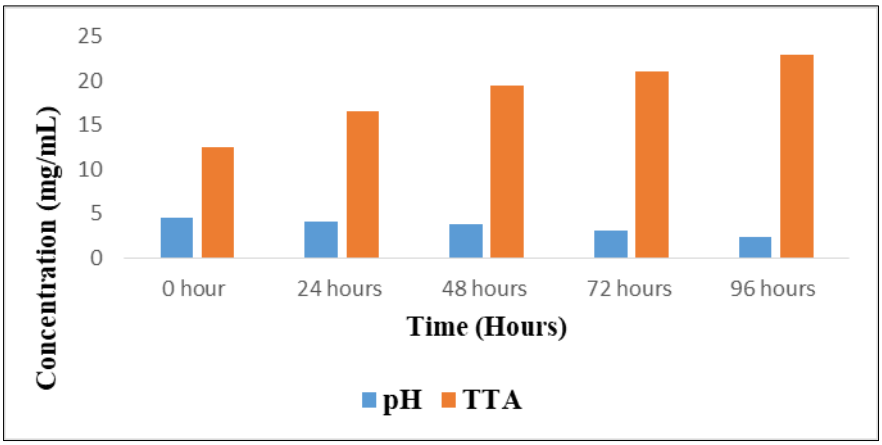

Figure 3 pH and TTA of the sorghum ogi

3.3. Proximate, vitamins, and mineral composition weaning blend samples

The proximate composition of the weaning blends is presented in Table 3. The weaning blend of sorghum ogi flour combined with soybean (60:40) had an improved proximate value of protein, ash, crude fiber, moisture content and fat ($p<0.05$) of 26.882 ± 0.044, 2.5.3±0.577, 0.590 ± 0.001, 9.333 ± 0.256 (%) respectively. The increased crude protein content of weaning blends is due to a combined ratio of soybeans and sorghum, which meet the Codex Alimentarius Standards [12] for complementary/weaning foods of 14 - 30g between 6 months and 5 years for infant diets. Protein supplementation can improve the quality of cereals protein, as observed by traditional evaluation methods. [35, 36, 37, 38, 39, 40). The values of crude fiber obtained for the weaning blends are within the Protein-Calorie Advisory Group's recommended range (PAG) (5 -8%) [41]. It is advised that infants consume a low-fiber diet because fiber-rich foods can be filling and may hinder nutrient absorption CDC [42]. The moisture content of the weaning blends is within the recommended values for weaning/complementary foods Less than 10% moisture content is recommended for better keeping quality. Moisture content is an important determinant of shelf-stability of foods. Low moisture content implies low water activity, which prevents micro-organism from acting freely on formulations [43]. The weaning blends' carbohydrate contents for the 60:40 and 70:30 ratios were 55.695 ± 0.780 and 61.344 ± 0.810 (%) respectively. The carbohydrate content may be attributed to the sorghum grain's amylose and amylopectin components [44]. Carbohydrate is most significant and easily accessible source of energy. Additionally, they play a crucial role in maintaining healthy immune, nervous, digestive, and heart systems [45]. The results obtained in this study are consistent with the findings of Wakil and Onilude [46], Elemo *et al.* [47]. Weaning blends of sorghum ogi combined with soybean (60:40) had improved vitamin A, ascorbic acid, riboflavin, and beta carotene contents ($P<0.05$) of 0.471 ± 0.001, 6.100 ± 0.755, 0.213 ± 0.015 and 76.663 ± 2.887 respectively; compared to weaning blends of sorghum ogi combined with soybean (70:30) (Table 3). Vitamins are antioxidants and foods from plant sources are good sources of vitamins [48]. The mineral content of the weaning blend of sorghum ogi combined with soybean (60:40) had an improved phosphorus, iron, potassium, sodium, calcium and zinc ($P < 0.005$) of 665.333 ± 12.097 13.500 ± 0.619, 778.400 ± 7.638, 688.952 ± 6.512, 130 ± 5.000 and 0.56 ± 0.100 respectively (Table 3). The increase in temperature after fermentation may be due to the accumulation of proteolytic enzymes produced by natural bacteria, which break down grain cell walls resulting in an increase in mineral content [49]. The findings are consistent with the findings of Day and Morawicki [50], which attribute the increase in mineral content to the loss of dry matter during fermentation as microbes degrade carbohydrates and protein, as well as the use of pretreatment.

3.4. Shelf-life monitoring of the weaning blends

The shelf-life of the weaning blends was monitored over a three-month period at room temperature (28 ± 2 ^{o}C), relative humidity at 65% (Table 4). The total bacteria count ranged from 0.11 ×10 - 0.23 ×10 which was within the tolerable limit recommended by FDA's Bacteriological Analytical Manual (BAM). However, no coliform counts were discovered. This is due to the weaning blends' moisture content, which prevents the proliferation and growth of spoilage organisms [43]. Moisture is an indicator of a food's shelf life. Moisture Content less than 10% has been reported to be responsible for food preservation [51].

Table 3 Proximate, minerals and vitamins of the weaning blends

Parameters	SOF	SBF	SOF +SBF (60:40)	SOF +SBF (70:30)
Proximate composition (%)				
Carbohydrate	68.682 ± 0.534^{d}	21.788 ± 0.706^{a}	55.695 ± 0.780^{b}	61.344 ± 0.810^{c}
Proteins	12.478 ± 0.044^{a}	49.166 ± 0.044^{d}	26.882 ± 0.044^{c}	24.518 ± 0.044^{b}
Ash	0.500 ± 0.100^{a}	5.403 ± 0.577^{d}	2.500 ± 0.577^{c}	1.43 ± 1.155^{b}
Crude fibre	0.274 ± 0.001^{a}	1.079 ± 0.001^{d}	0.590 ± 0.001^{b}	0.538 ± 0.001^{b}
Moisture	9.667 ± 0.577^{d}	5.167 ± 0.289^{c}	5.000 ± 0.645^{b}	4.833 ± 0.764^{a}
Fat	0.400 ± 0.001^{a}	17.330 ± 0.345^{d}	9.333 ± 0.256^{c}	7.333 ± 0.156^{b}
Mineral compositions (mg/100g)				
Phosphorus	130.000 ± 10.000^{a}	490.000 ± 13.229^{c}	665.333 ± 12.097^{d}	340.000 ± 13.229^{b}
Iron	12.024 ± 0.546^{b}	11.488 ± 0.206^{a}	12.500 ± 0.619^{b}	13.036 ± 1.237^{c}
Potassium	217.950 ± 9.871^{a}	909.198 ± 8.070^{d}	778.400 ± 7.638^{c}	359.420 ± 8.070^{b}
Sodium	305.463 ± 0.001^{a}	855.028 ± 0.001^{d}	688.952 ± 6.512^{c}	544.844 ± 4.509^{b}
Calcium	135.000 ± 5.000^{c}	145.000 ± 5.000^{d}	130.000 ± 5.000^{b}	125.000 ± 5.000^{a}
Zinc	0.600 ± 0.100^{c}	0.750 ± 0.001^{d}	0.560 ± 0.100^{a}	0.500 ± 0.100^{a}
Vitamin compositions (mg/100g)				
Vitamin A	0.291 ± 0.011^{a}	0.548 ± 0.008^{d}	0.471 ± 0.001^{c}	0.375 ± 0.001^{b}
Folic acid	0.133 ± 0.003^{b}	0.015 ± 0.003^{a}	0.391 ± 0.001^{c}	0.471 ± 0.001^{d}
Ascorbic acid	11.33 ± 0.004^{d}	3.123 ± 0.000^{a}	6.100 ± 0.755^{c}	3.190 ± 0.355^{b}
Vitamin D	0.023 ± 0.001^{b}	0.021 ± 0.002^{b}	0.016 ± 0.001^{a}	0.019 ± 0.001^{a}
Riboflavin	0.253 ± 0.021^{b}	0.130 ± 0.010^{a}	0.213 ± 0.015^{b}	0.170 ± 0.010^{b}
Niacin	2.867 ± 0.153^{d}	2.067 ± 0.153^{b}	1.867 ± 0.153^{a}	2.333 ± 0.153^{c}
β-carotene	68.333 ± 7.638^{a}	90.000 ± 5.000^{d}	76.663 ± 2.887^{c}	70.000 ± 5.000^{b}

Values are presented as Means ± Standard Deviation where n = 3. Values with different superscript letter within each row are significantly different ($p< 0.05$). SOF: Sorghum ogi flour, SBF: Soybean flour, SOF +SBF (60:40): Blend of Sorghum ogi flour and soybean flour (60-40), SOF +SBF (70:30): Blend of Sorghum ogi flour and soybean flour (70-30).

Table 4 Shelf-life monitoring of the weaning blends

Samples	Month 1		Month 2		Month 3	
	TBC	TCC	TBC	TCC	TBC	TCC
SOF	0.23 ×10^{3}	No growth	0.15×10^{3}	No growth	0.10 ×10^{3}	No growth
SBF	0.15 ×10^{3}	No growth	0.12 ×10^{3}	No growth	0.12×10^{3}	No growth
SOF +SBF (60:40)	0.13 ×10^{3}	No growth	0.11 ×10^{3}	No growth	0.11 ×10^{3}	No growth
SOF +SBF (70:30)	0.14 ×10^{3}	No growth	0.10 ×10^{3}	No growth	0.10 ×10^{3}	No growth

SOF: Sorghum ogi flour, SBF: Soybean flour, SOF +SBF (60:40): Blend of Sorghum ogi flour and soybean flour (60-40), SOF +SBF (70:30): Blend of Sorghum ogi flour and soybean flour (70-30). TBC: Total Bacteria Count; TCC: Total Coliform Count

4. Conclusion

The West Africa Sub-region's abundant cereals and legumes can be used to provide adequate weaning diets for infants, aiming to achieve the UN's Sustainable Development Goals by providing affordable, simple, and probiotic-rich weaning

foods. These blends meet daily nutritional requirements, provide health benefits, and meet recommended standards for weaning. Future research should optimize weaning food formulations to enhance nutritional value, sensory appeal, and infant acceptance, while also exploring the incorporation of locally available fruits and vegetables for improved health benefits.

Compliance with ethical standards

Disclosure of conflict of interest

The authors have not declared any conflict of interests.

References

[1] Sajilata G, Singhal RS, Kulkarni PR. Weaning foods: a review of the Indian experience. Food and nutrition bulletin. 2002; 23 (2), 208-226.

[2] Özogul F, Hamed I. The importance of lactic acid bacteria for the prevention of bacterial growth and their biogenic amines formation: A review. Critical reviews in food science and nutrition. 2018; 58 (10): 1660-1670.

[3] World Health Organization (WHO) Infant and young child feeding: Model chapter for textbooks for medical students and allied health professionals. WHO. 2009 Press, Geneva.

[4] Abeshu MA, Lelisa A, Geleta B. Complementary Feeding: Review of Recommendations, Feeding Practices, and Adequacy of Homemade Complementary Food Preparations in Developing Countries - Lessons from Ethiopia. Front Nutrition, 2016; 3 (41)

[5] Oladiran D, Emmambux M. Locally Available African Complementary Foods: Nutritional Limitations and Processing Technologies to Improve Nutritional Quality - A Review. Food Reviews International, 2020; 1-31.

[6] D'Odorico P, Carr JÁ, Davis KF, Dell'Angelo J, Seekell DA. Food inequality, injustice, and rights. BioScience. 2019: 69 (3), 180-190.

[7] Akinleye OM, Fajolu IO, Fasure AK, Osanyinpeju OS, Aboderin AO, Salami OO. Evaluation of microorganisms at different stages of production of Ogi in Alimosho Community, Area Southwest, Lagos, Nigeria. American Journal of Research Communication, 2014; *2*(10): 215-230.

[8] Omemu, AM, Bankole MO. Consumer's knowledge, attitude, usage and storage pattern of ogi-a fermented cereal gruel in south west, Nigeria (2015).

[9] Kaškonienė V, Stankevičius M, Bimbiraitė-Survilienė K, Naujokaitytė G, Šernienė L, Mulkytė K, Maruška A. Current state of purification, isolation and analysis of bacteriocins produced by lactic acid bacteria. Applied Microbiology and Biotechnology 2017;101(1) 1323-1335.

[10] Simović M, Banjanac K, Ćorović M, Jakovetić S, Milivojević A, Vukašinović-Sekulić M, Bezbradica D. Selection of lactic acid bacteria strain for simultaneous production of α-and β-galactosidases. Zaštita materijala 2016; 57(2); 265-273.

[11] Bolaji OT, Adenuga-Ogunji L, Abegunde TA. Optimization of processing conditions of Ogi produced from maize using response surface methodology (RSM). Cogent Food & Agriculture 2017; *3*(1); 1407279.

[12] Codex, Alimentarius. Guidelines on formulated complementary foods for older infants and young children CAC/GL 8-1991 (adopted 1991, revised 2013).

[13] Codex, Alimentarius. Codex standard for processed cereal-based foods for infants and children. CXS 74-1981 (Adopted in 1981. Revised in 2006. Amended in 2017, 2019) (Vol. 4): Codex Alimentarius.

[14] Temba MC, Njobeh PB, Adebo AO, Olugbile AO, Kayitesi E. The role of compositing cereals with legumes to alleviate protein energy malnutrition in Africa. International Journal Food Science Technology. 2016; 51(3): 543-554.

[15] Ukeyima MT, Acham IO, Awojide CT. Quality evaluation of ogi from acha (*Digitaria exilis*), soybean (*Glycine max*) and carrot (*Daucus carota L.*) composite flour. Asian Journal of Biotechnology and Bioresource Technology, 2019; *5*(1), 1-11.

[16] Fabiyi EF. Soyabean processing, utilization and health benefits. Pakistan Journal of Nutrition. 2006;5(5): 453-457.

[17] Yee K, Lee Y, Lee SY. Consumer acceptance of an extruded soy-based high-protein breakfast cereal. Journal of food science. 2008; 73(1): S20-S25.

[18] Tanyitiku, MN, Petcheu ICN. Formulation and Nutritional Analysis of Processed Sorghum, Soybeans, and Mango Complementary Foods. Journal of Food Research. 2022;11(3), 11-21.

[19] Adeyemo SM, Abimbola OG. Assessment of the nutritional qualities of a locally-produced weaning blend of sorghum ogi flour fortified with Bambara groundnut flour. The International Journal of Biotechnology, 2019; 8(2), 115-124.

[20] Association of Official Analytical Chemists (AOAC). Official Methods of Analysis, Association of official analytical chemist 19th edition 2000; Washington D.C., USA.

[21] Ogodo AC, Ugbogu OC, Agwaranze DI, Ihiabe FU. Some studies on the bacteriological quality of sorghum-based commercially prepared fermented Ogi (Akamu) in Wukari, Nigeria. American Journal of Food Science and Nutrition 2017; *4*(4): 48-51.

[22] Harrigan WF, Mccance ME. Laboratory Methods in Food and Dairy Microbiology. Academic Press. London, New York. 1998; 8(8): 66-71

[23] Olutiola PO, Famurewa O, Sonntag HG. An introduction to general microbiology: a practical approach 1991. Germany: Heidelberger Verlagsanstalt und Druckerei GmbH Heidelberg.

[24] Axelsson L. Lactic acid bacteria: classification and physiology. *Food Science and Technology-New York-Marcel Dekker*- 2004:139 (1) 1-66.

[25] Oyeleke SB, Oyewole OA, Kuta FA, Nabara HY. Occurrence of lactic acid bacteria in some locally fermented products sold in Minna markets. 2006

[26] Espeche MC, Pellegrino M, Frola I, Larriestra A, Bogni C, Nader-Macías, MF. Lactic acid bacteria from raw milk as potentially beneficial strains to prevent bovine mastitis. Anaerobe 2012; 18(1): 103-109.

[27] Holt JG, Krieg NR, Sneath PH, Staley JT, Williams ST. Bergey's Manual of determinate bacteriology. 1994.

[28] Association of Official Analytical Chemists (AOAC). Official methods of analysis of the Association of Analytical Chemists International, 18th edition 2012; AOAC, Gaithersburg, MD

[29] Gálvez A, Abriouel H, López RL, Omar NB. Bacteriocin-based strategies for food biopreservation. International journal of food microbiology. 2007; 120(1-2): 51-70.

[30] Assanvo JB, Agbo GNZ, Coulin P, Heuberger C, Farah Z. Production methods and physicochemical characteristics of cassava inoculum and attiéké from Southern Côte d'Ivoire. Journal of Food Research 2019; 8(6), 18-36.

[31] Tannock, G. W. A special fondness for lactobacilli. Applied and environmental microbiology 2004; 70(6), 3189-3194.

[32] Cotter PD, Ross RP, Hill C. Bacteriocins—a viable alternative to antibiotics? Nature Reviews Microbiology, 2013; 11(2), 95-105.

[33] Omafuvbe BO, Enyioha LC. Phenotypic identification and technological properties of lactic acid bacteria isolated from selected commercial Nigerian bottled yoghurt. African Journal of Food Science, 2011; 5(6): 340-348.

[34] Kobawila SC, Louembe D, Keleke S, Hounhouigan J, Gamba C. Reduction of the cyanide content during fermentation of cassava roots and leaves to produce bikedi and ntoba mbodi, two food products from Congo. African journal of Biotechnology 2005; 4(7), 689-696.

[35] Onilude AA, Sanni AI, Ighalo MI "Process upgrade and the microbiological, nutritional and consumer acceptability of infant weaning food from fermented composite blends of cereals and soybean." 2004: 64-68.

[36] Wakil SM, Onilude AA. Microbiological and chemical changes during production of malted and fermented cereal-legume weaning foods. Adv. Food Sci, 2009;31(3): 139-145.

[37] Nagai T, Staatz JM, Bernsten RH, Sakyi-Dawson EO, Annor GA. Locally processed roasted-maize-based weaning foods fortified with legumes: factors affecting their availability and competitiveness in Accra, Ghana. African Journal of Food, Agriculture, Nutrition and Development, 2009: *9*(9).

[38] Adeyemo SM, Onilude AA. Reduction of oligosaccharide content of soybeans by the action of Lactobacillus plantarum isolated from fermented cereals. African Journal of Biotechnology, 2014.*13*(37)

[39] Kehinde Alawode E, Idowu, MA, Adeola AA, Oke EK, Omoniyi SA. Some quality attributes of complementary food produced from flour blends of orange flesh sweetpotato, sorghum, and soybean. Croatian journal of food science and technology 2017;*9*(2): 122-129.

[40] Adebiyi FG, Adediran KI, Olaoye OA, Mosuro AO, Olaomi AO, Ogunwole OA. Biological evaluation of cereals and legumes weaning blends for infant weaning Food. Food Public Heal, 2021;11(2): 44-52.

[41] Protein Advisory Group (PAG). Guidelines of Protein Rich Mixture for Use In Weaning Foods. Protein Advisory Group. New York, 50. 2009.

[42] Center for Disease Control and Prevention (CDC). Division of Nutrition, Physical Activity, and Obesity, National Center for Chronic Disease Prevention and Health Promotion: US Physical Activity Statistics. http://www. cdc. gov/nccdphp/dnpa/physical/stats. 2022.

[43] Hallén E, İbanoğlu Ş, Ainsworth P. Effect of fermented/germinated cowpea flour addition on the rheological and baking properties of wheat flour. Journal of food engineering, 2004; 63(2): 177-184.

[44] Soe Htet MN, Wang H, Tian L, Yadav V, Samoon HA, Feng B. Integrated starches and physicochemical characterization of sorghum cultivars for an efficient and sustainable intercropping model. Plants, 2022; 11 12: 1574.

[45] Khan A, Khan NA, Bean SR, Chen J, Xin Z, Jiao Y. Variations in total protein and amino acids in the sequenced sorghum mutant library. 2023; Plants, *12*(8):1662.

[46] Wakil SM, Onilude AA. Microbiological and chemical changes during production of malted and fermented cereal-legume weaning foods. Adv. Food Sci, 2009; 31(3): 139-145.

[47] Elemo GN, Elemo BO, Okafor JNC. Preparation and nutritional composition of a weaning food formulated from germinated sorghum (Sorghum bicolor) and steamed cooked cowpea (Vigna unguiculata Walp) 2011.

[48] Yırtıcı Ü, Ergene A, Atalar MN, Adem Ş. Phytochemical composition, antioxidant, enzyme inhibition, antimicrobial effects, and molecular docking studies of Centaurea sivasica. South African Journal of Botany, 2022; 144(1), 58-71.

[49] Usman MA, Bolade MK, James S. Functional properties of weaning food blends from selected sorghum (*Sorghum bicolor (L.) Moench*) varieties and soybean (*Glycine max*).2016.

[50] Day CN, Morawicki RO. Effects of fermentation by yeast and amylolytic lactic acid bacteria on grain sorghum protein content and digestibility. Journal of Food Quality, 2018.

[51] Roshana MRR, Mahendran T. Storage Evaluation of Nutritionally Enriched Weaning Food for Infants. 2018