ISSN: 2338-1345 e ISSN 2808-8948 – Vol. 12(2) 49-60 https://ojs.bakrie.ac.id/index.php/APJSAFE/about

Asia Pacific Journal of Sustainable Agriculture Food and Energy (APJSAFE)

Physicochemical and microbiological properties of Finger Millet and Defatted Sesame seeds flours used as complementary foods

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Received: 31st July 2024 | Revised: 19th Oct 2024 | Accepted: 30th Oct 2024

Abstract- Finger millet and defatted sesame seeds were studied subject to germination and / or natural fermentation. Various kinds of treatment were given to the product which gave rise to non-germinated (NG) and non-fermented (NF) finger millet, germinated non-fermented (GN) and germinated fermented (GF) finger millet plus defatted sesame flour. Cerelac - commercial maize + soybean product was used as control with samples were formulated to provide 16g protein/100g solid based on their proximate composition using material balancing. Moisture content of complementary food ranged from 7.66- 8.13g/100g. Carbohydrate ranged from 63.92- 64.93g/100g with an equal increase in energy value from 368.04- 369.61kJ/100g. Also, the mineral content of complementary foods showed similar increase for calcium: 252.80- 281.10mg/100g, potassium: 946.35- 994.13mg/100g, iron: 4.87- 6.61mg/100g, zinc: 10.21- 11.45mg/100g with germination and fermentation. As expected, anti-nutritional factors reduced to acceptable values with oxalate ranging from 0.26- 1.96g/100g, tannins 0.44- 1.92g/100g, phytate 0.37- 2.31g/100g and cyanides 0.34-2.13g/100g. Total viable counts (cfu/g) ranged from 0.2×10^3 - 1.6×10^3 while there was no detection of *E.coli* in the samples.

Keywords— complementary foods, fermentation, germination, microbiological, minerals

INTRODUCTION

Breast milk is an important food for infants during growth and development. It is important for an infant to supplement breast milk with appropriate semi-solid foods for six months because they require sufficient nutrients for growing needs and high energy for vigorous activities (FAO, 2022). The introduction of complementary (weaning) foods after six months poses its challenges due to contamination, high bulk, temperature and pH resulting to diarrheal diseases among infants and young children in developing countries (Pollock, 2000). In fact, in rural settings, contamination of weaning food is at a higher level than drinking water (Lewis and Young 2001), though this varies between environmental settings (Abdelrahaman *et al.*, 2007, Velmurugu and Blair, 1991). Other factors that may lead to food-borne contamination are unhygienic storage practices, hot climate (Omary *et al.*, 2019), insufficient cooking time (Siwela *et al.*, 2010) and dirty feeding utensils for children. One of the commonest ways of acquiring food-borne disease is through the home and is due to unhygienic food practices (Gibson, 2019). Thus, mothers must adopt hygienic standards to reduce high loads of bacterial contamination of weaning foods and water (Devi *et al.*, 2011).

Complementary foods formulated must meet FAO/WHO/UNICEF standards/ principles of acceptability, low price, use of local food materials and high nutritional content to supplement breast milk (Dewey, 2003, Pelto *et al.*, 2003). Therefore, it should be easily accessible, digestible and readily available and consumed by the young children as they supply additional nutrients for growing needs (Ijarotimi *and Bakare,* 2006).

Proper blending and processing of complementary foods made from locally available materials like fingermillet and sesame seeds. These crops blends serve as complementary foods due to their supply of required amount of nutrients, prospects as vehicle for food fortification and functional foods (Zebib *et al*, 2015). The use of other varieties of millet like pearl millet, foxtail millet and proso millet for complementary foods has been the subject of more research (Omary *et al*., 2019-). Also, in developing countries, traditional foods are prepared mainly from rice, sorghum, and maize. These products may be inadequate in protein and minerals quality and quantity. There is a need to produce affordable complementary foods using locally available staple cereals and legumes / oil seeds through simple and adaptable technologies for the target groups. Therefore, the aim of the present study is to evaluate the effect of germination and fermentation on nutrient composition, mineral, anti-nutritional and protein quality of complementary foods formulated from germinated and fermented finger millet and defatted sesame seeds flours.

MATERIALS AND METHODS

A. Sources of raw materials and preliminary handling

Essentially 5kg of red finger millet (*Eleusine coracana, GPU-48- quality protein and drought resistant)* and white sesame seeds (*Sesamum indicum, SG-333-high protein content*) were bought from Wadata market, Makurdi. The raw materials were cleaned and sorted to remove defective and unwholesome particles.

B. Preparation of germinated and non-germinated finger millet flours

The processes for production of finger millet flours are shown in Fig. 1 as described by Ariahu *et al*., 1999b. Finger millet grains were washed and steeped in water at room temperature using the ratio of 1:3 (w/v grain: water) in a bucket. The steep water was replaced every 4 hours for a period of 12 hours and then drained. Wet grains were spread out to germinate while water was continuously sprinkled on it. The non-germinated and germinated grains were removed at 0 and 72 hours and dried. The dried seeds were rubbed between the palms to separate testa and rootlets from cotyledons and then the seeds windowed. The resulting dried seeds were milled using a blender, sieved and recycled to improve output.

C. Preparation of fermented finger millet flour

The fermented finger millet was obtained by natural lactic acid fermentation (Pradhan *et al.*, 2010-) as shown in Fig 1. 100g each of the germinated (GF) and non-germinated (NGF) finger millet was mixed with distilled water to form slurry then allowed to ferment naturally for 24 hrs. At the end of the period, 40% of the fermented mixture was used as a starter culture for a new fermentation cycle. pH and titratable acidity (an index of lactic acid bacteria activity) was monitored during this period. The process was allowed to continue to enable a stable and constant pH. The resultant concentrates were dried in an oven, milled in a blender to obtain germinated and fermented finger millet (GFF) and non-germinated fermented finger millet (NGFF).

D. Preparation of defatted sesame flour

The process for sesame seeds flour formulation by Velmurugu and Bakare, 1991 is shown in Fig.2. The seeds were sorted and cleaned to remove debris and stones. The seeds were soaked in warm water to soften the seed coat and dehulled by rubbing between palms followed by washing. The resultant seeds were dried, milled and defatted by a screw press method as described by Muthamilarasan *et al.* 2016. Defatted flour was analysed for fat until a fat content of 15% in the cake. The cake was dried in an oven and milled.

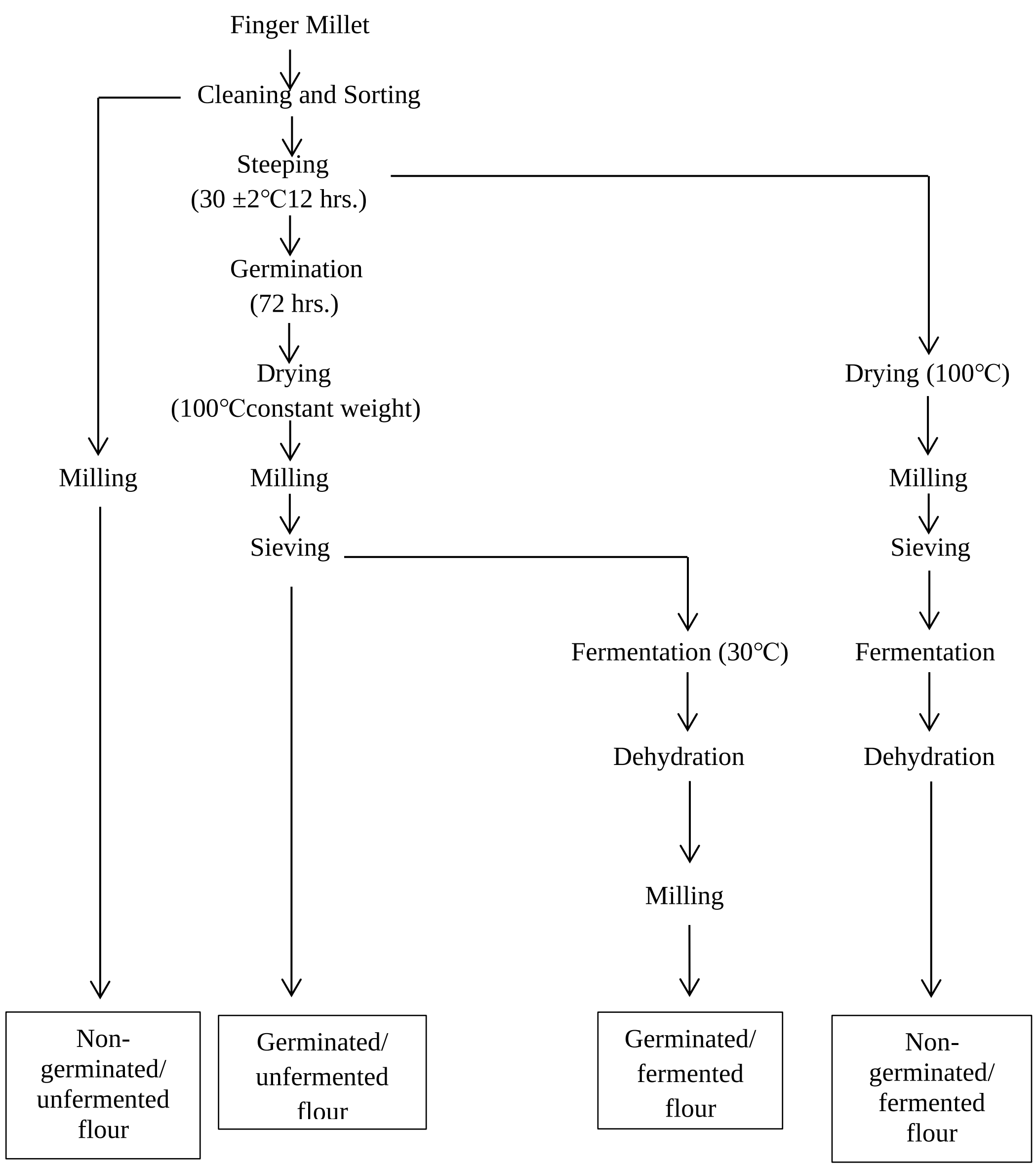

Fig.1: Preparation of germinated and fermented finger millet flour

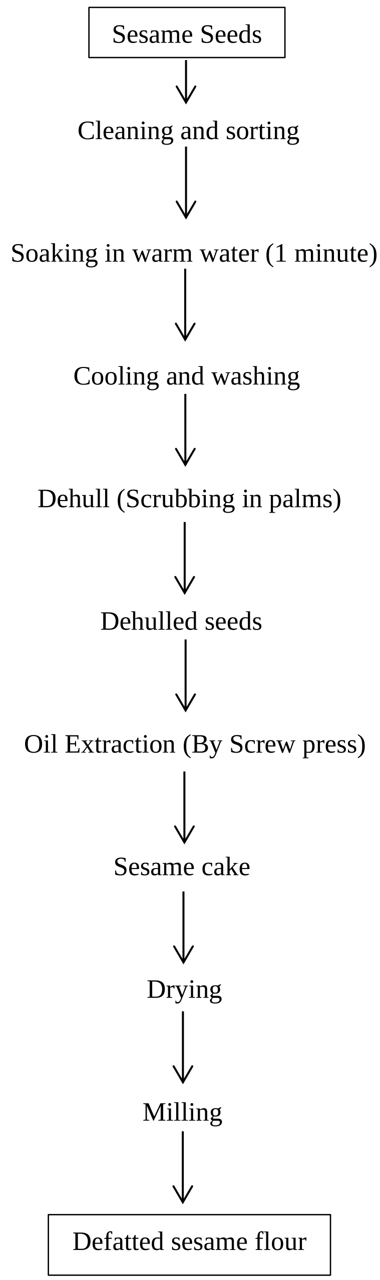

Fig. 2: Production of defatted Sesame seeds.
Source: Gernah *et al.* (2011)

E. Proximate and Mineral analysis Proximate Analysis

Standard procedures (AOAC, 2000) for determination of moisture content, crude fiber, crude fat, crude protein and ash were used. Carbohydrates were calculated by difference. Energy values were estimated by the Atwater factor method (4 x g protein, 9 x g fat, and 4 x g carbohydrates).

Mineral analysis

Analyses of zinc, iron, sodium, magnesium, calcium, potassium, and manganese were carried out using an atomic absorption spectrophotometer (AAS) method as described by Chethan, 2008. The mineral contents were evaluated using the AAS (AAS model SP9, Cambridge, UK).

pH Determination

The pH of the flour samples was measured using pH meter (model 2016, China). The method of Malomo *et al*., 2014 was adopted in which 2g of each blend was homogenized with 20 ml distilled water in a beaker. The pH electrode was standardized using a buffer of pH 4.00 and 9.00, rinsed with deionised water and dipped in the homogenate allowing for equilibrium before taking readings.

Bulk Density Determination

Water absorption capacity (WAC) and bulk densities were evaluated using the method described by ASAES standard 2017 while hydrogen cyanide, oxalate, tannins and phytate were determined as described by Sripriya, 1997.

$$\text{Bulk density (g/ml)} = \frac{Weight\ of\ sample\ (g)}{Volume\ occcupied\ (ml)} \quad (1)$$

$$WAC\ (\%) = \frac{volume\ of\ water\ used - volume\ of\ free\ water}{weight\ of\ sample\ used} \times 100 \quad (2)$$

Vitamin Analysis

Vitamin B1, B2, B3, B6, and carotene were evaluated using high performance liquid chromatography (HPLC) as described by FAO, 2012. About 3g of each sample is homogenized, centrifuged and filtered through a membrane. Peaks vitamins were recorded in relation to level of absorption.

Anti-nutrients Determination

The dried samples were analyzed for oxalate, phytate, tannins and hydrogen cyanide using the method by Sripriya, 1997.

Microbiological Analysis

Triplicate 11g samples were weighed aseptically from each formulated product and blended with 99ml of sterile water in a Warring blender to give 1:10 dilution of each homogenate as described by Gibson, 2019.

Statistical Analysis

Tukey's least significant difference (LSD) test was used for mean separation at 5% probability level as described by Babiker *et al.*, 2014. SPSS version 20.0 statistical software package was used for the statistical analysis of all the data. Similarities and differences amongst data were subjected to analysis of variance (ANOVA) by Duncan multiple range test (Bailey, 2000).

RESULTS AND DISCUSSIONS

Proximate composition of the formulated complementary foods.

The proximate compositions of the non-germinated non-fermented finger millet+ defatted sesame seed flour (NGNFFS), germinated non-fermented finger millet + defatted sesame seed flour (GNFFS), non-germinated fermented finger millet +sesame flour (NGFFS) and germinated-fermented finger millet + defatted sesame flour (GFFS) are shown in Table 1. The significant variations in proximate compositions between the flour samples could be because of germination and fermentation processes. The NGFFS, GNFFS and GFFS samples had higher moisture contents (8.13%, 8.10% & 8.07%) respectively while the germinated /fermented sample had the least values (7.66%). This could be as a result of the utilization of moisture for sprouting or germination and other chemical processes (Bolarinwa *et al.,* 2015). The moisture contents of all the formulated complementary foods samples reported in this study were within the recommended moisture content of dried foods (Ndife *et al.,* 2011, Temple, 2018). Low moisture content of food samples is desirable for extending the shelf life of food products while high moisture content in food samples encourage growth of microorganisms (Okaka 2019). The protein content of the finger millet samples showed significant differences ranging from 9.71% (NGNFF) to 9.50% (GNFF). The protein content of the defatted sesame seeds was high (57.12%), this could be attributed to reduction in moisture and fat contents. All the samples had values in agreement with the protein advisory group (PAG) of 9%. The protein content of all the formulated complementary foods products were like that of Cerelac. This is of great importance in reducing protein energy malnutrition (PEM) resulting from the high cost of animal protein and commonly consumed legumes. Protein is important for growth and tissue replacement (Oduro *et al.,* 2007). There was no significant difference ($p<0.05$) in protein content of all the formulated samples (16.00%). The values which were obtained by material balance agreed with the protein advisory group (PAG) for daily intake.

Statistical analysis showed that the crude fat content of formulated complementary foods significantly decreased with germination and fermentation. This result agrees with earlier reports by (Egbujie *and* Okoye, 2019) on chemical characteristics of complementary foods produced from sorghum, African yam bean and crayfish flours blends. The fat content of the complementary food samples was relatively high compared to the finger millet flour which is attributed to the supplementation of sesame which has high fat content in the products (Ishiwu and Onyeji, 2018). Fat increases the energy density and provides essential fatty acids needed in the body for proper neural development (Mariam, 2005).

The ash content showed significant difference only with germinated/fermented finger millet and defatted sesame (GFFS) flour. The ash content obtained in this study (2.15- 2.74g/100g) was lower than that of the ash content (4.25-5.81%) of complementary food prepared from sorghum and African yam bean flour blends reported by (Ijarotimi and Bakare, 2006). The decrease can be attributed to the utilization of minerals for growth by the plants and microorganisms.

The fibre contents of the formulated complementary foods were within the recommended value of FAO/WHO (1991). This observed low fibre content of these formulated diets would enable children to consume more of the food samples; and thereby will give children greater opportunity to meet their daily energy and other vital nutrient requirements (Blackman *et al.,* 2014). The crude fibre showed significant difference among all the samples. NGFFS recorded the highest value (3.91%) while GNFFS had the least value (3.74%). The values obtained in this study were higher than the crude fibre (0.31-1.82%) of complementary foods formulated from fermented maize, soybean and carrot flours as reported by (Barber *et al.*, 2017).

The carbohydrate content of the formulated complementary food ranged from 63.92 to 64.31g/100g. The high carbohydrate content of the samples could be attributed to the high proportion in finger millet flour. Carbohydrates such as starch and sugars are of nutritional benefits as children require energy to carry out other rigorous activities as growth continues. The values were lower than that (69.2-74.5%) of complementary foods formulated from malted millet, plantain and soybean flour blends reported by Temple, 2018.

The energy values are a function of protein, fat and carbohydrate contents of the formulated food products. The observed differences in the energy levels of the samples could be due to variation in protein, fat and carbohydrate content. The result shows that there is variation between the formulated food samples and non-formulated food samples. This could be due to the incorporation of defatted sesame flour as well as the germination and fermentation processes. The energy values of complementary food samples were below permissive values. The results obtained in this study are like the finding of Malomo *et al.*, 2014 who reported a decrease in the energy value content of complementary foods on substitution with legumes.

Effect of fermentation on pH and titratable acidity

The effects of fermentation on pH and titratable acidity of germinated and non-germinated finger millets are shown in Fig.1. For formulated food products, the pH was 6.50 for the non-germinated-non-fermented finger millet + defatted sesame flour (NGNFFS), 5.23 for germinated non-fermented finger millet +defatted sesame flour (GNFFS),4.51 for non-germinated fermented +defatted sesame flour (NGFFS) and 4.51 for germinated fermented finger millet+ defatted sesame flour (GFFS) respectively.

The TA varied from 0.15 to 0.94% and 0.14 to 0.90% lactic acid concentrations for the germinated and non-germinated finger millet at 36h of natural fermentation. The accelerated natural fermentation of finger millet indicated that inocula recycling resulted in a pH reduction from 5.78 to 3.56 in the germinated products and 5.90 to 3.30 in the non-germinated samples during fermentation. As expected, the titratable acidity (lactic acid/ 100g sample) increased from 0.15 to 0.94 in the germinated products and from 0.14 to 0.94 in the non-germinated samples. The pH of the formulated food products was higher (4.51- 6.50) than the finger millet flour. This could be due to the addition of sesame in the formulated food diets and its absence in the finger millet flour (Gernah *et al*., 2011).

Mineral composition of finger millet and defatted sesame flour

The result of the minerals composition of complementary food formulations are shown in Table 2. The Ca, Fe, K and Zn contents of the formulated complementary foods decreased significantly with germination and fermentation processes. There were variations in the mineral content of the samples with potassium content of food formulation being the most abundant (944mg/100g) of all the samples. These observations are like earlier findings by Oshodi *et al.,* 1999 and AU *et al.*, 2000 who reported potassium to be the most abundant mineral in Nigerian agricultural products. Potassium is essential for blood clotting and muscle contraction.

Table 1: Proximate composition of finger millet and defatted sesame based complementary foods

Nutrient (g/100g)	NGNFFS	Complementary NGFFS	Products GNFFS	GFFS	LSD
Moisture	7.66^{a} ±0.13	8.13^{a} ±0.1	8.10^{a} ±0.19	8.07^{a} ±0.18	3.956
Protein	16.05^{a} ±0.04	16.05^{a} ±0.04	16.01^{a} ±0.02	16.00^{a}±0.03	0.1476
Fat	5.36^{d}±0.975.365.36^{d}±0.97	5.31^{c} ±0.57	5.21^{a}±1.31	5.26^{b}±0.89	0.3802
Ash	2.74^{b}±1.10	2.68^{b}±0.08	2.68^{b}±0.05	2.15^{a}±0.99	0.1025
Fibre	3.91^{c} ±1.08	3.90^{bc}±0.99	3.74^{a}±0.87	3.88^{b}±0.14	0.0310
Carbohydrate	64.31^{a} ±0.07	63.92^{a} ±0.001	64.25^{b}±0.01	64.55^{d} ±0.01	0.0380
Energy(kJ/100g)	369.51^{c}±1.00	367.68^{a} ±0.02	368.04^{b}±0.01	369.61^{d}±0.30	0.0471

Results are means ± standard deviation of triplicate determinations. Means with common superscripts along each row are significantly different. **Key:** NGNFFS=non-germinated non-fermented finger millet and defatted sesame flour, GFFS=germinated fermented finger millet and defatted sesame flour, NGFFS=non-germinated fermented finger millet and defatted sesame flour, GNFFS=germinated non-fermented finger millet.

The phosphorus contents of the complementary foods were higher than the recommended minimum value with NGNFFS having higher values (682.18mg/100g) and GFFS having the least phosphorus value (611.58mg/100g). The values obtained in this study (611.58- 682.18mg/100g) were higher than those obtained from sorghum, African yam bean and mango mesocarp flour blends reported by Yusufu *et al.*, 2013.

The calcium content of the complementary food samples ranged from 252.80 to 281.10mg/100g. The result showed that the non-germinated non-fermented finger millet + defatted sesame had the highest value while the GFFS formulation had the least value as shown above. The decrease in value in the GFFS could be as a result of leaching during germination and soaking and or utilization during growth and fermentation (Ishiwu and Onyeji, 2018).

The values of the sodium were also observed to be relatively high ranging from 414.32mg/100g to 373.94mg/100g. The NGNFFS formulation had the highest iron content (6.61mg/100g), while the GFFS had the least value (4.87mg/100g) (Ishiwu and Onyeji, 2018).

Iron is a component of myoglobin, a protein that provides oxygen to muscles and supports metabolism in humans (Oduro *et al.*, 2007). Regular consumption of foods rich in iron has the potential to prevent anemia in infants and young children.

The zinc content of the complementary food samples ranged from 10.21mg/100g to 11.45mg/100g. The increase in zinc content could be attributed to the inclusion of sesame seeds. These values are above the recommended daily intake for Zinc. Zinc supports normal growth and development during pregnancy, childhood and adolescence. The substitution of finger millet- based complementary food with sesame increased mineral content of the products. Minerals are utilized for germination and fermentation and can explain lower values in the germinated and fermented products (Nzeagwu and Nwaejile, 2008).

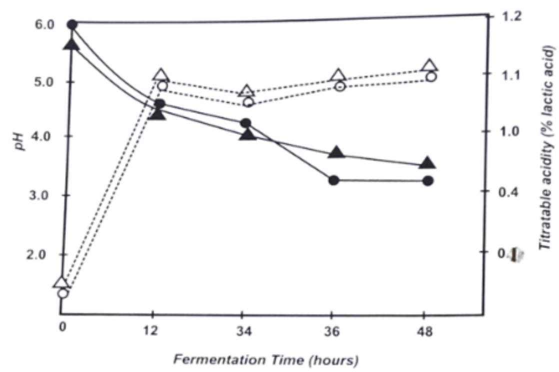

Fig.3: Effect of germination and fermentation on pH (● ,▲) and titrable acidity (○ , Δ) of finger millet; (Keys: Δ , ● = germinated, ▲ , ○ = non-germinated)

Physical Indices of Quality

Bulk density and water absorption capacity

The packed bulk densities of the formulated products are presented in Table 3. The water absorption capacity of complementary diet ranged from 1.15 g/ml in the germinated / non-fermented finger millet and defatted sesame (GNFFS) to 1.22 g/ml in the germinated/ fermented finger millet and defatted sesame (GFFS), the germinated/fermented finger millet and defatted sesame had the highest value. The germinated and fermented products (GFFS) had the least bulk density (0.71g/ml) while the non-germinate non-fermented products (NGNFFS) had the highest (0.83g/ml). This implies that for a given mass of the products, the fermented and germinated diets would have higher volume due to air incorporation and higher porosity. This is a disadvantage in packaging of such products (Zilic *et al.*, 2012).

Table 2: Mineral composition of finger millet and defatted sesame complementary foods

Nutrients (mg/100g)	NGNFFS	Products NGFFS	GNFFS	GFFS	LSD
Ca	281.10^{d} ±0.10	268.16^{c}±0.03	266.71^{b}±0.00	252.80^{a}±0.00	0.2028
K	994.13^{d}±0.00	948.32^{b}±0.02	956.36^{c}±0.01	946.35^{a}±0.00	0.03802
P	682.18^{d}±0.00	656.58^{b}±0.00	678.11^{c}±0.02	611.58^{a}±0.00	0.0340
Fe	6.61^{d}±0.02	5.81^{c}±0.01	5.74^{b}±0.02	4.87^{a}±0.01	0.0564
Na	414.32^{d}±0.02	375.22^{b}±0.02	377.64^{c}±0.02	373.94^{a}±0.02	0.0694
Zn	11.45^{d}±0.01	10.21^{a}±0.01	10.24^{b}±0.02	10.74^{c}±0.02	0.0500

Results are means ± standard deviation of triplicate determinations. Means with common superscripts along each row are not significantly ($p < 0.05$) different

Key: NGNFFS= non-germinated non-fermented finger millet and defatted sesame flour, GNFFS=germinated non-fermented finger millet and sesame flour, GFFS=germinated fermented finger millet and sesame flour, NGFFS= non-germinated fermented finger millet and defatted sesame flour

The lower loose bulk density implies that a smaller quantity of food samples would be packaged in constant volume thereby maximizing profit. However, the packed bulk densities would ensure more quantities of the food samples being packaged, but less economical. Nutritionally loose bulk density promotes easy digestibility of food products, particularly among children with immature digestive system (Gopaldas and John, 1992, Marero *et al.*, 1998).

Germination and fermentation also resulted in higher water absorption capacities. The water absorption capacity is an index of the maximum amount of water that a food product would absorb and retain (Mosha and Lorri, 2015, Giami and Bekebian, 2016). With respect to water absorption capacity, Onabanjo *et al.,* 2009 reported that the microbial activities of food products with low water absorption capacity would be reduced. Hence the shelf life of such food would be extended. Water absorption values (1.17 – 1.22g/ml) of the products were within permissive levels. Low values of water absorption indicate compactness in polymers while high value indicates loose structure of the starch polymers (Ijarotimi and Bakare, 2006).

Table 3: Functional properties of finger millet and defatted sesame flour

Parameter(g/ml)	NGNFFS	Samples	Parameter(g/ml)	NGNFFS	Samples
Bulk density	0.83±0.01^{a}	0.81±0.02^{a}	0.71±0.00^{b}	0.72±0.01^{b}	0.0416
Water absorption Capacity	1.15±0.14^{a}	1.17±0.21^{a}	1.22±0.10^{a}	1.20±0.1a^{b}	0.4551

Results are means of ± standard deviation of duplicate expressed on dry weight. Values along each row with superscripts are not significantly ($p<0.05$) different.

Key: NGNFFS=non-germinated non-fermented finger millet and defatted sesame flour, GNFFS=germinated non-fermented finger millet and defatted sesame flour, GFFS= germinated fermented finger millet and defatted sesame flour, NGFFS=non-germinated fermented finger millet and defatted sesame flour.

Vitamin content of finger millet and defatted sesame flour

Vitamins B1, B2, B3, B6 and β- carotene contents of the products are shown in Table 4. The β- carotene content was high compared to the rest of the vitamins analyzed. This could be due to the variety of fingermillet used for the complementary food formulations. The germinated/fermented finger millet and defatted sesame (GFFS) flour has relatively higher content (43.55mg/100g) while the non-germinated/ fermented finger millet and defatted sesame (NGFFS) flour had the least value (40.14mg/100g). The increase in β- carotene content is because of germination and fermentation processes which improved vitamins content. Both thiamin (B1) and riboflavin (B2) values were low (0.33-0.39mg/100g and 0.23-0.27mg/100g) respectively. The vitamin B6 content had mean values of 1.35 to1.85mg/100g. Both vitamins B1 and B2 coenzymes are needed for energy metabolism and are important for nerve functions and normal vision (Kin *et al*., 2012). Vitamin B6 is needed in the production of red blood cells. Germination has been reported to increase vitamins such as riboflavin (B2) and niacin (B3) due to synthesis by new sprouts (Zilic *et al*., 2012 and Olaofe and Sanni, 2014). However, losses of water-soluble vitamins are common during soaking and germination as a result of leaching and mass transfer.

Table 4: Vitamins composition of finger millet and defatted sesame flour based products

Nutrient (mg/100g)	NGNFFS	Products NGFFS	GNFFS	GFFS	LSD
Pyridoxine	$1.85^{b}\pm0.07$	$1.35^{a}\pm0.21$	$1.15^{a}\pm0.07$	$1.50^{ab}\pm1.41$	0.380
Vit B1	$0.35^{ab}\pm0.01$	$0.39^{b}\pm0.00$	$0.33^{a}\pm0.02$	$0.38^{b}\pm0.00$	0.046
Vit B2	$0.23^{a}\pm0.02$	$0.27^{a}\pm0.02$	$0.25^{a}\pm0.01$	$0.26^{a}\pm0.04$	0.083
Vit B3	$1.60^{b}\pm0.01$	$1.47^{a}\pm0.02$	$1.76^{c}\pm0.03$	$1.50^{a}\pm0.00$	0.067
β – carotene	$42.25^{b}\pm0.08$	$40.14^{a}\pm0.05$	$43.30^{c}\pm0.28$	$43.55^{c}\pm0.21$	0.511

Results are means ± standard deviation of triplicate determinations. Means with common superscripts along each row are not significantly ($p< 0.05$) different.

Key: NGNFFS=non-germinated/non-fermented finger millet, GNFFS= germinated non-fermented finger millet and defatted sesame flour,GFFS= germinated fermented finger millet**,** NGFFS= non-germinated fermented finger millet.

Table 5: Anti-nutritional properties of finger millet and defatted sesame based products

Anti-nutrient (g/100g)	NGNFFS	Products GNFFS	NGFFS	GFFS	LSD
Oxalate	$1.96^{d}\pm0.02$	$1.16^{c}\pm0.01$	$0.36^{b}\pm0.02$	$0.26^{a}\pm0.01$	0.050
Tannins	$1.92^{d}\pm0.02$	$1.77^{c}\pm0.01$	$0.82^{b}\pm0.01$	$0.44^{a}\pm0.02$	0.050
Phytate	$2.31^{d}\pm0.00$	$1.31^{c}\pm0.02$	$0.76^{b}\pm0.01$	$0.37^{a}\pm0.01$	0.042
Cyanides (mg/100g)	$2.13^{d}\pm0.00$	$0.85^{c}\pm0.01$	$0.57^{b}\pm0.00$	$0.34^{a}\pm0.01$	0.031

Results are means ± standard deviation of triplicate determinations. Means with common superscripts along each row are non significantly ($p< 0.05$).

Key: GNFFS= germinated non-fermented finger millet and defatted sesame flour,GFFS= germinated fermented finger millet, NGFFS= non-germinated fermented finger millet

Table 6: Microbiological quality of finger millet and defatted sesame seeds products

Microbial Index	NGNFFS	Microbial counts NGFFS	(cfu/g) GNFFS	GFFS
TVC	0.2×10^{3}	1.2×10^{4}	0.4×10^{3}	1.6×10^{3}
Coliform	<10	<10	<10	<10
E. coli	Nil	Nil	Nil	Nil
Staphylococcus aureus	<50	<30	<30	<30
Yeast	0.1×10^{2}	0.8×10^{2}	0.6×10^{2}	1.0×10^{2}
Mold	30	0.4×10^{2}	0.2×10^{2}	0.6×10^{2}
Enterobacteriae	<30	<30	<30	<30

TVC= total viable count.

NGNFFS= non-germinated non-fermented finger millet and defatted sesame seeds, NGFFS= non-germinated fermented finger millet and defatted sesame seeds, GNFFS= germinated non-fermented finger millet and defatted sesame seeds, GFFS= germinated fermented finger millet and defatted sesame seeds.

Anti-nutritional composition of complementary based food

The anti-nutritional compositions of the food formulations are as shown in Table 5. Anti-nutritional composition of the food formulations decreased among the diets. The effect of soaking, germination and fermentation with other processes like sprouting and some chemical reactions occurring in the grain could explain the reduction in anti-nutrients of the complementary foods. The anti-nutritional compositions of the complementary food samples were reduced to tolerable levels. This indicates that the formulated food product can be utilized effectively since the anti-nutritional composition has been reduced to levels of non-interference with nutrients like protein and minerals uptake from the food samples (Ijarotimi and Bakare, 2006). Earlier investigations have reported that germination, fermentation and other processing methods improved the nutritional quality of legumes and cereals by causing significant changes in their chemical composition and elimination of anti-nutritional factors (Motarijemi, 2002, Ochanda *et al.,* 2010, Olaofe and Sanni, 2014).

Microbiological analysis of finger millet and defatted sesame seeds flour

The results for the microbiological counts of complementary food produced from finger millet and defatted sesame seeds gruels are presented in Table 6. Total viable counts (cfu/g) were least for NGNFFS (0.2×10^3) and highest for the GFFS (1.6×10^3). *Escherichia coli* was not detected in all the samples while *coliform* count was <10 in all samples. As expected, the fermented products had higher yeast and mould counts. *Staphylococcus aureus* and *Enterobacteriacae* values were <30cfu/g. These counts in all the porridges indicate lack of recontamination or inability of these microorganisms to grow in the gruels. Fermented porridges prepared may inhibit growth of aerobes probably due to their higher acidity compared to the non-fermented porridges. It is common practices in Nigeria to prepare cereal based porridges and store them at ambient conditions for feeding of infants at intervals. This practice could pose public health hazards, especially if the gruels are unknowingly contaminated from the utensils or food handlers. A potential advantage of lactic fermentation in this regard can be observed from the *Staphylococcus aureus* result (Table 6). The sour gruels from GFFS (pH4.45) and NGFFS (pH 4.40) did not support the growth of the microbe while the sweet gruels made from NGNFFS (pH 6.50) and GNFFS (pH 5.23) could encouraged growth of this toxigenic microorganisms (Takhellambam *et al*, 2016).

CONCLUSIONS

Germination and/or fermentation of finger millet improved the quality and quantity of mineral and vitamin content, decreased bulk while lowering total plate count with inhibition of toxigenic microorganisms.

The effect of soaking, germination and fermentation with other processes like sprouting and some chemical reactions reduced anti-nutrients of the complementary foods. This indicates that the formulated food product can be utilized effectively since the anti-nutritional composition has been reduced to levels of non-interference with nutrients like protein and minerals uptake from the food samples.

RECOMMENDATION

Natural fermentation and germination of cereals and combination with legumes should be encouraged for production of complementary foods to improve nutritional and health status of more Nigerians.

Farmers should be encouraged to cultivate finger millet and sesame to reduce post- harvest loses of the products.

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