Innovative Journal of Home Economics, Volume 6, Number 2, 2024
ISSN: 4280-2176

QUALITY EVALUATION OF COMPLEMENTARY FOODS PRODUCED FROM BLENDS OF FONIO, TIGER NUTS AND AKIDI (Vigna unguiculata) FLOURS

[1]Aliche, C.L., [2]Okpulor, S.U. and [2]Oyinloye G. M.
[1]Department. of Home Economics.Alvan Ikoku Federal University of Education Owerri, Imo State, [2]Department Of Food Technology, Federal Polytechnic, Nekede, Owerri, Imo State, Nigeria

Corresponding Author`s Email- stanleyokpulor@gmail.com

ABSTRACT
The research focused on creating and evaluating complementary foods using blends of fonio, tiger nut, and akidi flours. The process involved fermenting fonio and melting tiger nut and akidi before processing them into flour. The flours were then blended in different ratios, and the resulting composite flour samples underwent various analyses, including proximate, functional, and sensory properties. The proximate composition results of the complementary flour samples showed variations in moisture content (ranging from 9.76% to 10.36%), fat (2.34% to 2.92%), ash (3.04% to 3.25%), fibre (2.20% to 2.87%), protein (6.14% to 7.23%), and carbohydrate (74.28% to 75.69%). These variations were significant ($p<0.05$) among all the samples. Additionally, the functional properties such as water absorption capacity (ranging from 80.26% to 92.94%), bulk density (0.47 to 0.75g/ml), oil absorption capacity (60.41 to 69.04%), gelation capacity (14.47 to 19.94%), and emulsifying capacity (47.30 to 49.89%) also displayed significant differences ($p<0.05$) among the samples, except for bulk density. The sensory evaluation indicated that the best complementary gruel was produced from flour samples blended with 15% tiger nut and 15% akidi flour. Overall, the study confirmed that high-quality complementary food could be derived from combining fonio, tiger nut, and akidi flours.

INTRODUCTION
Early nutrition is crucial for a child's future health (World Health Organization, 2014). Children aged 6 to 23 months and under five have high nutritional needs, but many lack access to nutrient-rich complementary foods, especially in developing countries like Nigeria (Osendarp et al., 2016). In Nigeria and other developing countries, malnutrition is caused by limited access to essential protein, vitamins, and minerals, especially those from animal sources. During complementary feeding, iron, zinc, and vitamin A are particularly challenging due to their low concentration in human milk compared to infants' needs. Deficiencies during this time can have lifelong health consequences for children (Ogbonna *et al.,* 2010; Dewey, 2013; Raymond *et al.*, 2017)
The high cost of nutritious complementary foods in Nigeria is often unaffordable for most families, who rely on inadequately processed traditional foods. Researchers have been working on processing and blending locally available food commodities to improve nutrient density and prevent malnutrition (Nnam, 2002). Fonio (Digitaria exilis) is a cereal grain grown in large quantities in northern Nigeria. It is used as whole grain, porridge, couscous, and in pastries in African and Asian cuisines (Ayo & Nkama, 2006; Chukwu & Abdul-Kadir, 2008).
Princewill-Ogbonna (2015) stated that Fonio is a highly nutritious cereal, rich in protein, leucine, methionine, and valine compared to other cereals. It also contains easily digestible carbohydrates, vitamins, and minerals, but its potential has been limited to traditional and domestic use in regions like Nigeria where it is primarily grown. Tigernut (Cyperus esculentus L.) belongs to the division Magnoliophyta and the family Cyperaceae (Belewu & Belewu, 2007). The tubers are abundant in Nigeria and known by various Indigenous names such as 'Aya' (Hausas), 'mum' (Yorubas), 'aki Hausa' (Igbos), and "off" (Ijaws). (Udeozor, 2012). Anderson *et al.*, (1994) reported that Tiger nuts contain 5.8% moisture and are rich in protein (7%) and carbohydrates, including reducing sugars (7.4%), soluble polysaccharides (7.4%), and starch (86.4%). The protein in tiger nuts is of high biological value due to its essential amino acid content, exceeding standard guidelines. (FAO/WHO,

2002a; FAO/WHO, 2002b) and satisfy the amino acid needs of adults (Bosch *et al.*, 2005). However, the nut is still utilized below Nigeria's nutritional and production yield potentials.
Cowpea (Vigna unguiculata), locally known as aikido in Igbo, is a bean belonging to the Fabaceae family. It is a cherished native delicacy in the cuisine of southeastern Nigeria (Ashogbon & Akintayo, 2013). Aikidi is a small legume with two common species. They differ in size and colour, but both provide a good source of dietary protein with high bioavailability and a relatively lower proportion of anti-nutritional factors (Papalamprou *et al.,* 2009). It's a good protein source and also contains high levels of soluble and insoluble dietary fiber, minerals, and vitamins (Ashraduzzaman et al., 2011). The importance of exploring underutilized foods to address nutritional challenges has been emphasized, with a recent focus on using local non-conventional foods with high nutritional value in infant and young children's diets (Chadare et al., 2018). This study aimed to assess the nutritional value of a meal made from tiger nuts, hungry rice (fonio), and akidi beans for complementary feeding to improve nutrition among vulnerable populations in Nigeria and other developing countries. Malnutrition continues to threaten many households in Nigeria and other developing countries, especially among children under five. Factors such as poverty, inadequate food knowledge, and high food prices contribute to this issue. Also, Tigernut, fonio, and akidi are underutilized food crops in Nigeria, often consumed domestically. Despite their potential in managing malnutrition and food insecurity, they are among the least popular crops in the country. Research is needed to promote their production and utilization of complementary foods. The main objective of this study is to produce and evaluate the quality of complementary food made from blends of fonio, tiger nut, and aikido flours.

MATERIALS AND METHODS

Material collection

Tiger nut and fonio grain were purchased from Ama-Hausa, while cowpea (Vigna unguiculate) was obtained from Relief Market, all in Owerri, Imo state. Other ingredients, such as an anti-caking agent (Tricalcium phosphate), powdered milk flavour, and sucrose food grade, were purchased from the DE-CROSS FOOD store in Oke-arin market in Lagos State. Processing and laboratory analysis were conducted in the Food Science and Technology Laboratory, Imo State University, Owerri.

Processing of malted tiger nut flour meal

Two kilograms (2kg) of dried fresh tiger nut was sorted and cleaned to remove foreign particles. The cleaned nuts were steeped in portable water at 1:3 w/v at ambient condition 30$\pm$2°C for 48 h. During the steeping process, the soaked water was removed and replaced with fresh water at every 6 h interval. At the end of the steeping period, the tiger nut was spread on a damped jute bag sterilized with steam at a temperature of 121±20C for 60 minutes for the sprouting process and covered with another damped sterilized jute bag. The sprouting process lasted 5 days, with sprouts reaching 50-100mm. The tiger nuts were then washed, drained, and dried at 78°C until the moisture content reached 8-10%. The malted tiger nuts were milled in a hammer mill (model: EU 5000D) and sieved through a 120µm mesh sieve. The tiger nuts flour produced was packaged in a labelled airtight plastic container and kept for further use.

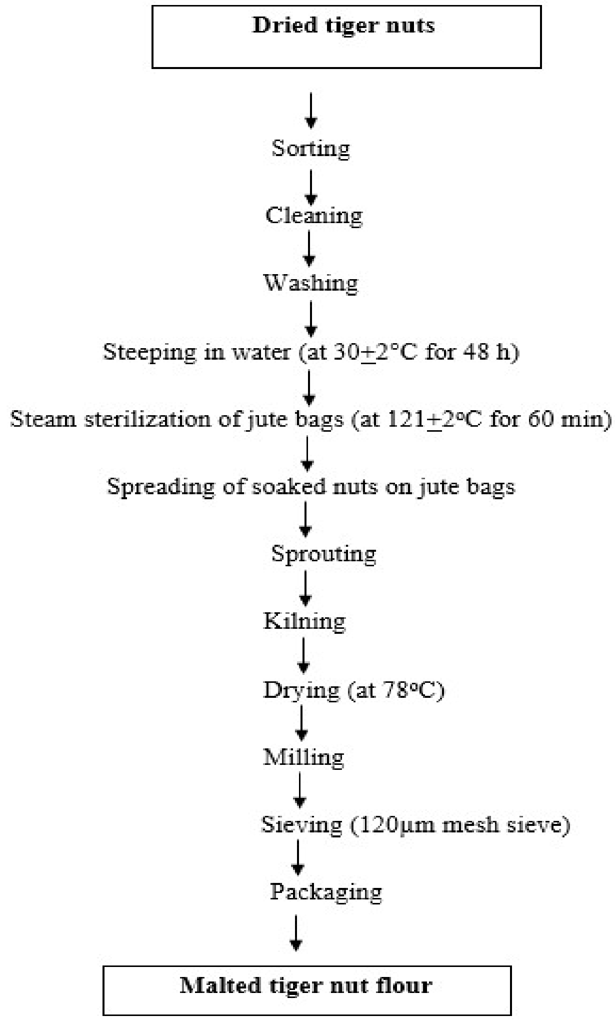

Figure 1: Preparation of Malted Tiger Nut Flour (MTNF)

Processing of fermented 'fonio' flour

In preparing fermented fonio flour, a method combining the techniques of Adegoke (2004) and Osungbaro (2009) was used. Two kilograms of fonio grains were cleaned, steeped in water, fermented for 36 hours, dried in a cabinet dryer, milled, and sieved. The resulting fermented fonio flour was then packaged for further use.

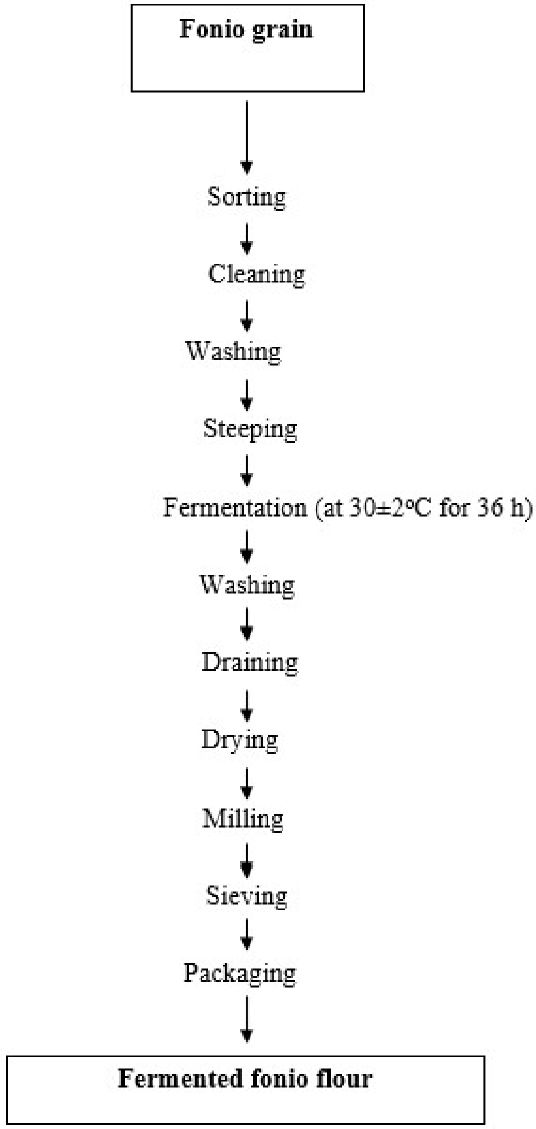

Figure 2: Preparation of Fermented Acha Starch flour 'FASF'

Processing of malted Cowpea (*Vigna ungulculata)* flour

The procedure described by Egbujie and Okoye (2019) was used with slight modification (Figure 3). The akidi bean seeds were cleaned and soaked in water, then disinfected with a 2% sodium hypochlorite solution. After rinsing, they were left to sprout for 24 hours. The seeds were carefully spread on the jute bag and allowed to germinate at room temperature (30±2oC), and sprinkle seeds with water every 8 hours in a high-humidity environment for 48 hours to aid germination. Discard the non-germinated and dry germinated seeds in a controlled environment at 68°C until the moisture content is 8-10%. During the drying process, the sprouted aikido beans were occasionally stirred at intervals of 30 min to ensure uniform drying. The malted aikido bean seeds were cleaned, dehulled, milled, sieved, and packaged as 'MAKBM' for further use.

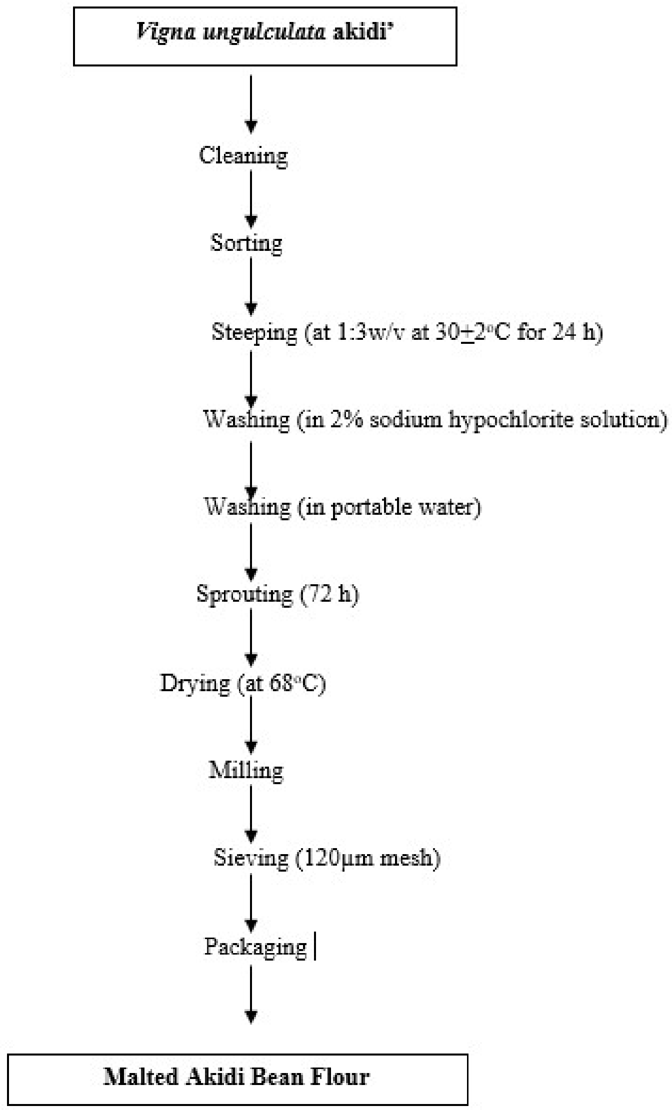

Figure 3: Preparation of Malted Akidi Bean Flour (MAKBF)

Formulation of Cereal based complementary foods

Complementary foods from three raw materials were blended with a target protein of 20% by the recommendation of the World Health Organization (Ikujenlola *et al.,* 2017). The blend proportion recommendation of 75% cereal and 25% legume for infant complementary food formulation was considered (Plahar *et al.,* 2003). Furthermore, the formulation was done by referring to secondary sources of nutrient compositions of the raw ingredients to meet recommended levels of vital nutrients recommended in various guidelines of infants and children complementary foods (World Health Organization, 2003; Codex Alimentarius Commission, 1991). Fermented fonio flour, malted tiger nut flour and malted cowpea flour were blended in the ratio of 100:0:0, 90:5:5, 80:10:10, 70:15:15 and 60:20:20. 5% milk flavor, as shown in Fig. 4, was added to all flour blends. Each blend was mixed thoroughly in a Kenwood mixer (Model A. 220) for 10 min to produce composite complementary food formulations. The formulations developed were individually packaged in sealed polyethylene bags until used for analysis. In addition, a 100% fermented Acha flour formulation was similarly prepared as a control sample and commercial complementary food was used as a reference sample in this study. Figure 4 shows the flow chart for the preparation of complementary food samples.

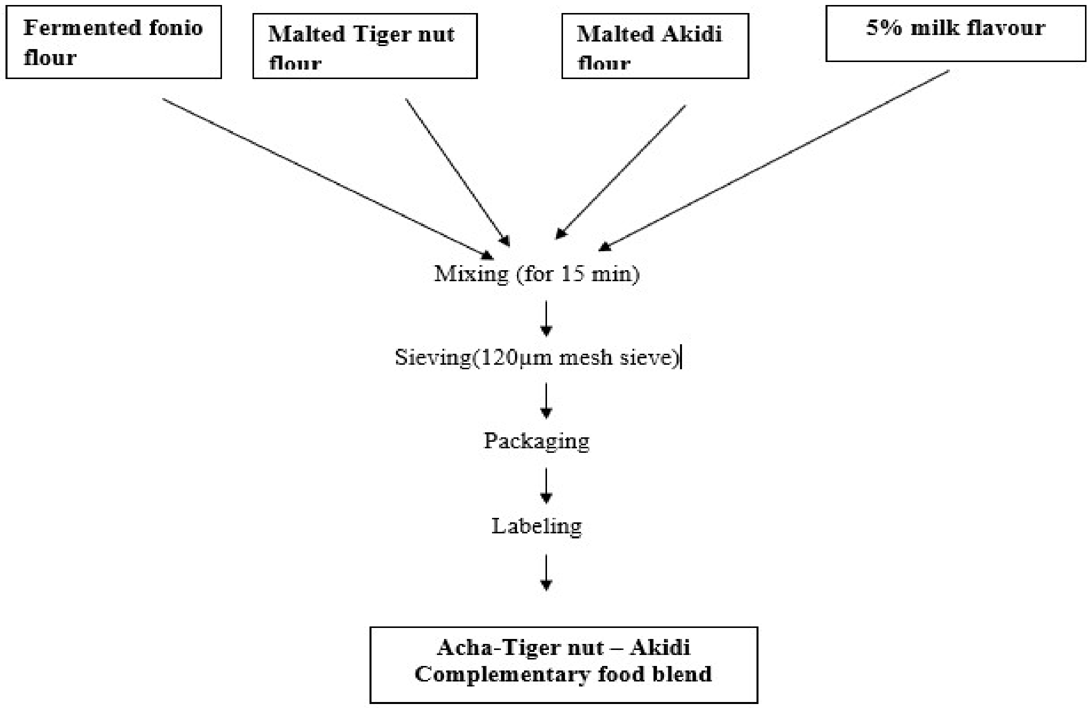

Figure 4: Preparation of complementary foods

Proximate Composition Determination

Determination of moisture content

According to (Onwuka, 2005), the sample was oven-dried at 105°C for 3 hours in a pre-weighed crucible. The crucible was then cooled and weighed, and the process was repeated until a constant weight was obtained. The moisture content was calculated as a percentage of the sample's weight.

% Moisture content = $\frac{100}{1} \times \frac{W_2 + W_3}{W_2 - W_1}$ .... (1)

Where W1 = weight of the empty crucible
W_2= weight of empty crucible + sample before drying
W_3= weight of crucible + sample dried to constant weight

Determination of ash content

The gravimetric method described by five grams (5g) of the sample was measured into a clean dried crucible. The sample was placed in a muffle furnace at 550°C for 2h until a white or light gray ash resulted. It was cooled in a desiccator and weighed. The weight of ash obtained was calculated by difference and expressed as a percentage of the weight of the sample analyzed, as shown below:

% Ash = $\frac{100}{1} \times \frac{W_2 - W_1}{Wt of sample}$ .... (2)

Where W_1 = weight of the empty crucible
W_2 = weight of crucible + Ash

Determination of protein

This was done using the Kjeldahi method described by AOAC (2010). A 0.5g sample was mixed with 10 ml of concentrated H2SO4 in a digestion flask and heated. After dilution, the solution was mixed with NaOH, distilled, and titrated using EDTA. N2 content and protein were calculated using a formula.

$\%N_2 = \frac{100}{N} \times \frac{N \times 4}{1000} \times \frac{VTT.B}{VA}$ .... (3)
Where W = weight of sample (0.5 g)
N = Normality of titrant (0.02N H_2SO_4)
VT = Total digest volume (100mls)
VA = Volume of digest that was analyzed (ions)
T = Sample titre value
B = Blank titre value
% Protein = % N_2 x 6.25 .... (4)

Determination of Crude Fat
The solvent extractive gravimetric method (AOAC, 2010) was used. A 5g sample was placed in a thimble and extracted using petroleum ether in a soxhlet apparatus for 4 hours. The oil extract was then dried, cooled, and weighed to determine the fat percentage in the sample.
$\%Fat = \frac{W_{2-}W_1}{Wt} \times \frac{100}{1}$ .... (5)

Determination of Crude Fibre
The method by AOAC (2010) was employed. The 5g sample was boiled in 150ml of 12.5% H2SO4 solution for 30 minutes, then washed and boiled in 150ml of 1.25% NaOH for another 30 minutes. After drying and burning to ash, the weight of the fiber was obtained and expressed as a percentage of the sample weight.
% Crude fiber = $\frac{100}{1} \times \frac{w1-w2}{Wt}$ .... (6)
Where Wt = weight of sample
W_1 = weight of crucible + sample after boiling, washing and drying.
W_2 = weight of crucible + sample (ash)

Determination of Carbohydrate Content
The carbohydrate content was calculated using the formula below described by James (1995).
% Carbohydrate = 100 - % (protein + fat + fibre + ash + moisture content)

Sensory Evaluation
The complementary flour samples were evaluated for attributes like color, taste, aroma, mouthfeel, and overall acceptability by a panel of thirty judges from Imo State University Owerri, Nigeria.A 9-point hedonic scale ranging from one to nine was used to assess the food samples.
Where; 1 = dislike extremely
2 = dislike very much
3 = dislike moderately
4 = dislike slightly
5 = neither like nor dislike
6 = like slightly
7 = like moderately
8 = like very much
9 = like extremely

Statistical Analysis
The data generated in this study were subjected to one-way analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS, Version 20) software. Significant means were separated using Tukey's Least Significance Difference (LSD) test at $p<0.05$, and the results were expressed as mean ± standard deviation of triplicate determinations.

RESULTS AND DISCUSSION

The proximate composition of the complementary flour samples

Table 1: Proximate Composition of the Complementary Flour Samples (%)

Samples	A	B	C	D	E	LSD
MC	10.36^a±0.02	10.11^b±0.01	10.03^c±0.03	9.89^d±0.03	9.76^e±0.01	0.03
Fat	2.34^d±0.04	2.36^{cd}±0.01	2.42^c±0.02	2.56^b±0.03	2.92^a±0.04	0.08
Ash	3.25^a±0.04	3.25^a±0.01	3.15^b±0.03	3.11^{bc}±0.04	3.04^d±0.01	0.08
Fibre	2.20^e±0.03	2.27^d±0.02	2.34^c±0.01	2.51^b±0.02	2.87^a±0.04	0.07
Protein	6.14^d±0.03	6.20^d±0.02	6.45^c±0.02	6.83^b±0.06	7.23^a±0.03	0.10
CHO	75.69^a±0.08	75.47^b±0.11	75.07^c±0.02	74.61^d±0.04	74.28^e±0.08	0.19

Values are means of triplicate analysis ± standard deviation. Means with same superscripts in the same row are not significantly (p>0.05) different.

Key:
A = Complementary flour from 100% Acha + 0% tigernut + 0% akidi flour
B = Complementary flour from 90% acha + 5% tigernut + 5% akidi flour
C = Complementary flour from 80% acha + 10% tigernut + 10% akidi flour
D = Complementary flour from 70% acha + 15% tigernut + 15% akidi flour
E = Complementary flour from 60% acha + 20% tigernut + 20% akidi flour

Moisture Content

The moisture contents of the blends of fermented fonio, malted tiger nut and malted aikido flour ranged from 9.76% to 10.36% (Table 1). There was a significant (p<0.05) difference among all the complementary food samples in terms of their moisture content. The result shows that sample A (complimentary food from 100% acha flour) recorded the highest value, 10.36%, while the lowest value, 9.76%, was recorded in sample E. This indicates that the moisture content of the complementary food samples decreased as the quantity of acha flour was reduced. This implies that fermented fonio flour contains more moisture than a combination of malted tiger nut and akidi flour. The moisture content results obtained in this study were closely related to 8.21 to 10.49% reported by Okoye and Egbujie (2018) for complementary foods made from the blends of malted sorghum, malted soybean and Irish potato. Moisture content is necessary for estimating the quality factor of most weaning foods, and it is expected to have between 3 – 8% moisture content (Amankwah et al., 2009). Comparing the report of Amankwah *et al.* (2009) on the expected moisture content of weaning food to the values obtained in this present study indicates higher moisture content. Low moisture content is desirable for extending the shelf-life of food products, while high. Moisture contents in food products encourage microbial growth and subsequent spoilage.

Fat Content

The fat content of the complementary flour samples fell from 2.34% to 2.92%. No significant (P>0.05) difference was statistically shown between food samples A and B as well as between samples B and C. However, samples D and E differed significantly (p<0.05) from each other and the rest of the samples. The fat content values of the complementary flour samples are 2.34%, 2.36%, 2.42%, 2.56 and 2.92% for samples A, B, C, D and E, respectively. The trend of the result revealed that the fat content of the food samples increased with the increased inclusion of tiger nut and aikido flour. The highest fat (2.92%) was observed in sample E (complimentary food from 60% acha, 20% tiger nut and 20% aikido flour), while sample A had the least fat content (2.34%). The values obtained in this present work for fat content were found to be higher than 0.86-2.00% reported in the work of Okoye and Egbujie (2018) for complementary foods made from blends of malted sorghum, malted soybean and Irish potato. Hawa *et al. (2018) and Igbabul et al. (*2018) respectively reported fat content in the range of (16.03-20.06) and (6.21-8.43). Fat is essential for the metabolism of fat-soluble vitamins such as Vitamin A, D, E and K. It also forms the structure of the nerve fibres. It aids the insulation of vital organs of the body against mechanical injury. Fat is also essential in the diets of infants and young children as it provides essential fatty acids like omega-3 and omega-6 polyunsaturated fatty acids (PUFA's) needed in the body for proper neural development (Mariam, 2005).

Ash Content

From the result shown in Table 1, the ash content of the complementary flour samples ranged from 3.04% to 3.25%. Complementary flour sample D differed significantly (P<0.05) from the rest of the samples, while samples A and B, as well as C and D, recorded no significant (P>0.05) difference in terms of their ash content. Food samples A and B recorded the highest ash value (3.25%) followed by samples C and D with values 3.15% and 3.11% while the lowest value (3.04%) was recorded in sample E. The results revealed that the ash content of the complementary food samples was reduced with the increased inclusion of tiger nut and aikido flour. This implies that fonio flour contains more ash than tiger nut and akidi flour. This high ash content of the fonio could be an indicator of high mineral content in it. Total ash content is directly proportional with the amount of inorganic elements content of the crop (Mesfin & Shimells, 2013). Hence, the samples with high percentage ash contents were expected to have high concentrations of various mineral elements, which could speed up metabolic processes and improve growth and development (Hebtamu,2004).

Fibre content

The fibre contents of the complementary flour samples varied from 2.20% to 2.87%. The values are 2.20%, 2.27%, 2.34%, 2.51% and 2.87% for samples A, B, C, D and E respectively. There were significant (p<0.05) differences among all the blended flour samples. The result shows that the fonio flour contains less fibre than the tiger nut and aikido flour, probably because of the high fibre of the tiger nut. Hence, the highest fibre content (2.87%) of the complementary blended flour samples was observed in sample E (complimentary food from 60% fonio, 20% tiger nut and 20% aikido flour). In comparison, sample A had the least value (2.20%). The report of Okoye and Egbujie (2018) showed fibre content in the range of 2.18 to 3.66% for complementary foods made from malted sorghum, malted soybean and Irish potato, while fibre content of 2.38 to 2.67% for complementary food produced from sorghum, sesame, carrot and crayfish was reported by Onabanjo *et al.* (2009). Both reports correlate with the values obtained in this work. Fibres exhibit beneficial physiological effects on the human body, stimulating and accelerating intestinal contraction and transit and increasing feces volume (Ahmed *et al.,*2010).

Protein Content

The protein content of the complementary flour samples ranged from 6.14% to 7.23%. Statistically, samples A and B recorded no significant difference in protein value (P>0.05), but the protein values of samples C, D and E were significantly different (p<0.05). The result revealed that as the rate of substituting Fonio flour with tiger nut and Aikido flour increases, the protein content of the complementary flour blends increases. This might probably be as a result of the high protein content of tiger nut and akidi flour. Hence sample E (complimentary food from 60% fonio, 20% tiger nut and 20% aikido flour) recorded the highest protein value (7.23%), while the lowest protein content (6.14%) of the complementary flour samples was recorded in the 100% fonio flour. The trend of this study corroborates with the report of Mohammed *et al.* (2018) that tiger nuts can be a good source of plant protein if it is bioavailable. According to Mohammed *et al. (2018), tiger nuts could contribute more than 17% of protein to an* adult's daily protein need and more than 26% to a child's daily protein requirement. Protein is needed for growth and repair of tissues in the body and for synthesizing enzymes and certain hormones.

Carbohydrate Content

The carbohydrate content of the complementary flour samples were within the range of 74.28% to 75.69% (Table 1). There were significant ($p<0.5$) difference among all the flour samples carbohydrate contents. The highest carbohydrate content of 75.69% was recorded in sample A while the least value (74.28%) was recorded in sample E (complementary food from 60% fonio, 20% tiger nut and 20% akidi). It was observed that the higher the rate of adding malted tiger nut and malted aikido flour to the blend, the lesser the value of carbohydrates in the complementary flour samples. This is not unexpected because the protein content of the food samples showed an increasing trend with a higher rate of inclusion of tiger nut and Aikido flour. However, the values obtained for carbohydrate content in this study were higher than the carbohydrate content (55.86-70.00%) of complementary food formulated from fermented maize, soybean and carrot flours reported by Barber *et al*. (2017). Carbohydrates are the major energy source in the body's stream. It is the only source of energy (glucose) for the red blood cells and the major source for the brain.

Table 2 Functional Properties of the Complementary Flour Samples

Samples	A	B	C	D	E	LSD
WAC (%)	$92.94^a \pm 0.04$	$91.27^b \pm 0.05$	$84.27^c \pm 0.06$	$81.54^d \pm 0.02$	$80.26^e \pm 0.06$	0.12
BD (g/ml)	$0.75^a \pm 0.01$	$0.71^a \pm 0.01$	$0.64^b \pm 0.03$	$0.53^c \pm 0.04$	$0.47^d \pm 0.02$	0.05
OAC (%)	$60.41^e \pm 0.04$	$62.15^d \pm 0.03$	$66.24^c \pm 0.02$	$68.75^b \pm 0.03$	$69.04^a \pm 0.04$	0.09
GC (%)	$19.91^a \pm 0.02$	$19.24^b \pm 0.04$	$17.40^c \pm 0.07$	$15.16^d \pm 0.01$	$14.47^e \pm 0.02$	0.11
EC (%)	$47.30^e \pm 0.09$	$47.97^d \pm 0.03$	$48.78^c \pm 0.01$	$49.35^b \pm 0.03$	$49.89^a \pm 0.10$	0.16

Values are means of triplicate analysis and standard deviation. Means with the same superscripts in the same row are not significantly ($p>0.05$) different.

Key:

A = Complementary flour from 100% fonio + 0% tigernut + 0% akidi flour
B = Complementary flour from 90% fonio + 5% tigernut + 5% akidi flour
C = Complementary flour from 80% fonio + 10% tigernut + 10% akidi flour
D = Complementary flour from 70% fonio + 15% tigernut + 15% akidi flour
E = Complementary flour from 60% fonio + 20% tigernut + 20% akidi flour

Functional Properties of the Complementary Flour Blends

Water absorption capacity (WAC)

The water absorption capacity of the flour samples ranged from 80.26% to 92.94%. There were significant differences ($p<0.05$) among all the samples. Sample A (100% fonio flour) had the highest capacity (92.94%), while sample E (60% fonio, 20% tiger nut, and 20% akidi flour) had the lowest (80.26%). As the ratio of tiger nut and aikido flours increased, the water absorption capacity decreased, indicating that fonio flour has a higher water absorption capacity compared to tiger nut and aikido flour. This was not unexpected as the value of fonio flour carbohydrate content in Table 1 was highest (75.69%) in the complementary flour made from 100% fonio flour. This high-water absorption capacity of fonio flour agrees with the study by Lasekan (1994), which states that fonio grain is said to have a high water absorption capacity due to its appreciable amount of pentosan content. The ability of flour to absorb water is called water absorption capacity. Water absorption capacity represents a product's ability to associate with water under conditions where water is limited (Singh, 2001). High water absorption capacity could be attributed to high amounts of carbohydrates (starch) in the flour (Chandra & Singh, 2013). Water absorption capacity is an essential functional property required in food formulations. Thus, the sample with the highest water absorption capacity is best accepted for baking applications.

Bulk density

The bulk densities of the complementary flour samples range from 0.47g/ml to 0.75g/ml (Table 3). The bulk density values include 0.75g/ml, 0.71g/ml, 0.64g/ml, 0.53g/ml and 0.47g/ml for samples A, B, C, D and E, respectively. The result showed that increasing ratios of substitution of fonio flour with tiger nut and aikido flours in the formulation of the complementary flour blends resulted in significant ($p<0.05$) decreases in the bulk density of the complementary flour samples except for sample B. The result revealed that the sample with 100% fonio flour (sample A) had the highest bulk density while sample E (60% fonio, 20% tiger nut and 20% akidi flour), had the lowest (0.47g/ml). This implies that fonio flour contains more carbohydrates than tiger nut and aikido flour. This low carbohydrate of tiger nut and aikido flour is also reflected in Table 1, where sample E (60% fonio, 20% tiger nut and 20% aikido flour) had the least carbohydrate content. The variation in bulk density could be as a result of the variation in starch content. This corroborates with Iwe and Onadipe (2001), who reported that starch content increases bulk density. Therefore, there is a linear correlation between carbohydrate content and bulk density; hence, reduction in carbohydrate content among the food samples also reduces the bulk density of the complementary food samples. Ocheme *et al.*(2018) stated that the higher the starch, the higher the bulk density.Lower bulk density in the blends compared with 100% fonio flour could be a result of reduction in carbohydrate content (Gernah *et al.,* 2011). Nutritionally, low bulk density is advantageous because it engenders the consumption of more quantities of lighter food items, which will translate into more nutrients for the consumer. This implies that the food samples with higher ratio of tiger nut and akidi flour could be more nutritious compared to sample A with 100% fonio flour.

Oil absorption capacity (OAC)

The oil absorption capacity of the complementary food samples ranged from 60.41% to 69.04%. Sample A (100% acha flour) had the least absorption capacity at 60.41%, followed by sample B at 62.15%, sample C at 66.24%, sample D at 68.75%, and the highest capacity was in sample E (60% fonio, 20% tiger nut, and 20% akidi flour) at 69.04%. The high oil absorption capacity of sample E could be attributed to a higher percentage of protein present in the sample as Appiah et al. (2011) reported that the oil absorption capacity of complementary flour samples differed significantly due to the positively charged amino acid compositions in flour. Substituting fonio flour with tiger nut and akidi flours had a significant effect ($p<0.05$). The oil absorption capacity increased when using tiger nut and aikido flours as substitutes for fonio flour, while the water absorption capacity decreased. This is likely due to the low starch content of tiger nut and akidi flours. Oil absorption capacity is an important functional property that enhances the mouthfeel and flavor of food products (Adebowale & Lawal, 2004). The absorption of oil by food products improves mouthfeel and flavour retention, making it an important property in food formulations (Iwe *et al.*, 2016).

Gelation capacity

Gelation capacity for the complementary food samples ranged from 14.47%to 19.91%. There were significant ($p<0.05$) differences among all the flour samples gelation capacity values. The gelation capacity values includes 19.91%, 19.24%, 17.40%, 15.16% and 14.47% for samples A, B, C, D and E respectively. The trend of the result indicates that as the ratio of inclusion of tiger nut and akidi flour increases, the gelation capacity of the complementary food samples decreased. Hence it was revealed that among all the food samples, the ability to form gel is recorded highest (19.91) in sample A (100% acha flour) while the least (14.47) ability is found in sample E (60% fonio flour, 20% tiger nut and 20% akidi flour).

Gelation capacity is the ability of flour to form gel. Gelation is also related to the water absorption index of starch-based flour during heating as was observed by Yusuf and Ejeh (2018) where partial inclusion of Bambara groundnut flour into wheat flour caused a decline in gelation capacity which is similar to the trend of this study. Gelation capacity of the complementary food samples followed the same trend with water absorption of the flour samples. Gelation capacity decreased as the level of substitution of fonio with tiger nut and akidi flour increased. This decrease in gelation capacity among the food samples may be attributed to low starch content of akidi and tiger nut flour as shown in Table 2 . Iwe *et al.*(2016) stated that the property of starch granules to form a gel when subjected to heat is important in the formulation of baked foods.

Emulsifying Capacity

The emulsifying capacity of the complementary food samples ranged from 47.30% to 49.89%. Substituting fonio flour with tiger nut and akidi flours at different levels significantly affected the emulsifying capacity. As the blending ratio of tiger nut and akidi flour increased, the emulsifying capacity also increased. Sample E (60% fonio, 20% tiger nut, and 20% akidi flour) had the highest emulsifying capacity at 49.89%, while sample A (100% fonio flour) had the lowest at 47.30%. The emulsifying capacity of the food samples followed the same trend as the oil absorption capacity, increasing as the level of substituting fonio flour with tiger nut and akidi flour increased. Similar to the oil absorption capacity, the increase in emulsifying capacity of the food samples may be attributed to the higher protein content of akidi flour compared to fonio flour. Iwe *et al.,* (2016) stated that the higher emulsifying capacity could be due to a higher protein content. Emulsion formation and stability are crucial in food systems like salad dressing. Proteins, made of charged, non-charged polar, and non-polar amino acids, can act as emulsifiers by interacting with both water and oil in the food system (Yu *et al.*, 2007). Highly insoluble proteins are not good emulsifiers and can generate coalescence (Moure *et al.*, 2006).

Table 3 Sensory Evaluation of the Complementary Flour Gruels

Samples	Aroma	Taste	Appearance	Mouth Feel	Overall Acceptability
A	6.21^{b}	6.35^{b}	7.50^{a}	7.47^{a}	6.36^{b}
B	6.28^{b}	6.40^{b}	7.73^{a}	7.55^{a}	6.44^{b}
C	7.50^{a}	6.65^{b}	6.81^{b}	7.64^{a}	7.37^{a}
D	7.78^{a}	7.19^{a}	6.42^{c}	6.48^{b}	7.63^{a}
E	6.64^{b}	7.37^{a}	6.11^{c}	6.34^{b}	6.51^{b}
LSD	0.47	0.40	0.38	0.45	0.50

Means on the same column with same superscripts are not significantly different ($p>0.05$) from one another

Note

A = Complementary gruel from 100% fonio + 0% tigernut + 0% akidi flour
B = Complementary gruel from 90% fonio + 5% tigernut + 5% akidi flour
C = Complementary gruel from 80% fonio + 10% tigernut + 10% akidi flour
D = Complementary gruel from 70% fonio + 15% tigernut + 15% akidi flour
E = Complementary gruel from 60% fonio + 20% tigernut + 20% akidi flour

Aroma

The aroma scores of complementary flour gruels ranged from 6.21 to 7.78. Samples C and D were moderately liked, with sample D scoring the highest at 7.78. There were no significant differences between samples A, B, and E, as well as between samples C and D. Aroma plays a crucial role in attracting consumers to food products.

Taste

The sensory score for taste of the complementary flour gruel ranges from 6.35 to 7.37 (Table 3). The sample with the highest score was sample E with value (7.37) followed in descending order by sample D with a score of 7.19, sample C with a score of 6.65 and sample B with a 6.40 score while sample A was rated the least (6.35). From the scores, the panelists liked the complementary flour gruels A, B, and C slightly while samples D and E were liked moderately. The panelists may have preferred the taste of sample E most because of the sweet taste of tiger nut which was included up to the level of 20%. There was no significant ($p>0.05$) difference among complementary gruel samples A, B, and C as well as between samples D and E in terms of taste.

Appearance

The appearance scores of the complementary flour sample gruels ranged from 6.11 to 7.73. There were significant differences between sample C and the other flour gruels, with samples A and B, as well as D and E, having similar scores. Sample B (90% fonio, 5% tiger nut, and 5% aikido flour) received the highest appearance rating (7.73), while sample E (60% fonio, 20% tiger nut, and 20% aikido flour) scored the lowest (6.11).

Mouth feel

Please remember the following results from the flour sample evaluation: Sample C had the highest score (7.64) for mouth feel, followed by sample B, sample A, and sample D with scores of 7.55, 7.47, and 6.48 respectively. The sample produced from 60% fonio, 20% tigernut, and 20% akidi flour (sample E) received the lowest score of 6.34

Overall acceptability

The overall acceptance scores for complementary food samples are as follows: A - 6.36, B - 6.44, C - 7.37, D - 7.63, and E - 6.51. Sample D, made from 70% fonio, 15% tigernut, and 15% akidi flour, received the highest score (7.63) and was well-liked. Sample C also scored well at 7.37. Panelists' preferences for sample D were influenced by the aroma and taste of the tigernut and akidi blend. There were no significant differences between samples C and D, nor among samples A, B, and E. Sample A had the lowest score (6.36). Overall acceptability reflects consumer acceptance of the product.

CONCLUSION

This study proved the actualization of complementary food production from fonio, tiger nut, and Aikido flour blends. The protein, fat, and fibre contents of blends improved with the inclusion of tiger nuts. The organoleptic attributes of the food samples were very much appreciated, especially the mouthfeel and general acceptability. The complementary food containing 70% fonio and 15% tiger nut and aikido was most preferred to other samples for organoleptic assessment. The study generally proved that good quality food, in terms of nutrients and consumer acceptance, could be produced from locally available raw materials like fonio, tiger nut, and aikido.

RECOMMENDATIONS

Based on the high nutrient content of tiger nut and akidi flour, there is a need for their inclusion into some food products as complements to enhance the nutritional (especially protein, fibre and vitamins) requirements of individuals, especially infants and children in developing countries, in order to help eradicate malnutrition. Also, more research into locally available under-utilized plant foods such as tiger nut and aikido with great nutritional potential is recommended to enhance novel food production and reduce food scarcity.It is also recommended that the cultivation of fonio, tiger nut and akidi be increased to make them available round-the-year.

REFERENCES

Adebowale, K. O. and Lawal, O. S. (2004). Comparative study of the functional properties of bambara groundnut (*Voandzeia subterranean*), jack bean (*Canavalia ensiformis*) and mucuna bean (*Mucuna pruriens*) flours*. Food Research International 37: 355-365.*

Adegoke G.O. (2004). Understanding Food Microbiology.2nd Edition. Nigeria: Alleluia Venture Ltd.

Amankwah, E. A., Bariaah, J., Huamah, A. K. M., Oldhan, J. H. and Nnai, C. O. (2009). Formulation of wearing food from fermented maize, rice, soybean and fishmeal. *Pakistan Journal of Nutrition 8:1747-1752.*

Anderson, J.W., Smith, B.M. and Gustafson, N.J. (1994).Health benefits andpractical aspects of high fibre diets.*Am. J. Clinical Nutr.59:1242-1247*.

AOAC.(2010). Official Method of Analysis of the Analytical chemist.18th Ed. Washington D.C.

Appiah, F., Asibuo, J.Y. and Kumah, P. (2011).Physicochemical and functional properties of bean flours of three cowpea (*Vigna unguiculata L. Walp*) varieties in Ghana.*Afr. J. Food Sci. 5:100-104.*:

Ashogbon, A.O. and Akintayo, E.T. (2013). Isolation and characterization of starches from two cowpea (*Vigna unguiculata*) cultivars.*Int. Food Res*. 20:3093-3100.

Ashraduzzaman, M., Alam, M. A., Khatun, S., Banu, S. and Absar, N. (2011). *Vigna unguiculata* walp seed oil exhibiting anti-diabetic effects in alloxan-induced diabetic rats. *Mal.J. Pharm. Sci*. 9:13-23.

Ayo, J.A. and Nkama, I.(2006).Acha (*Digitaria exilis*).*West Africa International Journal of Food and Agriculture,*1 (1):129-144.

Barber, L.I., Obinna-Echem, P.C. and Ogburia, E.M. (2017). Proximate composition, micronutrient and sensory properties of complementary food from fermented maize, soybean and carrot flours.*Sky Journal of Food Science; 6(3): 033 – 039.*

Belewu, M.A. and Belewu K.Y. (2007).Comparative Physico-Evaluation of Tiger-nut, Soybean and Coconut Milk Sources.*Int. J. Agric. Biol.* 9:785-787.

Bosch, L., Alegria A. and Farri, R. (2005).RP-HPLC determination of tiger-nut and orgeat amino acid contents.*Food Sci. Technol. Inter.*, 11: 33-40.

Chadare, F.J., Madode, Y.E., Fanou-Fogny, N., Kindossi, J.M. and Ayosso, J.O. (2018). Indigenous food ingredients for complementary food formulations to combat infant malnutrition in Benin: A review: Potential of indigenous foods in the formulation of infant foods. *J Sci. Food Agric.,* 98: 439-455.

Chandra, S. and Singh, S. (2013). Assessment of functional properties of different flours. *African Journal of Agricultural Research, 8(38): 4849-4852.*

Chukwu O. and Abdul-kadir A.J. (2008).Proximate Chemical Composition of Acha(*Digitaria exilis* and *Digitaria iburua*) Grains.*Journal of Food Technology,* 6: 214-216.

Codex Alimentarius Commission.(1991). Guidelines on formulated supplementary foods for older infants and young children CAC/GL08. Rome: Italy

Dewey, K.G. (2013). The Challenge of Meeting Nutrient Needs of Infants and Young Children during the Period of Complementary Feeding: An Evolutionary Perspective. *J. Nutr., 143: 2050-2054.*

Egbujie A.E. and Okoye J.I. (2019).Chemical and sensory evaluation of complementary foods produced from sorghum, African yam bean and crayfish flours.*International Journal of Food Science and Nutrition*, 4(3): 114-119.

FAO/WHO (2002a).Milk and milk products. Joint FAO/WHO Food standards programme. CODEX Alimentarius Commission, P. 42.

FAO/WHO, (2002b). Joint FAO/WHO Expert Report on diet, nutrition and the prevention of chronic diseases, cited in *Food and Nutrition Bulletin*, 24: 255-256.

Gernah, D. I., Ariahu, C. C. and Ingbian, E. K. (2011). Effects of malting and lactic fermentation on some chemical and functional properties of maize. *American Journal of Food Technology, 6: 404-412.*

Hawa, A., Satheesh, N. and Kumela, D. (2018). Nutritional and anti-nutritional evaluation of cookies prepared frookara, red teff and wheat flours. International Food Research Journal, 25(5): 2042-2050.

Igbabul, B.D., Bello, F.A and Ekeh, C. N. (2018). Proximate composition and functional properties of potato and hamburger bean flour blends. *Journal of Food Science and Technology. 3(4):118.*

Ikujenlola A. V., Ahmida, A. F. and Gbadamosi, O. S. (2017).Nutritional Quality and Safety Assessment of Complementary Food Produced from *Acha* (*Digitaria exilis*) Flour and *Kariya* (*Hildergardia barteri*) Protein Concentrate Blends.*Journal of Food Chemistry and Nanotechnology;*3(1): 24-30.

Iwe, M. O., Onyeukwu, U. and Agiriga, A. N. (2016).Proximate, functional and pasting properties of FARO 44 rice, African Yam bean and brown cowpea seeds composite flour. Cogent Food and Agriculture, 2: 1-10.

James, C. S. (1995). *Analytical chemistry of foods*, London: Blackie Academic and Professionals, pp. 256-257.

Lasekan, O. O. (1994) Chemical composition of acha (*Digitaria exilis*) flour.*J Food Sci. Agric., 14:177–179.*

Mariam, S. (2005). Nutritive value of three potential complementary foods based on cereals and legumes. *Afr. J. Food Nutr.Sci., 5(2): 1–14.*

Mesfin, W. and Shimells, A. (2013). Effect of soybean cassava flour blend on the proximate composition of Ethiopian traditional bread prepared from quality protepin maize. African Journal of Food, Agriculture, Nutrition and Development, 3:7985-8003.

Mohammed, S. S.,Olajide, J. E., Jamila, A.,Okpachi, C. A. and Daniel, O. E. (2018).

Proximate composition, mineral and some vitamin contents of tigernut (Cyperus esculentus). Clinical Investigation.8: 4.

Nnam, N.M. (2002). Evaluation of Complementary Foods based on Maize, Groundnut, Pawpaw and Mango flour Blends*. Nig. J. Nutr. Sci.*, 22&23: 8 – 18.

Ocheme, O. B., Adedeji, O. E., Chinma, C. E., Yakubu, C. M. and Ajibo, U. H. (2018). Proximate composition, functional and pasting properties of wheat and groundnut protein concentrate flour blends. *Food Science and Nutrition. 6:1173-1178.*

Ogbonna, A. I., Akueshi, E. U., Aguiy, U. B., Onosemuode A., Mercy Emefiene M.and Okunuga, D. O. (2010). Nutrient Analysis of Indigenous Fortified Baby Weaning Foods from Nigerian Cereals.*Nigerian Journal of Biotechnology,* 21:41-45.

Okoye, J. I. and Egbujie, A.E. (2018).Production and Quality Evaluation of Complementary Food from Blends of Malted Sorghum, Soybean and Irish Potato Flour.*Intl. J. Agri. Environ. Biores., 3(3):301-313*.

Onabanjo, O.O., Akinyemi, C.O. and Agbon, C.A. (2009). Characteristics of Complementary Foods Produced from Sorghum, Sesame, Carrot and Crayfish. *Journal of Natural Sciences, Engineering and Technology; 8(1): 71 – 83.*

Onwuka, G.T. (2005). Food analysis and instrumentation, theory and practices. Naphtali prints, Lagos Nigeria.

Osendarp, S.J., Broersen, B., Van Liere, M.J., De-Regil, L.M. and Bahirathan, L. (2016). Complementary Feeding Diets Made of Local Foods can be Optimized, but Additional Interventions will be Needed to Meet Iron and Zinc Requirements in 6-to 23-Month-Old Children in Low- and Middle-Income Countries. *Food Nutr. Bull., 37: 544-570.*

Osungbaro, T.O. (2009). Physical and nutritive properties of fermented cereal foods.*African Journal of Food Science, 3(2):023-027*.

Papalamprou, E.M., Doxastakis, G. and Kiosseoglou, V. (2009). Chickpea protein isolates obtained by wet extraction as

Plahar, W.A., Okezie, B.O. and Gyato, C.K. (2003).Development of a high protein weaning food by extrusion cooking using peanuts, maize and soybeans.*Plant Foods for Human Nutrition,* 58(3): 1-12.

Princewill-Ogbonna, I.L. (2015). Proximate and Anti-Nutritional Studies of Two Varieties of Germinated Acha Seed *(Digitaria Exilis)*.*The International Journal of Science and Technology*. 3 (4) 213-218.

Raymond, J., Agaba, M., Mollay, C., Rose, J. W. and Kassim, N. (2017). Analysis of nutritional adequacy of local foods for meeting dietary requirements of children aged 6−23 months in rural central Tanzania. *Archives of Public Health*, 75(1), 1–8. 10.1186/s13690-017-0226-4

Singh, U. (2001). Functional properties of grain legume flour.*Journal of Food Science and Technology, 38:191-199.*

Udeozor, L. O. (2012). Tigernut-Soy Milk Drink: Preparation, Proximate Composition and Sensory Qualities. *International Journal of Food and Nutrition Science,*1 (4): 1-26.

World Health Organization (2003).World Health Organization, & UNICEF.Global strategy for infant and young child feeding.WHO, 2003; Geneva.

World Health Organization (2014).Comprehensive Implementation Plan on Maternal Infant and Young Child Nutrition.

World Health Organization/FAO. (2004). Vitamin and mineral requirements in human nutrition, 2nd ed. Geneva: WHO, 2004.

Yusuf, M. I. and Ejeh, D. D. (2018). Production of bambara groundnut substituted whole wheat bread functional properties and quality characteristics. *Journal of Nutrition and Food Science, 8(5): 2-7.*