

## Maize and groundnut cake based formulated foods products: Influenced of fermentation and malting on nutritional and microbial properties

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### Abstract

Maize grains were divided into four treatment groups, namely: malted-fermented maize (MFM), malted non-fermented maize (MNFM), non-malted fermented maize (NMFMM) and non-malted non-fermented maize (NMNFM). Maize and Groundnut cake based products (MFMG, MNFMG, NMFMMG and NMNFMG) from all four maize grains were formulated. Germination (Malting) and fermentation were investigated as methods of improving the nutritional and functional properties of the formulations. Inocula recycling (use of 50% fermenting mixture as starter) was done. The essential amino acid composition ranged from 340.00 mg/16gN (NMNFMG) to 360.06 mg/16gN (MFMG) for isoleucine and 7.38.01 mg/16gN (NMNFMG) to 806.06 mg/16gN (MFMG) for leucine. Most of the essential amino acid contents of non-fermented / non malted weaning food was significantly ( $p < 0.05$ ) less than the corresponding fermented and/or malted samples. A greater proportion of the essential amino acids in fermented and/or malted samples shown higher amino acid score and were reported above 100 while NMNFMG showed amino acids score below 100 in some essential amino acids. Amino acid score above 100 indicates high availability of amino acids. Fermentation resulted in a significant ( $p < 0.05$ ) increase in the microbial load with total aerobic counts ranging from  $1.5 \times 10^4$  CFU/g in NMNFMG to  $1.0 \times 10^{10}$  CFU/g in MFMG. The results of the microbial quality test of the complementary foods were within acceptable limits (Commission for microbiological specification for foods limit) and therefore, the product is microbiologically safe. Sensory scores for flavor ranged from 3.09 out of 7 (fair) for MFMG to 6.13 (like very much) for Nutrend. The MNFMG was characterized as having a sweet taste while the MFMG and NMFMMG were characterized as having fairly sour taste. The appearance score of 5.04 for MNFMG was significantly ( $p < 0.05$ ) higher compared with the other test products. The product made from Nutrend had the highest score of 6.20 (like very much) while MGFMR had a value of 3.09 (neither like nor dislike) for overall acceptability. Germination and/or fermentation of maize with added groundnut cake have been used to formulate acceptable products which could be used as a weaning food. The addition of groundnut cake implies that the final products have potential for improved protein quality beneficial to its consumers.

**Keywords:** Germination, fermentation, amino acid score, microbial safety, sensory acceptability

### Introduction

Maize is commonly cultivated and consumed in Nigeria as one of the major staple food commodities. Different types of food products are produced through processing of maize. On average, maize grains contain approximately 8.06g crude protein/100g, 3.94g ether extract/100g, 1.40g ash/100g, and 73.4g carbohydrates/100g, while mushroom contains about 26.0g crude protein/100g, 6.0g ether extract/100g, 6.0g ash/100g, and 19.3g carbohydrates/100g (Ariahu *et al.*, 2009) [1]. Groundnut is among the most important sources of edible vegetable oils in Nigeria and is mainly cultivated for this reason (Hussaini & Oladimeji, 2025). Its nutty and pleasant flavor makes it a highly suitable vegetable food when roasted. It is commonly boiled and consumed with maize in various regions of the country. Groundnut flour is employed as a food condiment in soups, stews, sauces, confectioneries, puddings, and bakery products (Srivastava *et al.*, 2018). The flour is increasingly used to fortify or enrich carbohydrate-based foods such as cassava flour, gari, maize, and yam flour to boost their protein content for infants, children, and other vulnerable groups (Chuku & Okogbule, 2017).

An earlier study by Egbegbedia *et al.* (2025) [11] showed that when maize is combined with legumes or nuts, food formulations of improved nutritive value, which could be

used as weaning foods, can be produced. When ground cereals and legumes are cooked with water into a porridge or gruel, two problems arise. Such products have a low protein bio-availability caused by anti-nutritional factors. The neutral pH (6.0–6.5) of such porridges make them a good substrate for growth of spoilage and pathogenic microorganisms.

Germination and fermentation are among the simple, easily adaptable technologies for reduction of bulkiness (high viscosity) and increasing shelf-life of cereal and legume based food formulations. High counts of indicator (e.g. *Escherichia coli*) and spoilage (e.g. *Bacillus cereus*) microorganisms were found in stored, non-fermented traditional Gambian weaning foods. While severe contamination of Kenyan children's food with Enterobacteriaceae and *Staphylococcus aureus* was reported by van (Ariahu *et al.*, 1999). Challenge tests using *Salmonella typhimurium* and *Staphylococcus aureus* revealed growth in porridges from non-fermented concentrates while the inoculated bacteria died in the fermented porridges.

The objectives of this study were to investigate (a) the effects of germination and fermentation on the microflora, (b) microbial safety, (c) amino acid profile, (d) chemical

scores and sensory properties maize and groundnut cake - based food products.

## Materials

### Materials and Methods

#### 1. Sourcing of raw Materials

Maize grains were obtained from a local market in Makurdi, Benue State, Nigeria. The grains were cleaned prior to use.

#### 2. Sample Preparation

##### 2.1. Malting (Germination)

Malting was performed following the method described by Eli *et al.*, (2022) [4]. Maize grains were disinfected with a 5% NaCl solution, soaked in tap water at  $30 \pm 2^\circ\text{C}$  for 12 hours (changing the water every 4 hours), and germinated for 72 hours on a moistened bag, with water sprayed every 12 hours. After germination, the grains were dried at  $60^\circ\text{C}$  in an air draft oven for 3 days. The dried seeds were manually split to remove testa and rootlets, which were winnowed off. The cotyledons were milled into flour (0.2 mm particle size). The resulting non-malted (NMM) and malted (MM) maize flours were packaged in airtight polyethylene bags and stored at  $30 \pm 2^\circ\text{C}$  for product formulation and analysis.

##### 2.2. Fermentation

Fermented maize dough was prepared using an accelerated natural lactic acid fermentation method (back – slopping). Non-malted (NM) and malted (MM) maize flours (120 g each) were mixed with 80 mL of distilled water and fermented in covered glass beakers at room temperature ( $30 \pm 2^\circ\text{C}$ ) for 24 hours. Half of the fermented mixture was used as a starter culture for subsequent fermentation cycles. The pH and titratable acidity were monitored until the pH stabilized. The fermented mixtures were dried at  $60^\circ\text{C}$  for 3 days, milled to a 0.2 mm particle size, and packaged in low-density polyethylene bags. The flours were stored in airtight containers at ambient conditions prior to product formulation and analysis (Forwoukeh *et al.*, 2024) [7].

#### 3. Product formulation

Material balancing was used to compute the amount of each maize and groundnut cake required to obtain 16g protein/100g from their respective proximate composition to obtain four blends of maize and groundnut cake consisting non germinated, non-fermented maize + groundnut cake [NMNFMG], germinated, non-fermented maize + groundnut cake (MNFMG), non-germinated, fermented maize + groundnut cake (NMFMG) and germinated fermented maize +groundnut cake (MFMG) in accordance with material balancing described by Ariahu *et al.*, (2009) [1] Figure 1. In this method, the amount of ingredients required in the final product is obtained by calculation based on pre-determined percentage composition.

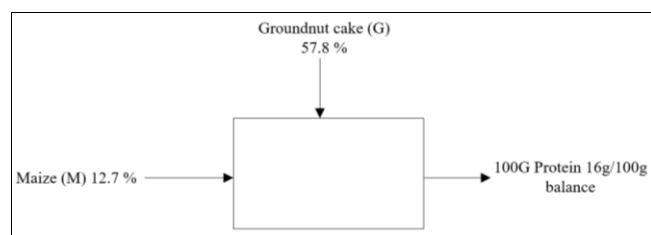


Fig 1: Material balancing

### Figure legend

Total mass balance

$$M + G = 100\dots \quad (2)$$

Protein balance

$$0.12M + 0.578G = 16\dots \quad (1)$$

#### 4. Sensory evaluation

Sensory evaluation was performed using descriptive analysis and effective testing (Ariahu *et al.*, 2009) [1]. The panelists consisted of 20 mothers' familiar with commercial weaning foods. They were staff members and graduate students of the Joseph Sarwuan Tarka University, Makurdi, Benue State, Nigeria. A 7-point unstructured descriptive scale (1=very poor, 7 = excellent) was used to rate the sensory attributes of appearance and flavor. The panelists (semi-trained) were asked to identify flavor as rancid, putrid, beany, sour, sweet or other. A 7-point structured hedonic scale (1 – dislike extremely, 7 = like extremely) was used to score overall acceptability of the products. Each attribute was evaluated separately (at a time) at daily intervals between 10.00 a.m. - 11.00 am from Monday to Friday. The assessments were conducted under fluorescent light in a special room with cubicles (separate partitions for each judge) for sensory evaluations. At each session, each panelist judged five samples. The order of presentation of the samples to the panel was randomized (Ariahu *et al.*, 2009) [1].

The formulated products were each cooked with distilled water (1:20w/v) by boiling and stirring with a glass rod to prevent sticking and lump formation for 10 min into smooth gruels. The porridges were stored in insulated 2L food flasks (Eleganza, Nigeria Plc, Lagos) from which they were served to the panelists. The gruels were served in 100ml colourless transparent plastic cups coded with 4-digit random numbers. About 50ml of each sample was served hot (70-800C). Colourless transparent plastic spoons were provided for testing the samples. Fresh tap water was provided to rinse the mouth between evaluations. The familiarity of panel members with commercial weaning foods and the added training (semi-trained panelists) served as control to calibrate the panel.

#### 5. Determination of Amino Acid Profile of the Complimentary Foods

Amino acid analysis was by ion exchange chromatography (IEC) (Sengev *et al.*, 2016) [15] using the Technicon Sequential Multisample (TSM) Amino Acid Analyser (Technicon Instruments Corporation, New York). The period of analysis was 76 min for each sample. The gas flow rate was 0.50 mL/min at  $60^\circ\text{C}$  with reproducibility consistent within  $\pm 3\%$ . The net height of each peak produced by the chart recorder of the TSM (each representing an amino acid) was measured and calculated. The amino acid values reported were the averages of two determinations. Norleucine was the internal standard

#### 6. Estimation of chemical scores (%) of the formulations

Amino acid scores (AMSS) were estimated by (Chinonyerem *et al.*, 2017) [3] formula:

$$\% \text{ chemical score} = \frac{\text{value of amino acid in complementary food} \left( \frac{\text{g}}{100\text{g protein}} \right)}{\text{FAO Ref. valued}} \times 100$$

## 7. Microbial Analysis of the Complementary Foods

**Sample processing:** Each sample (10.0 g) was homogenized with 90.0 mL of sterile normal saline to prepare stock solution. Stocks were serially diluted (1:10) to 10<sup>-5</sup> by adding 100µl of stock solution to 900µl normal saline in eppendorfs tubes. 100µL of diluted sample was inoculated on Nutrient agar (NA), Mannitol Salt Agar (MSA), Violet Red Bile Salt Glucose agar (VRBG) and Sabouraud Dextrose agar (SDA) media following spread plate method and incubated at 37 °C for 18-24 hours except for SDA which was incubated at 25 °C for 48-72 hours. All media were procured from Himedia Laboratories Ltd., India (Khanom *et al.*, 2016)<sup>[9]</sup>.

### 7.1. Total Viable Count of the complementary foods

Nutrient agar (NA) media was used to determinate the total bacterial count. NA plates were dried and labeled for appropriate dilutions to be used for dilution and spread plate method. Plates were inoculated and incubated at 37 °C for 18-24 hours. Total number of bacteria cfu/g of sample was calculated and recorded for interpretation of the result by Gernah *et al.* (2011)<sup>[5]</sup>; Khanom *et al.* (2016)<sup>[9]</sup>; Uchegbu Nneka *et al.* (2019)<sup>[12]</sup>.

### 7.2. Yeast and Moulds count of the complementary foods

Diluted samples were inoculated onto SDA medium supplemented with chloramphenicol (40mg/L) by spread plate method as mentioned earlier. The plates were incubated at 25°C for 48-72 hours. Visible colonies were counted and calculated as the total yeast and mold and recorded as cfu/g (Gernah *et al.*, 2011<sup>[5]</sup>; Khanom *et al.*, 2016<sup>[9]</sup>; Oben *et al.*, 2021)<sup>[13]</sup>

### 7.3. Determination of total Enterobacteriaceae

Violet Red Bile Salt Glucose agar (VRBG) agar was used for propagation of Enterobacteriaceae. After incubation at 37 °C for 24 hours characteristic purple and red colonies were counted as members of Enterobacteriaceae. Suspected colonies were counted to determine cfu per gram of sample (Khanom *et al.*, 2016)<sup>[9]</sup>.

### 7.4. Determination of counts of *Staphylococcus aureus*

Mannitol Salt Agar (MSA) was used to determine the counts of *Staphylococcus aureus* in flour samples. The suspected colonies of *Staphylococcus aureus* showed yellow color for mannitol fermentation and yellow halo for coagulase production around the colony. Suspected colonies were further confirmed by catalase, coagulase tests and Gram staining technique (Khanom *et al.*, 2016)<sup>[9]</sup>. Typical *S. aureus* colonies were counted to calculate cfu per gram of sample.

## 8. Statistical analysis

Significant (P<0.05) differences in sensory scores, essential amino acids profile, chemical scores and Microbiological quality were determined by analysis of variance. Duncan's multiple range was used for separating the means (Amanda *et al.*, 2023).

## Results and Discussion

### 1. Sensory scores of Maize and groundnut cake food formulations

**Table 1:** Sensory scores of Maize and groundnut cake food formulations

Product	ATTRIBUTES				
	Flavour	Texture	Taste	Appearance	Overall acceptability
MFMG	3.09 <sup>d</sup> ± 0.01	4.01 <sup>c+</sup> ±0.01	3.09 <sup>d</sup> ±0.03	5.03 <sup>c</sup> ± 0.04	3.09 <sup>c</sup> ± 0.54
MNFMG	5.07 <sup>b</sup> ± 0.04	4.06 <sup>c</sup> ±0.02	5.06 <sup>b</sup> ±0.01	5.04 <sup>b</sup> ± 0.02	4.04 <sup>b</sup> ± 0.02
NMFMG	4.08 <sup>c</sup> ± 0.01	4.03 <sup>c</sup> ±0.04	5.02 <sup>c+</sup> ± 0.02	5.03 <sup>c</sup> ± 0.02	4.03 <sup>c</sup> ± 0.01
NMNFMG	4.05 <sup>c</sup> ± 0.02	5.03 <sup>b</sup> ±0.01	50.1 <sup>c</sup> ± 0.04	5.01 <sup>c</sup> ± 0.54	4.01 <sup>d</sup> ± 0.75
NUTREND	6.13 <sup>a</sup> ± 0.01	6.01 <sup>a</sup> ±0.05	6.09 <sup>a</sup> ± 0.02	5.87 <sup>a</sup> ± 0.21	6.20 <sup>a</sup> ± 0.42

Values are means of triplicate determinations ± S.D. Means followed by different superscript letters in the same column indicate significant difference at (p<0.05). MFMG: Malted Fermented Maize, MNFMG: Malted Non - Fermented Maize, NMFMG: Non- Malted Fermented Maize, NMNFMG: Non- Malted Non - Fermented Maize, G: Groundnut cake

Table 1 shows the sensory scores for porridges made of maize/groundnut cake and the control (Nutrend) formulation. Flavor scores ranged from 3.09 out of 7 for MFMG, 6.13 for Nutrend. Flavor scores for the control sample (Nutrend) was significantly (p<0.05) higher than the fermented and/or malted samples. The MNFMG was characterized as having a sweet taste while the MFMG and NMFMG were characterized as having fairly sour taste results. The sweet taste observed in the malted samples could be attributed to breakdown of the maize starch to

simple sugars during germination as earlier reported by (Forwoukeh *et al.*, 2024)<sup>[7]</sup>. The sour taste in the fermented products is attributed to actions of lactic acid bacteria resulting in hydrolysis of starch to organic acids. This observation goes to support the lesser pH and higher titratable acidity in the fermented products (Ariahu *et al.*, 2009)<sup>[1]</sup>. However, there is a significantly (p<0.05) lower score for appearance of the fermented products (3.09 and 4.03) than the non-fermented products (4.05 and 4.04). It was observed that malting significantly (p<0.05) improved the overall acceptability. This observation is conformity with reports with report by Egbegbedia *et al.* (2025)<sup>[11]</sup>. The porridge made from MNFMG had the highest score of 4.04 for overall acceptability. It was encouraging to note that although the fermented products had lower scores they were still acceptable to the panelist probably because sour gruels are common in local food preferences.

## 2. Essential Amino acids profile of maize and groundnut - cake formulated food products

**Table 2:** Essential Amino acids profile of maize and groundnut - cake formulated food products

Products	Essential Amino acids (mg/16gN)							
	Isoleucine	Leucine	Lysine	Phenylalanine	Methionine	Threonine	Tryptophan	Valine
MFMG	360.06 <sup>a</sup> ± 0.02	806.06 <sup>a±</sup> 0.01	190.01 <sup>d±</sup> 0.02	316.02 <sup>c±</sup> 0.03	166.01 <sup>a</sup> ± 0.02	236.04 <sup>a±</sup> 0.07	50.04 <sup>a±</sup> 0.08	326.03 <sup>a</sup> ± 0.05
MNFMG	350.09 <sup>b±</sup> 0.07	775.00 <sup>b±</sup> 0.04	200.01 <sup>c±</sup> 0.01	316.02 <sup>c</sup> ± 0.01	159.02 <sup>b</sup> ± 0.05	234.07 <sup>c</sup> ± 0.04	48.02 <sup>b±</sup> 0.01	324.06 <sup>c±</sup> 0.02
NMFMG	350.08 <sup>b±</sup> 0.09	773.09 <sup>b±</sup> 0.01	201.04 <sup>b±</sup> 0.03	316.09 <sup>b±</sup> 0.01	159.02 <sup>b±</sup> 0.06	235.03 <sup>b</sup> ± 0.05	48.05 <sup>b±</sup> 0.09	325.01 <sup>b±</sup> 0.07
NMNFMG	340.00 <sup>c±</sup> 0.02	738.01 <sup>c±</sup> 0.02	214.00 <sup>a±</sup> 0.04	317.08 <sup>a±</sup> 0.02	151.06 <sup>c</sup> ± 0.02	233.2 <sup>d±</sup> 0.08	46.08 <sup>c</sup> ± 0.01	323.08 <sup>d±</sup> 0.01
FAO/ WHO REF	270.00	300.00	270.00	180.00	140.00	18.00	9.00	270.00

Values are means of triplicate determinations ± S.D. Means followed by different superscript letters in the same column indicate significant difference at (p<0.05). MFMG: Malted Fermented Maize, MNFMG: Malted Non - Fermented Maize, NMFMG: Non- Malted Fermented Maize, NMNFMG: Non- Malted Non - Fermented Maize, G: Groundnut cake

Essential Amino acids profile of maize and groundnut - cake formulated food products are shown in Table 2: Most of the essential amino acid contents of non-fermented / non malted weaning food was significantly (p<0.05) less than the corresponding fermented and/or malted samples. This could be due to the synthesis of some essential amino acids during fermentation (Simwaka *et al.*, 2015 [19]; Bhathal and Kaur, 2015 [2]; Sengev *et al.*, 2016) [15]. The increase in amino acids in the fermented and/or malted product shows that the carbohydrate utilization is closely proportional to protein production during fermentation and malting. Sengev *et al.* (2016) [15] reported that single cell protein produced by *Aspergillus niger* contained 30.4 % crude protein and had an essential amino acid profile featuring a high lysine content and appreciable amounts of methionine and tryptophan. The

most important physiological processes associated with the germination phase are the synthesis of amylases, proteases and other endogenous hydrolytic enzymes, for the release of sugars and amino acids from starch and protein, respectively (Baranwal, 2017) [3]. Similar observations were found in a study by Shalaby & El-shourbagy (2016) [16]; Kaur *et al.*, (2020) [8]; Sibian & Riar, 2022 [18], who reported increase in essential amino acid content of germinated kidney bean. The quality of protein is mainly a function of its essential amino acids. The essential amino acids are necessary for tissue maintenance and are also required for the growth of infants (Shalaby & El-shourbagy, 2016) [16]. The lysine is and tryptophan usually low in plant products (Gulab *et al.*, 2022). The low chemical scores for lysine and tryptophan in relation to FAO/WHO reference pattern has nutritional and product development implications (Sá *et al.*, 2023). This observation limits the formulated foods to complementary roles with breast feeding in infants use of less exploited animal protein sources.

## 3. Chemical scores for maize and groundnut cake formulated food products

**Table 3:** Chemical scores for maize and groundnut cake formulated food products

Products	Essential Amino acids (mg/16gN)							
	Isoleucine	Leucine	Lysine	Phenylalanine	Methionine	Threonine	Tryptophan	Valine
MFMG	133.03 <sup>a</sup> ± 0.06	268.08 <sup>a±</sup> 0.03	170.04 <sup>b±</sup> 0.09	175.07 <sup>b±</sup> 0.01	118.60 <sup>a</sup> ± 0.01	130.20 <sup>b±</sup> 0.02	151.60 <sup>b±</sup> 0.01	120.90 <sup>a</sup> ± 0.02
MNFMG	130. <sup>b0</sup> ± 0.01	258.03 <sup>b±</sup> 0.04	174.01 <sup>a±</sup> 0.03	175.07 <sup>b</sup> ± 0.03	113.90 <sup>b</sup> ± 0.01	130.40 <sup>b±</sup> 0.01	153.60 <sup>a±</sup> 0.03	120.20 <sup>a±</sup> 0.01
NMFMG	129.03 <sup>c±</sup> 0.02	257.09 <sup>c±</sup> 0.02	174.06 <sup>a±</sup> 0.01	176.01 <sup>a±</sup> 0.05	113.70 <sup>b±</sup> 0.02	130.70 <sup>b</sup> ± 0.01	53.90 <sup>d±</sup> 0.02	120.40 <sup>a±</sup> 0.01
NMNFMG	125.09 <sup>d±</sup> 0.03	246.00 <sup>d±</sup> 0.05	79.03 <sup>c±</sup> 0.01	176.06 <sup>a±</sup> 0.01	108.30 <sup>c</sup> ± 0.01	131.20 <sup>a±</sup> 0.01	56.40 <sup>c</sup> ± 0.04	119.90 <sup>b±</sup> 0.08

Values are means of triplicate determinations ± S.D. Means followed by different superscript letters in the same column indicate significant difference at (p<0.05). MFMG: Malted Fermented Maize, MNFMG: Malted Non - Fermented Maize, NMFMG: Non- Malted Fermented Maize, NMNFMG: Non- Malted Non - Fermented Maize, G: Groundnut cake

The amino acid scores of food formulations are presented in Table 3. The detrimental factor for food protein quality greatly depends on the content and availability of amino acids (Sibian & Riar, 2022) [18]. A greater proportion of the essential amino acids in fermented and/or malted samples shown higher amino acid score were reported above 100 while NMNFMG showed amino acids score below 100 in some essential amino acids. Overall amino acid scores showed increment as a result of germination and fermentation (Sibian *et al.*, 2017) [17]. Amino acid score

above 100 indicates high availability of amino acids. This results agrees with reports presented by Sibian *et al* (2017) [17]; Sengev *et al.* (2016) [15]; Sibian & Riar (2022) [18], who reported fermentation and malting improved the availability of essential amino acid score of red kidney beans and sorghum. The most important physiological processes associated with the germination phase are the synthesis of amylases, proteases and other endogenous hydrolytic enzymes. During germination, the hydrolytic enzymes migrate from the germ into the endosperm where starch and protein are hydrolyzed to sugars and amino acids, respectively (Kaur *et al.*, 2020) [8]. The most important processes associated with the fermentation phase is the hydrolysis (by lactic acid bacteria and yeasts) of some complex organic molecules such as lipids, protein and phytin to fatty acids, lactic acid, acetic acid, amino acids and phosphate (Tope & Soji, 2013) [20].

#### 4. Microbiological quality of various maize- groundnut cake food formulations

**Table 4:** Microbiological quality of various maize- groundnut cake food formulations

Microbial parameter	Product			
	MFMG	MNFMG	NMFMG	NMNFMG
Total aerobic count	1.0 <sup>a</sup> x10 <sup>10</sup>	2.0 <sup>c</sup> x10 <sup>4</sup>	3.5 <sup>b</sup> x10 <sup>9</sup>	1.5 <sup>d</sup> x10 <sup>4</sup>
Yeast and molds	2.5 <sup>a</sup> x10 <sup>5</sup>	2.5 <sup>d</sup> x10 <sup>3</sup>	3.0 <sup>b</sup> x10 <sup>4</sup>	5.0 <sup>c</sup> x10 <sup>3</sup>
Yeast	1.5x10 <sup>3</sup>	<30	0.6x10 <sup>3</sup>	<30
Enterobacteriaceae	<30	0.15x10 <sup>3</sup>	<50	0.3x10 <sup>3</sup>
Staphylococcus	<30	<30	<30	0.1x10 <sup>3</sup>

Values are means of triplicate determinations ± S.D. Means followed by different superscript letters in the same row indicate significant difference at (p<0.05). MFMG: Malted Fermented Maize, MNFMG: Malted Non - Fermented Maize, NMFMG: Non- Malted Fermented Maize, NMNFMG: Non- Malted Non - Fermented Maize, G: Groundnut cake

The total aerobic, Enterobacteriaceae, Staphylococcus, Yeast and Mould counts of the maize – groundnut cake products are shown in Table 4. Fermentation resulted in a significant (p<0.05) increase in the microbial load with total aerobic counts ranging from 1.5x10<sup>4</sup> CFU/g in NMNFMG to 1.0x10<sup>10</sup> CFU/g in MFMG. Total viable count from this study was similar to those reported by Ariahu *et al.* (1999) and Nneka *et al.* (2019). The bacterial flora in the non – fermented products (NMNFMG, MNFMG) consisting mainly of bacillus staphylococcus, Enterobacteriaceae, and proteus species. Lactobacillus, Pediococcus, Leuconostoc and yeast species dominated in the fermented products. Enterobacteriaceae, Staphylococcus counts were low (<50 CFU/g) in the fermented products. These latter group of microorganisms can cause spoilage of food poisoning. Natural fermentation resulted to increased dominance by lactic acid bacteria and inhibition of growth of toxigenic microorganisms. The Enterobacteriaceae family contains genera such as Escherichia, Salmonella, Shigella and Yersinia which are borne gastroenteritis. Other enterotoxigenic genera including Staphylococcus, serratia and proteus have also been implicated in bacterial diarrheal diseases (Kiiru *et al.*, 2024) <sup>10]</sup>. The higher Bacillus counts in non- fermented products could be due to the high heat resistance of these microorganisms which could result in the survival of the blanching and drying processes used in product preparation and consequent growth in the less inhibitory low acidity medium. (pH 6.38 – 4.0).

#### Conclusion

Acceptable protein quality (essential amino acid profile and chemical scores products, which could be used as a weaning food, can be formulated from maize and groundnuts using germination and/or fermentation technologies. Fermentation and germination increased the protein quality (essential amino acid profile and chemical scores) of the product. The sensory properties of porridges from flours of the germinated seeds are superior to those from the fermented flours.

The use of an oven dryer for dehydration of the fermented concentrates due to limitation of equipment available exposed the products to unduly long periods of drying which could have affected their nutritional and organoleptic properties. The use of a drum dryer with its attendant advantage of a high temperature and short time (HTST) processing could potentially further improve the nutritional

and sensory properties of the fermented maize groundnut cake food formulations.

#### Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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#### Competing Interests

Authors have declared that no competing interests exist.

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