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Functional properties and storage stability of optimized cereal-based complementary foods

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ABSTRACT

The functional properties and good quality of food materials are important factors that determine the suitability for complementary foods for children. This study evaluated the functional properties and storage stability of cereal-based and legume- based complementary food (CF). Nutri-survey (2007) was used to optimize and generate six composite blends designated F1, F2, F3, F4, F5, and F6 from yellow maize (*Zea mays*), wheat (*Triticum aestivum*), millet (*Pennisetumglaucum*), groundnut (*Arachis hypogea*), soyabeans (*Glycine max*), and *Moringa oleifera.* Freshly prepared samples were subjected to analysis of functional properties. During storage, the composite blends were subjected to sensory evaluation, microbial count, moisture content, peroxide value and free fatty acid determination at 15-day intervals for a period of 60 days. Data obtained were analyzed by ANOVA and results expressed as mean and standard error of mean. Results of functional properties revealed that bulk density ranged from (0.63-0.81 g/cm^3), water absorption capacity (86-90%), swelling index (0.33-1.34 cm^3/g), reconstitution index (2.20-3.20) and pH (6.52-6.69). The organoleptic properties and keeping quality of the formulated complementary foods were not significantly different (P> 0.05) at baseline and end line. Therefore, this study provides a basis for the development of acceptable complementary foods with optimal functional properties and storage stability.

Introduction

Complementary food is any solid or liquid food with nutritional value other than breast milk, offered to breast-fed infants (Eucharia et al., 2020). Complementary food may also be defined as transitional foods consumed by infants and young children between the time when the diet is composed exclusively of mother's milk and when it is mostly made up of family foods (UNICEF, 2018). Complementary foods can be specially prepared for the child or can be the same foods available for other family members, modified in order to meet the eating skills and needs of the child (UNICEF, 2018).

Complementary food can be homemade or bought as ready-to-eat or ready-to-mix commercial products. However, some parents prepare complementary food at home for different reasons, such as cost, freshness, and the avoidance of preservatives. Thus, homemade complementary foods remain commonly used (Motuma et al., 2016). In low -income countries like Nigeria, complementary foods are mostly produced from only cereals or sometimes in combination with legumes (FAO/WHO, 1994).

Cereals and legumes are staple foods, which play an important role in supplying nutrient and energy to the

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majority of Nigerians. Millet (*Pennisetumtyphoides*), maize (*Zea mays*), wheat (*Triticum aestivum*),soy bean (*Glycine max*) and groundnut (*Arachis hypogea*) are cheap sources of energy and protein in Nigeria. One way these cereals and legumes are used as food products is by milling to flours which can be easily handled, packaged and stored for future use (Adeoye et al., 2018).

Traditional processing methods, such as malting, soaking, fermentation, dry roasting and milling influence the nutritional, functional properties and storage stability of flours from these grains (Adeoye et al., 2018). Flours are susceptible to moisture uptake, caking, discolouration and oxidative deterioration. These deteriorative changes, which are influenced by storage time and other intrinsic and extrinsic factors affect the suitability of flours for food products (Brixi et al., 2018). Therefore, the present study was conducted to investigate the functional properties and storage stability of optimized cereal-legume based complementary foods.

Materials and methods

Procurement and processing of food materials

The food materials: millet (*Pennisetumtyphoides*), maize (*Zea mays*), wheat (*Triticum aestivum*), soy bean (*Glycine max*) and groundnut (*Arachis hypogea*) *Moringa oleifera* leaves were purchased from Birnin Kebbi New Market, Kebbi State, Nigeria, in November 2020. The food items were identified by a Taxonomist in the Department of Biology, Federal University Birnin Kebbi. Samples of the authenticated materials with voucher numbers VN78A for *Pennisetumtyphoides*, *Zea mays* (VN311A), *Triticum aestivum* (VN45B), *Glycine max* (VN518B) and *Arachis hypogea* (VN56A), respectively, were kept at the herbarium section of the Department.

The cereals and legumes were manually sorted to remove stones and dirt. This was followed by roasting of the cereals for about 10 to 15 minutes. The *Arachis hypogea*was dehulled after roasting. *Glycine max*was soaked for about six hours, then dehulled and blanched for about 15 minutes, dried and roasted. The *M. oleifera*leaves were manually sorted to remove stones and dirt. The leaves were washed to remove dirt and soaked in 1% saline solution (NaCl) for 5 minutes to get rid of microbes. The leaves were drained and shade dried. The dried leaves were ground and sieved.

Optimization and formulation of the complementary foods

NutriSurvey software (version, 2007) was used to optimize the composite blends by varying the amounts of the various ingredients to enhance the nutritional quality. The proportion of various ingredients in the composite blend is presented in Table 1.

Table 1. Percentage composition of the formulations

Ingredients	F1	F2	F3	F4	F5	F6
Zea mays	67.00	55.00	-	-	-	-
Triticum aestivum	-	-	67.00	55.00	-	-
Pennisetumtyphoides	-	-	-	-	67.00	55.00
Glycine max	8.00	10.00	8.00	10.00	8.00	10.00
Arachis hypogea	22.50	32.50	22.50	32.50	22.50	32.50
Moringa oleifera	2.50	2.50	2.50	2.50	2.50	2.50

Determination of functional properties
Bulk density

The bulk density was determined following the procedures described by Okezie and Bello (1988). A 10 cm^3 graduated cylinder, previously tarred, was gently filled with the complementary diet. The bottom of the cylinder was gently tapped on a laboratory bench several times until there was no further diminution of the sample level after filling to the 10 cm^3 mark. Bulk density was calculated as weight of sample per unit volume of sample (g/cm^3) using the formula:

$$\text{Bulk density}\left(\frac{\text{g}}{\text{cm}^3}\right) = \frac{\text{Weight of sample}}{\text{Volume of sample}}$$

Reconstitution index (RI)

From the ground sample, five grams of each sample were dissolved in 50 cm^3 of boiling water. The mixture was agitated for 90 seconds and was transferred into a 50 cm^3 graduated cylinder and the volume of the sediment was recorded after settling for 30 minutes (Onwuka, 2005).

$$\text{RI}(\text{cm}^3/\text{g}) = \frac{\text{Volume of sediment}}{\text{Weight of sediment}}$$

Determination of water absorption capacity (WAC)

From the ground sample, 1g was weighed into conical graduated centrifuge tubes of known weights and mixed with 10 cm^3 of distilled water for one minute with a glass rod. The tubes were centrifuged at 5000 rpm for 30 minutes. The volume of the supernatant was discarded and each tube together with its content was reweighed as water absorbed per gram of sample. The gain in mass was the water absorption capacity of the flour sample. The volume difference gave the volume of water absorbed per gram sample. Absorption capacity is expressed as grams of water absorbed per gram of sample (Onwuka, 2005).

$$\text{WAC} = \frac{\text{Density of water} \times \text{Volume absorbed}}{\text{Weight of sample}}$$

Determination of swelling index (SI)

Swelling index was determined according to the procedure described by Ukpabi and Ndimele (1990). From each sample, 3g were transferred into clean, dry, and graduated (50 cm^3) cylinders. The samples were gently leveled and the volumes noted. Distilled water (30 cm^3) was added to each sample. The cylinder was swirled and allowed to stand for 60 minutes, while the change in volume (swelling) was recorded every 15 minutes. The ratio of the initial volume to the final volume gave the swelling index.

$$\text{Swelling Index}(cm^3/g) = \frac{\text{Change in volume of sample}}{\text{Change in weight of sample}}$$

Determination of wettability

Triplicate samples were weighed and, in each case, 1.00 g was introduced into a 25 cm^3 measuring cylinder with a diameter of 1 cm and a finger was placed over the end of the cylinder. The mixture was inverted and clamped at a height of 10 cm from the surface of a 250-cm^3 beaker, containing 100 $cm^3$of distilled water. The finger was removed to allow the test material to be dumped. Wettability was taken as the time required for the sample to become completely wet (AOAC, 2005).

pH measurement

The pH of the samples was determined according to Mathew et al. (2015). The samples (10%W/V) were suspended in distilled water. The suspensions were mixed thoroughly in 100 cm^3 beaker before the pH was taken. This was repeated three times and the average was calculated.

Determination of iodine value

Iodine value was determined according to the method of Ebunoluwa et al. (2017). To 5cm^3 of chloroform solution of the fat sample, 5cm^3 of Dam's reagent was added. The mixture was kept in fume cupboard for 10 min. and 5cm^3 of 10% KI and 20cm^3 of water were added. The mixture was thoroughly mixed and titrated to a colourless end point with 0.025 M $Na_2S_2O_3$ solution.

Storage stability analyses

The products were packaged in laminated aluminum foil. Freshly prepared formulations were subjected to microbial count, moisture, peroxide value and free fatty acid determination at 15-day intervals for 60 days (AOAC, 2005; Amankwah et al., 2009).

Estimation of peroxide value

The peroxide value was determined according to Ebunoluwa et al. (2017). From the sample, 2.0g was weighed into a clean dry flask and 22 cm^3 of the mixture of 10 cm^3 of acetic acid and 12 cm^3 of chloroform was added, then 0.5 cm^3 of potassium iodide was also added. The flask was closed and allowed to stay with constant shaking for 1 minute. About 30 cm^3 of distilled water was then added and titrated against 0.1 M of sodium thiosulphate ($Na_2S_2O_3$) solution until an initial yellow colour disappeared and a faint blue colour appeared. The titration continued after the addition of 0.5 cm^3 of starch indicator until there was a sudden disappearance of the blue colour, which signifies the end point. The peroxide value was calculated using the equation:

$$\text{Peroxide value}(\text{meq/kg}) = \frac{\text{S} \times \text{N} \times 100}{\text{W}}$$

S = Volume in cm^3 of sodium thiosulphate solution used up by the sample,

N = Normality of sodium thiosulphate solution,
W = Weight in grams of the sample.

Estimation of free fatty acid

Free fatty acid was determined according to the method of Ebunoluwa et al. (2017). From the sample, 2.0 g was transferred into a 250 cm^3. Erlenmeyer flask followed by the addition of 100 cm^3 of ethanol and 2 cm^3 of phenolphthalein indicator. After mixing the content properly, it was titrated against 0.04 M NaOH. The shaking continued until a slight pink colour was observed, which was steady for about 30 seconds and signified the end point. The percentage of free fatty acids was calculated using the equation:

$$\%FFA = \frac{V \times M \times 28.2}{W}$$

V= average volume of NaOH used (cm^3),
M = molarity of NaOH,
28.2g/mol = Molecular weight of oleic acid,
W = weight of the flour sample.

Moisture content determination

Moisture content was determined by oven drying according to Association of Official Analytical Chemist (2005). The moisture dishes were washed and placed in an oven drier at 105 °C for one hour. They were then placed in a desiccator to cool down and the initial weight of the dishes was recorded (W1). Three grams of samples were taken and placed in the moisture dish and the weight was recorded (W2). The dishes were then placed in an oven drier overnight. After drying, the moisture dishes with dried samples were removed from the oven drier, cooled down in a desiccator and the final weight was recorded (W3). The percentage moisture content of the samples was calculated using the formula below:

$$\text{Moisture content}(\%) = \frac{W3 - W1}{W2 - W1} \times 100$$

Organoleptic evaluation of the composite blends

Sensory evaluation was conducted according to USAID (2015). The test formulations were judged by 15 semi trained panelists at baseline and end line. Five (5) points hedonic rating scale was used. Scores were defined as: 1 for dislike extremely or bad, 2 for like slightly only or tolerable, 3 for like or good, 4 for like very much or very good, 5 for like extremely or excellent.

Microbial loadcount

The packaged products were tested for bacteria, mould, and yeast. Serial dilutions were made from 1g of each sample dissolved in 9 cm^3 of distilled water in a Mac Cartney bottles to give 10^{-1} dilution. Serial dilutions were made up to 10^{-3}. Each diluent was plated out in duplicate using the pour plating technique by transferring 1 cm^3 from each Mac Cartney bottle into 2 different Petri dishes and pouring 15cm^3 of the nutrient agar media on each sample as described by Speck (1992). The plates were incubated at 37 °C for 48 hours for bacterial growth and at 27 °C for 5 days for yeasts and mould. The average colony, obtained from the countable duplicate plates, were expressed as colony forming unit per gram (Cfu/g) using the formula:

$$N = A \times D$$

Where N = Number of colonies (cfu/g),
A = Average count of colonies in petri plates,
D = Dilution factor.

Data analysis

Data obtained was subjected to statistical analysis. Means, Analysis of Variance (ANOVA) were determined using the Graph Pad PRISM version 6.05 software (Statcon, Witzenhausen, Germany) and significant difference was establish at (P<0.05).

Results

The functional properties (bulk density, water absorption capacity, swelling index, reconstitution index and wettability) of the complementary food blends are presented in Table 2. The data reveals that bulk density ranged from 0.63-0.81, water absorption capacity (86-90%), swelling index (0.33-1.34) reconstitution index (2.20-3.20) and pH (6.52-6.69).
The result of the pH values of the complementary food blends is showed in Figure 1.
Values were expressed as mean ± standard error of mean (SEM) of triplicate determinations. F1, F3, and F5 contain 67% of Maize, Wheat, and Millet respectively; 22.5% of Groundnut, 8% Soybeans and 2.5% *Moringa*. F2, F4 and F6 contain 55% of Maize, Wheat and Millet respectively; 32.5% Groundnut, 10% Soybeans, 2.5% of *Moringa*.

Table 2. Functional properties of the cereal-legume complementary foods

Samples	Bulk Density (g/cm^3)	Swelling index (cm^3/g)	Reconstitution index	Wettability (s)	WAC (%)
F1	0.81^b ±0.02	0.50^a ±0.06	2.40^a ±0.06	10.0^a ±0.28	90.0^a ±0.57
F2	0.66^b±0.01	0.33^a ±0.01	2.20^a ±0.06	10.0^a ±0.34	88.0^a ±0.46
F3	0.64^b ±0.01	1.34^b ±0.02	3.20^b ±0.12	10.0^a ±0.29	86.0^a ±0.23
F4	0.65^b±0.02	1.13^b ±0.04	2.20^a ±0.29	10.0^a ±0.46	84.0^a ±0.23
F5	0.77^b ±0.01	1.00^b ±0.02	2.60^a ±0.06	10.0^a ±0.28	86.0^a ±0.28
F6	0.63^b ±0.01	1.13^b ±0.01	2.50^a ±0.11	10.0^a ±0.57	86.0^a ±0.57

Values were expressed as mean ± standard error of mean (SEM) of triplicate determinations. Values in the same column with different superscripts are significantly different at ($P < 0.05$). WAC= Water absorption Capacity.

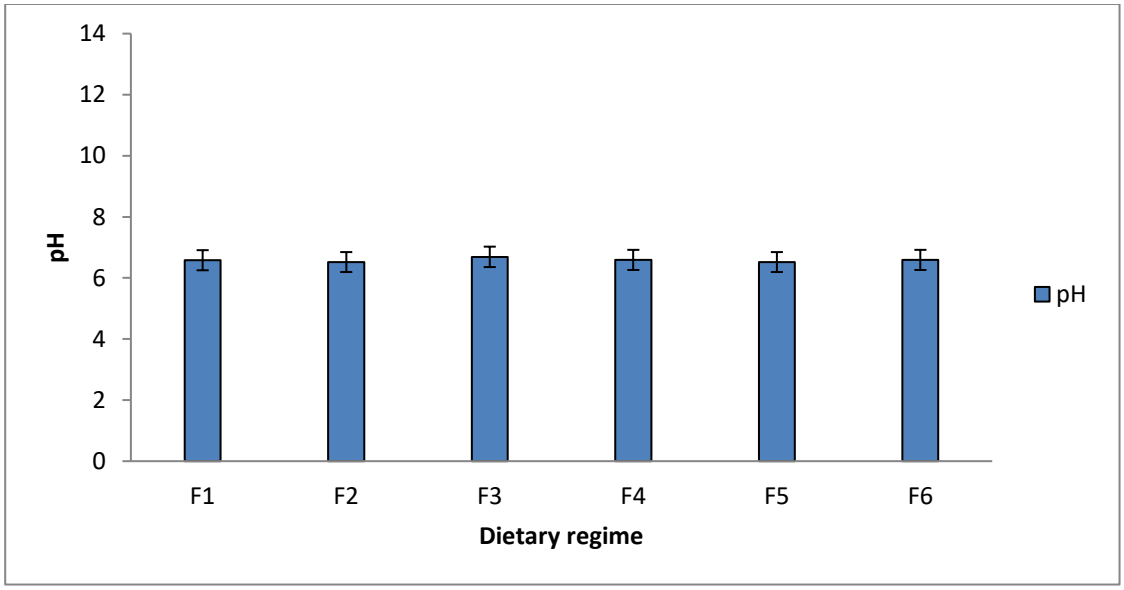

Figure 1. pH of the optimized cereal-legume based complementary foods

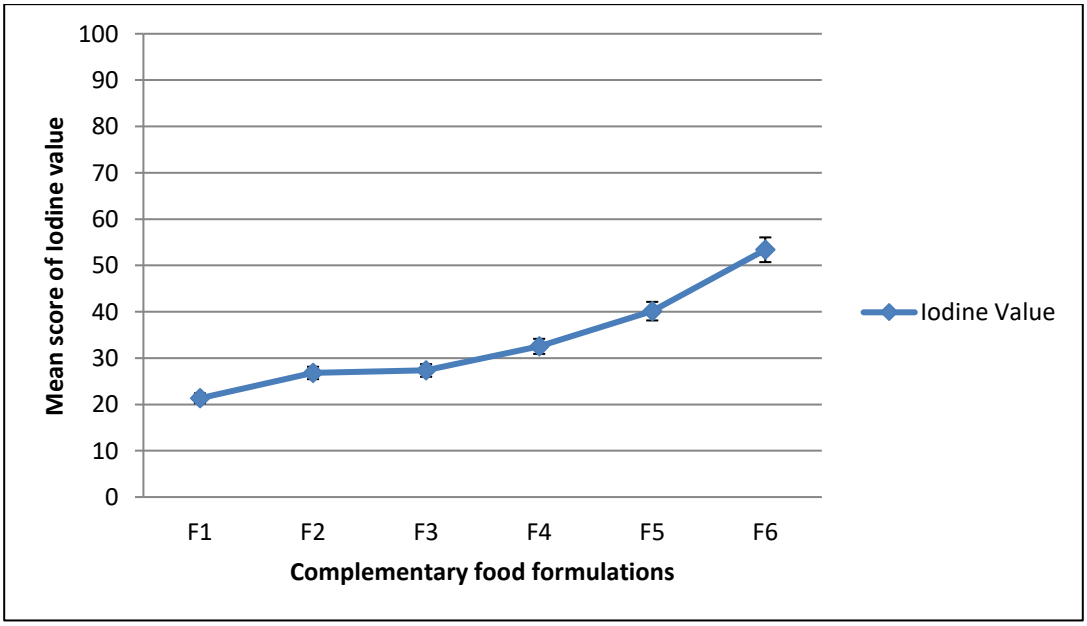

Figure 2. Iodine values of the optimized complementary food formulations

Table 3. Moisture content (%) of the optimized cereal-legume based complementary foods during 60 days torage

Days of Storage	F1	F2	F3	F4	F5	F6
0	3.20^{a} ±0.01	3.15^{a}±0.57	3.55^{a} ±0.32	3.55^{a} ±0.01	3.12^{a}±0.57	3.42^{a}±0.05
15	3.55^{a} ± 0.06	3.50^{a} ±0.19	3.60^{a}±0.35	3.98^{a} ±0.05	3.88^{a}±0.58	3.93^{a} ±0.06
30	4.50^{b} ± 0.57	4.10^{b} ±0.28	4.65^{b} ±0.29	4.40^{b} ±0.29	4.55^{b} ±0.03	4.25^{b} ±0.17
45	5.50^{b} ± 0.01	5.00^{a} ± 0.01	5.85^{b} ± 0.02	5.75^{b} ± 0.02	5.68^{b} ± 0.01	5.00^{a} ± 0.01
60	6.80^{c} ± 0.01	5.50^{a} ± 0.01	7.50^{d} ± 0.01	7.50^{d} ± 0.01	6.88^{c} ± 0.01	6.79^{c} ± 0.01

Values were expressed as mean ± standard error of mean (SEM) of triplicate determinations. Values in the same row with different superscripts are significantly different at ($P < 0.05$).

Table 4. Percentage free fatty acids of the optimized cereal based complementary food formulations

Days of Storage	F1 (%)	F2 (%)	F3 (%)	F4 (%)	F5 (%)	F6 (%)
0	0.13±0.01^{b}	0.15±0.01^{b}	0.16±0.02^{b}	0.17±0.01^{b}	0.10±0.01^{a}	0.12±0.01^{a}
15	0.27±0.01^{b}	0.36±0.01^{a}	0.39±0.01^{a}	0.41±0.01^{a}	0.25±0.02^{c}	0.29±0.01^{a}
30	0.30±0.01^{b}	0.44±0.01^{a}	0.46±0.01^{a}	0.49±0.01^{a}	0.36±0.01^{b}	0.46±0.02^{a}
45	1.37±0.01^{b}	1.47±0.02^{a}	1.44±0.01^{a}	1.47±0.03^{a}	1.47±0.01^{a}	1.49±0.05^{a}
60	2.17±0.02^{c}	2.52±0.04^{a}	2.13±0.04^{a}	2.58±0.05^{a}	1.58±0.01^{b}	2.50±0.01^{a}

Values were expressed as mean ± standard error of mean (SEM) of triplicate determinations.

Table 5. Peroxide value of the optimized cereal based complementary foods during 60 days storage

Day(s)	F1(meq/kg)	F2(meq/kg)	F3(meq/kg)	F4(meq/kg)	F5(meq/kg)	F6(meq/kg)
0	0.50±0.01	0.60±0.01	0.70±0.02	0.90±0.03	0.55±0.01	0.57±0.01
15	0.90±0.05	1.0±0.02	1.12±0.03	1.19±0.02	0.87±0.03	0.90±0.02
30	1.12±0.03	1.16±0.02	1.19±0.01	1.28±0.03	1.0±0.01	1.11±0.03
45	1.26±0.10	1.30±0.03	1.33±0.05	1.35±0.04	1.19±0.01	1.22± 0.01
60	1.30± 0.03	1.32±0.01	1.40±0.02	1.45±0.03	1.20 ±0.02	1.25 ±0.03

Values were expressed as mean ± standard error of mean (SEM) of triplicate determinations. F1, F3, and F5 contain 67% of Maize, Wheat, and Millet respectively; 22.5% of Groundnut, 8% Soybeans and 2.5% *Moringa*. F2, F4 and F6 contain 55% of Maize, Wheat and Millet respectively; 32.5% Groundnut, 10% Soybeans, 2.5% of *Moringa.*

Table 6. Variation in organoleptic properties of the optimized cereal based complementary foods during 60 days storage

Parameter	Days of Storage	F1	F2	F3	F4	F5	F6
Aroma	0	4.10^{a} ±0.06	4.30^{a}±0.11	4.10^{a}±0.28	4.20^{a}±0.06	4.00^{a} ± 0.06	4.50^{a} ±0.23
	60	3.95±0.01	4.05±0.57	4.00±0.32	4.10±0.01	3.85±0.57	4.30±0.05
Texture	0	4.60^{a} ±0.10	4.80^{a} ±0.12	4.80^{c} ±0.35	4.00^{a}±0.23	4.40^{a}±0.43	4.50^{c} ±0.50
	60	4.20±0.19	4.50± 0.01	4.00±0.29	3.80^{a}±0.23	4.10± 0.01	4.15±0.05
Colour	0	4.50^{b} ±0.57	4.10^{b} ±0.28	4.40^{b} ±0.29	4.55^{b} ±0.03	4.25^{b} ±0.17	4.65^{b} ±0.29
	60	3.55^{a} ± 0.06	3.50^{a} ±0.19	3.88^{a}±0.58	3.98^{a} ±0.05	3.60^{a}±0.35	3.93^{a} ±0.06
OA	0	4.20^{a} ±0.07	4.00^{a} ±0.03	3.80^{a} ±0.10	3.90^{a} ±0.18	4.00^{a}±0.12	4.50^{b} ±0.03
	60	3.80^{a} ±0.12	3.60^{a}±0.35	3.65^{a}±0.23	3.70^{a}±0.26	3.80^{a}±0.34	4.00^{b}±0.23

Values were expressed as mean ± standard error of mean (SEM) of triplicate determinations. Values in the same row with different superscripts are significantly different at ($P < 0.05$). OA= Overall acceptability.

Table 7. Bacterial count of the optimized ereal-based complementary foods during 60 days storage

Food Samples	Bacterial count(cfu/g)	
	Baseline	End line
F1	$3.0\pm 0.03\times10^{-3}$	$17\pm0.29^{b}\times10^{-3}$
F2	$2.0\pm0.01\times10^{-3}$	$26\pm0.56^{a}\times10^{-3}$
F3	$2.0\pm0.02\times10^{-3}$	$32\pm0.28^{c}\times10^{-3}$
F4	$3.0\pm0.03\times10^{-3}$	$47\pm0.57^{d}\times10^{-3}$
F5	$4.0\pm0.02\times10^{-3}$	$23\pm0.57^{a}\times10^{-3}$
F6	$4.0\pm0.03\times10^{-3}$	$24\pm0.35^{a}\times10^{-3}$

Values were expressed as mean ± standard error of mean (SEM) of triplicate determinations.
Values in the same row with different superscripts are significantly different at ($P < 0.05$).

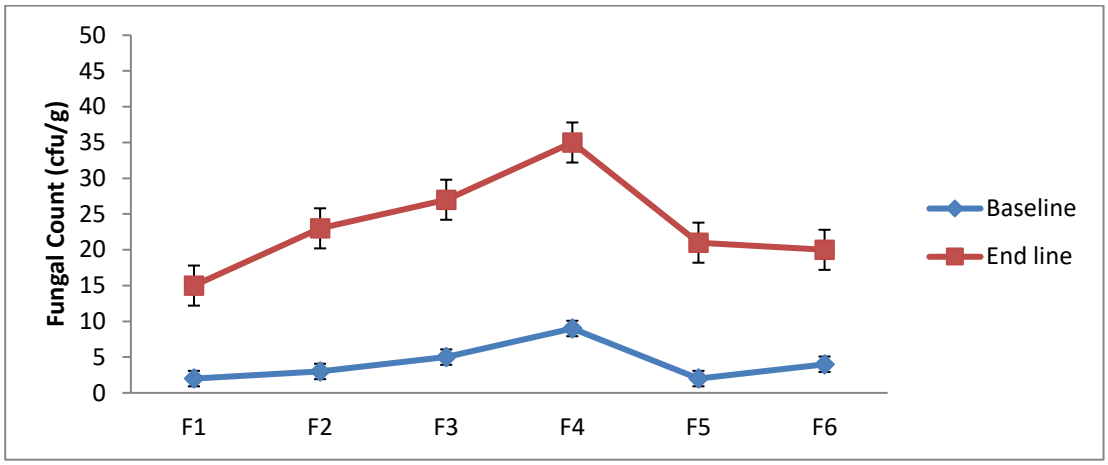

Figure 3. Fungal count of the optimized ereal-based complementary foods during 60 days storage

Values were expressed as mean ± standard error of mean (SEM) of triplicate determinations. F1, F3, and F5 contain 67% of Maize, Wheat, and Millet respectively; 22.5% of Groundnut, 8% Soybeans and 2.5% *Moringa*. F2, F4 and F6 contain 55% of Maize, Wheat and Millet respectively; 32.5% Groundnut, 10% Soybeans, 2.5% of *Moringa*.

Discussion

Functional properties determine the applicability and suitability of food materials for use in food products (Ebunoluwa et al., 2017). This study investigated the functional properties of the flour of some composite blends to ascertain their suitability for making gruel for complementary feeding. The results as presented in Table 2 show there was no significant difference (P>0.05) in the swelling index between samples F1 and F2. However, they differ significantly with other blends under investigation. The swelling index is the amount of watersoluble solids per unit weight of the sample. Swelling index influences the hydrodynamic properties of food products thereby impacting characteristics such as thickening. It is pertinent to note that complementary foods do not require high swelling index as this imply that the food would absorb more water and have less solid resulting in low nutrient density for infants and young children. Samples with least swelling index are preferred for complementary food (Yusuf et al., 2013); thus, blends F1 and F2, with lower swelling index values, are preferred.

Bulk density is a measure of heaviness of flour sample and this gives an indication that the relative volume of the composite flour in a package will not reduce excessively during storage. The bulk density is influenced by particle size and the density of the flour (Yusuf et al., 2013). There was no significant difference (P>0.05) in the bulk density value among blends F2, F3, F4, and F6 (Table 2). They showed, however, a significant difference (P<0.05) with blends F1and F5. Low density values of the complementary food samples imply that more of the samples could be prepared using a small amount of water, while giving the desirable energy density and semi-solid

consistency which can easily be spoon fed to infants and young children. The results obtained for the bulk density were slightly higher than the one reported by Yusuf et al. (2013) for complementary foods. According to Nnam (2000), low bulk density has nutritional and economic significance as more of the products can be eaten resulting in high energy and nutritional density.

Water absorption capacity is the ability of flour to absorb water and swell, for improved consistency in food. The water absorption capacity of the composite blends of the optimized cereal-legume blends did not differ significantly (P>0.05) (Table2). Yusuf et al. (2013) reported slightly lower values for sorghum base complementary foods. The results obtained for the WAC in the current study agree with earlier report by Igyoret al. (2011) that protein functions in binding water and fat while retaining them. Thus, the availability of legume protein has increased the ability of the CF to absorb water.

As shown in Table 2, there was no significant difference (P>0.05) in the pH values of the complementary food blends. The high pH values obtained show that the formulated complementary food falls within weak acid foods.

The iodine values of the complementary food formulations differ significantly ($p<0.05$) as indicated in Figure 2. While blend F6 had the highest iodine value, Blend F1 had the lowest iodine value. Iodine value in food samples is a measure of the degree of unsaturation of fatty acids. CF formulations with high iodine value are more susceptibleto lipid peroxidation, leading to a rancid product with unpleasant odour and taste. The iodine value also has great influence on storage stability. CF formulations with higher iodine value have shorter shelf life, because they are more susceptible to oxidative and hydrolytic oxidation.

Peroxide is an indicator of rancidity, which is a common quality issue in food products. As oxidation takes place in food product, double bonds in unsaturated fatty acids break down to produce secondary oxidation products which indicate rancidity (Ibeanu et al., 2015). Peroxide tests are typically used in conjunction with other tests to determine the level of deterioration and to keep quality of foods over their expected shelf life (USAID, 2015). Peroxide values are measured to give an indication of expected shelf life of foods. Typically, they are measured in combination with free fatty acid levels, moisture content and organoleptic testing (USAID, 2015).

The peroxide values during the period of storage are presented in Table 4. The values recorded in this study may be attributed to dry roasting that was done before milling into flour. The dry roasting may have partially inactivated lipolytic enzymes that are responsible for degradation of triglycerides. Sample F1 had the lowest peroxide value at baseline, while sample F4 had the highest peroxide value during storage at end line (8 weeks). During storage, the peroxide value increased gradually, but the values recorded at end line did not differ significantly from values at baseline (P>0.05). These results agree with the report by Ebunoluwa et al. (2017), who stated that the peroxide value of weaning food developed from locally available staple increased with the increase in the storage period.

Free fatty acids are a measure of the extent to which glycerides in a food sample have been decomposed by lipase or other actions (USAID, 2015). At baseline, all the samples had FFA value of <0.18% (Table 4). These values gradually increased during the 60 days of storage probably due to hydrolysis of fat. This is in agreement with the report of Ibeanu et al. (2015) that hydrolysis of glycerides could account for increased values of free fatty acid in stored flours. Rancidity is accompanied by free fatty acids formation and is used as a criterion to ascertain edibility. Free fatty acids of the flour samples ranged from 0.10 to 2.58%. This is an indication of good storage stability. Sample F5 had the lowest free fatty acids during storage at baseline and end line. The low FFA values observed in sample F5 after 60 days of storage may be attributed to lesser proportion of the oil seeds in the ingredients used for formulation. This may translate to longer keeping quality and by extension longer shelf life (Ibeanu et al., 2015).

The moisture content of samples during storage was ≤7.50%. Nelson (1992) posits that moisture content of CF should be between 3-8%, while Codex Alimentarius Commission recommends ≤ 10% for cereal-based products (CAC, 2017). The moisture content is a function of the drying time. Higher moisture content indicates increased susceptibility to spoilage and thus reduces shelf life. Low moisture contents recorded will ensure better storage stability and shelf life (Sanni and Oladapo, 2008), as higher moisture contents of foods encourages microbial growth and spoilage (Temple et al., 1996). The result obtained at end line is an indication that there was a gradual uptake of moisture by all the samples throughout the storage period. This could be attributed to extrinsic factors such as temperature, relative humidity, and time (Daramola et al., 2010).

Organoleptic or sensory characteristics can change over time. Sensory evaluation is an important tool to assess consumer acceptability (USAID, 2015). This study conducted organoleptic analysis at baseline and end line by visual observation of product appearance (colour, texture/consistency), and product odour. No major organoleptic changes were noted with regards to product appearance, odour or colour during storage.

The sensory attributes of the complementary food formulations did not differ (P>0.05) (Table 6). Muhimbula et al. (2011) posits that sensory evaluation is easy in its principle, but its implementation in the field could be challenging when the panellist have low literacy level. It is pertinent to note that some processing techniques can improve some of the sensory attributes. For instance, roasting of the legumes and cereals before blending had an important improvement on the aroma of the formulations. Aroma is an integral part of taste and general acceptance of the food before it is put in the mouth. It is therefore an important parameter when testing acceptability of formulated foods (Muhimbula et al., 2011). Similarly, the colour or appearance of CF formulations is an important attribute in food choice and preference.

The overall acceptability of the complementary food samples at baseline and end line did not differ (P>0.05). Food sample F6 had the highest score for overall acceptability, both at baseline and end line. This signifies preference by the panellists. This result was in agreement with a previous study by Mbata et al. (2009) who reported high overall acceptability score for cereal-legume based complementary food.

Microbial spoilage of foods is an economically significant problem for food manufacturers, retailers, and consumers. Depending on the product, process, and storage conditions, the microbiological end of shelf life can be determined by either the growth of spoilage or pathogenic microorganisms. Microbial analysis was conducted to determine if blends are wholesome for consumption. Bacterial and fungal count at baseline and end line (8 weeks) were low (<50cfu/g). The international microbiological standard recommends bacteria contaminant limits of less than 10^6cfu/g for food products (ICMSF, 1996). Low bacteria counts may be attributed to high standard of hygiene, drying process, roasting of the ingredients during the food formulation process.

Conclusions

It can be deduced from the results of this study that complementary foods with appropriate functional properties and storage stability can be formulated by optimizing the blending ratio of cereals, legumes and *M. Oleifera* leaf powder. The technique for the production of these complementary foods is simple and the ingredients are readily accessible and affordable. The values of swelling index, water absorption capacity and bulk density indicated that higher amount of the flour particles can stay together and thus increase energy content.

Organoleptic parameters (colour, odour, texture and overall acceptability) of test formulations evaluated on a five-point hedonic scale point to acceptability, both at the base line and the end line. The storage stability profile also indicates good keeping quality at the end line. Therefore, the results of the current study provide a basis for the development of acceptable complementary foods with improved functional properties and shelf life.

Author Contributions: This study was carried out in collaboration among all authors. YS, SAI and JB participated in designing, supervising, and coordinating the study. TAA and YAB conducted the experimental studies (functional and storage stability tests); analyzed, interpreted data and drafted the manuscript. All authors read and approved the final manuscript.

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