EFFECT OF PROCESSING METHODS ON THE CHEMICAL COMPOSITION AND STORAGE STABILITY OF MAIZE-MILLET-SOYBEAN COMPLEMENTARY FOOD

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Abstract
There is paucity of information concerning the use of multiple processing methods in the production of food products especially complementary foods. Multiple processing methods could provide alternative for improving the nutritional quality of food products. This study was carried out to investigate the effect of combining two or more processing methods on the proximate composition, chemical, and storage stability of maize-millet-soybean complementary foods. Maize, millet, and soybean grains were processed using submerged fermentation, germination and roasting methods (120 ± 10 ^{o}C) singly and combined. The fermented, germinated, roasted, and untreated (control) grains were dried in an air oven at 55 °C for 48 h to 10% moisture content and milled separately into fine flours (450 µm). Four complementary food samples (including the control) were formulated and mixed in ratio 50:30:20 maize, millet, and soybean respectively, and analyzed for proximate composition, chemical, and storage stability. The complementary food samples were stored for 13 weeks at ambient temperature (30 ± 2 ^{o}C) to determine its storage stability and shelf-life. Data were analyzed using computer software for analysis of variance, while Duncan multiple range test (DMRT) was used to separate means where there is a significant difference. Results showed that combining fermentation or germination with roasting method significantly ($p<0.05$) increased the crude fat, fiber, and free sugar, while starch content of the complementary food samples compare to SC (control) as a result of combined processing methods. The results shows that there were significant difference ($p<0.05$) in the shelf life of the complementary foods with SFR sample having the best storage stability and shelf life. The study showed that combination of fermentation and roasting methods enhanced proximate composition, chemical, and shelf stability complementary food produced from maize-millet-soybean for infants and young children.

Keywords*:* Multiple processing methods, proximate composition, chemical, storage stability

Received: 27.02.2017 Received in revised form: 24.05.2017 Accepted: 27.05.2017

1. INTRODUCTION

Processing methods have been shown to have significant effect on the proximate composition, chemical, and storage stability of most traditional complementary foods (Ikujenlola and Fashakin 2005; Anigo *et al*., 2010). Research has shown that fermentation of cereal grains to produce *ogi* (complementary food) not only removes parts of its kernel such as seed coat and germ, but also involves washing, sieving and decanting, all of which induce changes in the proximate composition, chemical, and storage stability of the final fermented. Cereal based traditional complementary foods commonly fed to infants are inadequate to meet daily nutrients, energy and micronutrients requirements, while infant's formula foods are too expensive for mothers of low socio-economic status. Banigo *et al.* (1974) reported on the proximate composition of *ogi* made from common whole maize which was uncooked and freeze-dried or cooked and freeze-dried after fermentation. Changes were relatively small in all major nutrients, with a slight increase in fibre and a decrease in ash compare with whole maize. Akingbala *et al.* (1987) found a decrease in protein ether extract, ash, crude fibre and carotene (vitamin A precursor) in *ogi* as compared with maize that was processed as a whole grain or dry

milled. Moreover, most traditional complementary foods apart from having low storage period of less than one week (Simango, 1997), do not contain more than 10 – 12% dry matter, the rest is water (Juke *et al*., 2002; Rapley, 2006).

It is obvious from the pictures painted above that the Nigerian commonest complementary food (*Ogi*) is adequate only in thiamine, fibre, serine and glutamic acid with acceptable flavour imparted by sour taste, but insufficient in protein generally, lysine, ether extract, ash, and vitamin A. However, many researchers in Nigeria (food technologists, food scientists, nutritionists, and etcetera) have worked extensively on how to improve the nutrient value of existing complementary foods by trying to combine cereals, legumes, and other staples in such a way that will maximize the efficiency of their proteins for weaning, while neglecting the effect of combined processing methods with these grains/legume. Ikujenlola and Fashakin (2005) and Anigo *et al*. (2010) earlier observed that no single protein from a particular legume grain could be adequate to promote growth or enhance nitrogen retention compared to a milk-based diet. They suggested that a mixture of cowpea, melon, soya bean and ogi was found to be superior to any single protein source in protein efficiency ratio, net protein retention, biological value and net protein utilization. This type of multi-mix formulation and processing may be cumbersome for our rural and urban women to embrace at cottage level because of its pre-processing preparations, processing, and yet unable to keep for a longer time (shelf-stable) than the existing ones.

Most of these formulated complementary foods cannot be stored for more than a week, and still need to be fortified with one or other food supplement to meet the young child's daily requirement. It could therefore be concluded that the search for local foodstuffs in the formulation of nutrient-dense and organoleptic accepted complementary food has long been in existence and is still in progress. Therefore, it is inevitable to develop and produce traditional complementary foods of high nutrients density, chemical composition, and at the same time shelf stable for longer period which provides enough food intakes per meal in relation to their small stomach through cottage industry processing. The study employed fermentation, germination, with roasting methods on maize-millet-soybean with a view of producing a complementary food that would be easy to formulate and produce at cottage level technology. Therefore, one of the aims of this study is to develop an optimum processing method for a proximate composition, chemical, and complementary food that will be easy to prepare at cottage level and at same times stored for longer period using yellow maize, millet and soya beans as raw food materials.

2. MATERIAL AND METHODS

Materials

The yellow maize (*Zea mays*), finger millet (*Eleusine coracana*), and soybean (*Glycine max*) used in this study were purchased at Lafenwa market, Abeokuta, Ogun State, Nigeria. The three raw materials of four kilogram each were divided into four portions and each portion (1 kg) of raw material was subjected to processing methods of fermentation-roasting, germination-roasting, and germination-fermentation-roasting, while the last portion served as control.

Flour preparation

The complementary flours were formulated by blending all the already dried fermented and germinated flours of maize, millet, and soybean in 50:30:20 ratios, respectively. Three kilogram of each raw material (yellow maize, millet, and soybean) was sorted to remove dirt, stones, damaged and discoloured grains, winnowed and washed in clean plastic bucket at 30 $\pm$ 2 ^{o}C and soaked for 48 h as described by Adeyemi and Beckley (1986). Also, three kilogram of each raw material (yellow maize, millet and soya bean) was sorted to remove dirt, stones, damaged and discoloured grains, winnowed and washed in clean distilled water. Each of the raw materials was germinated using the method described by Kulkarni *et al*. (1991). The dried

fermented and germinated grains were milled and roasted separately at 120±5 ^{o}C for 10 mins and packaged in low density polyethene (LDPE) bags. The packed samples were stored at a cool dry room at 30±2^{o}C. The composite flours of the four complementary foods include the control were formulated equally to determine the effect of combined processing methods on them.

Sample 1 (Control): Raw maize, millet, and soybean flour

Sample 2 (SFR): Fermented (maize, millet, soybean) and roasted

Sample 3 (SGR): Germinated (maize, millet, soybean) and roasted

Sample 4 (SGFR): Germinated (maize, millet, soybean), solid fermentation for 36 hrs and roasted

Methods

Proximate Composition

The proximate composition of the flour including moisture content, crude protein, crude fat, total ash, crude fibre and carbohydrate content were determined according to the standard methods of Association of Analytical Chemists (AOAC, 2005)

Chemical Composition

Determination of pH Value

pH value was determined according to the standard methods of Association of Analytical Chemists (AOAC, 2005). A 10% (w/v) flour suspension of each sample in distilled water was used. Each sample was filtered into a flat bottle after degassing. The pH meter (Jenway 3015 pH meter, USA) was calibrated using a buffer solution of 7.0 and swirled with electrode placed in the sample. pH reading was taken when the reading stabilized. The electrode was rinsed with distilled water and gently blot dried with a cleaned napkin between each sample.

Determination of Total Starch and Sugar

The method described by Dubois *et al.* (1956) was used to determine the total starch and sugar. About 0.02g of the finely ground sample was weighed into centrifuge tubes and wetted with 1ml of ethanol. 2ml of distilled water was added, followed by 10ml hot ethanol. The mixture was vortexed and centrifuged using Sorvall centrifuge (Newton, Connecticut, USA, model GLC-1) at 2000rpm for ten minutes. The supernatant was collected and used for free sugar analysis, while the residue was used for starch analysis. 7.5ml of perchloric acid was added to the residue and allowed to hydrolyze for 1hour.

The hydrolyzed solution was diluted to 25ml with distilled water and filtered through Whatman no 2 filters paper. About 0.05ml of the filtrate was taken, made up to 1ml with distilled water, vortexed and ready for colour development as was described for standard glucose curve preparation.

The supernatant was made up to 25ml with distilled water; an aliquot of 0.2ml was taken from the solution. About 0.5ml phenol (5%) and 2.5ml concentrated sulphuric acid was added. The sample was allowed to cool and the absorbance read on spectrophotometer (Milton Roy Company, USA, Model Spectronic 601) at 490nm wavelength.

The optical values of the samples were compared to the optical value of the standards and an interpretative result was determined using the standard graphs that comes with the machine and expressed as % starch and %sugar.

$$\%\ \text{Sugar} = \frac{\text{Abs-Intercept} \times \text{Dilution factor} \times \text{Volume}}{\text{Weight of sample} \times \text{slope} \times 10{,}000}$$

Abs= Absorbance; Dilution factor= 5; Volume= 25; Slope= 0.0055, and Intercept= 0.0044

$$\%\ \text{Starch} = \frac{\text{Abs-Intercept} \times \text{Dilution factor} \times \text{Volume}}{\text{Weight of sample} \times \text{slope} \times 10{,}000}$$

Abs= Absorbance; Dilution factor= 5; Volume= 25; Slope= 0.0055, and Intercept= 0.0044

Determination of Amylose Content

The method of Williams *et al.* (1958) was used to determine amylose content of the complementary flour samples. This involved the preparation of stock iodine solution reagent. About 0.1g of the samples was weighed into a 100ml volumetric flask and then 1ml of 99.7-100% (v/v) ethanol and 9ml 1M sodium hydroxide (NaOH) were carefully added. The mouth of the flask was covered with parafilm or foil and the contents were mixed well. The samples were heated for 10min in a boiling water bath to gelatinize the starch (the timing started when boiling began). The samples were removed from the water bath and allowed to cool very well, then made up to the mark with distilled water and shaken thoroughly. Then, 5ml was pipetted into another 100ml volumetric flask and 1.0ml of 1M acetic acid and 2.0 ml of iodine solution were added. The flask was stopped up to the mark with distilled water. Absorbance (A) was read using a spectrophotometer at 620nm wavelength. The blank contained 1ml of 1M ethanol, 9 ml of 1M sodium hydroxide, boiled and topped up to the mark with distilled water. Thereafter 5 ml of the solution was pipetted into a 100ml volumetric flask, 1ml of 1M acetic acid and 2 ml of iodine solution were added and topped up to mark. This was used to standardize the spectrophotometer at 620 nm. The amylose content was calculated as:

Amylose content (%) = 3.06× 20

Where A= Absorbance value

Determination of Titratable Acidity

The method of Pearson *et al.* (1991) was used to determine the titratable acidity of each sample. 10g of sample flour was mixed with 100ml of distilled water. The mixture was shaken thoroughly. 25ml of the mixture was measured into a conical flask and titrated against 0.1M NaOH using two drops of phenolphthalein indicator. The volume of NaOH used was noted as the titre value and % TTA calculated as %Lactic acid.

%Lactic acid = 0.009×Titre Value× DM

DM =100/100-M.C

Determination of Free Fatty Acid (FFA)

The free fatty acid content of the complementary flour was determined using the method described by Pearson, (1991). 5g of each sample was weighed into a 250ml Erlenmeyer flask. Thereafter, 50ml neutral diethylether-ethanol mixture and 0.5ml of phenolphthalein indicator were added. After thorough mixing to disintegrate the sample in the solvent, the solvent-mixture was titrated against 0.1M NaOH until a pink colour which persisted for 15seconds was obtained. The volume of NaOH was used noted as the titre value and %FFA calculated as linolenic acid, the predominant fatty acid in soybeans.

Equation of the reaction:

$$RCOOH_{(aq)} + NaOH_{(aq)} \Longrightarrow RCOONa_{(aq)} + H2O_{(l)}$$

% FFA= Titre value×0.0276g×100/wt

Where

Wt = Weight of sample; 0.0276g=Molecular weight of linolenic

Determination of Peroxide Value (PV)

The peroxide value was determined using the method described by Pearson, (1991). Approximately 2.5g of the sample was weighed into 250ml conical flask covered with a glass stopper and 30ml of 0.1M acetic acid was added to it. The flask was further swirled until the sample dissolved completely in the solution. About 1ml saturated solution of potassium iodide (KI) was added. The solution was mixed thoroughly and stored in a dark cupboard for 30mins. The suspension was titrated against 0.1M sodium thiosulphate solution ($Na_2S_20_3$) using soluble starch solution as an indicator until yellow colour of the solution turned blue black. A blank was also

titrated at the same time. The volume of $Na_2S_20_3$ used was noted as the titre value and peroxide value was calculated as mEq/kg.
PV (mEq/kg) = S-B×M sodium thiosulphate used ×1000/wt of sample
Where
S= Titration of Sample, B= Titration of blank

Storage Stability of Maize-Millet-Soybean Complementary food

Determination of Storage Stability

The method described by Wadud *et al*. (2004) was used to determine storage stability, while shelf life was determined using linear regression method of Gacula (1975). Each of the complementary flour samples were packed in air-tight low density polyethylene of 100g per sample sealed and kept at ambient temperature (30 ± 2^{o}C). Samples were examined at intervals of four weeks for moisture content, free fatty acid and peroxide value for a storage period of 12 weeks.

Statistical Analysis

All data were statistically analyzed using SPSS version 21.0 for analysis of variance, while Duncan multiple range test (DMRT) was used to separate means where there is a significant difference. For each sample, triplicate determinations were carried out.

3. RESULTS AND DISCUSSION

Proximate Composition of Maize-Millet-Soybean Complementary Foods

Proximate composition is the fastest way of scanning the nutritional quality of food and food substances. The proximate composition of the complementary food samples are as shown in Table 1. Moisture content of the samples ranged from 4.31% for SGR (germinated-roasted) to 10.94% for SC (control) sample. There were significant differences ($p< 0.05$) in the moisture content of the complementary foods. All processed samples had relatively low moisture contents which is an indication that the complementary foods would have good storage stability and shelf life, if properly packaged. High moisture content in foods has been shown to encourage microbial growth (Onabanjo, 2007; Igyor *et al*., 2010). These moisture content values compared well with the values (3.00 – 7.80%) reported for complementary foods by other authors (Wadud *et al*., 2004; Addo and Akeredolu, 2005; Solomon, 2005). The similarity could be attributed to the choice of food components and the preparation methods. The low residual moisture content of the blend could be attributed to drying (less than 10%) and further roasting of some of the complementary flours obtained. This in essence is advantageous in that microbial load is reduced and storage life is enhanced and prolonged. The crude protein value of samples ranged from 14.19% in SC (control) to 17.08% in SGFR (germinated-fermented-roasted). These values are greater than the recommended value (13 – 14g/100g) of Anigo *et al*. (2009). The requirements for the maintenance of body protein equilibrium as well as the optimum pattern of individual essential amino acids change little between the ages of 6 and 24 months (Reeds and Garlick, 2003; Onabanjo, 2007).
The calculations of the dietary requirement for whole protein suggest that a minimum protein-energy ratio of 6% in complementary foods is desirable (Dewey and Brown, 2003). According to the Codex standard, the estimated amounts of protein that should be supplied by complementary foods are between 6 and 11g/100g of dry food. The crude protein content of the study being reported is similar to values reported by Sanni *et al*. (1999), Onuorah and Akinjide (2004), and Asma, *et al*. (2006). This in essence indicates that complementary foods with suitable protein (amino acid) combination can be formulated from locally available plant sources; such formulated diets can also substitute for animal proteins, which are usually expensive, and are not within the reach of the vulnerable groups, especially rural and low income earners of the nation.

Table 1: Proximate composition of maize-millet-soybean complementary foods

Parameter	SC	SFR	SGR	SGFR
Moisture content (%)	10.94±0.11^{g}	5.57±0.11^{d}	4.31±0.10^{b}	5.05±0.03^{c}
Crude Protein (%)	14.19±0.52^{a}	14.67±0.30^{ab}	16.02±0.14^{c}	17.08±0.06^{d}
Crude Fat (%)	7.69±0.30^{a}	8.33±0.14^{c}	8.33±0.27^{c}	8.77±0.16^{c}
Ash (%)	1.84±0.04^{cd}	1.50±0.07^{ab}	1.80±0.10^{c}	1.80±0.03^{c}
Crude Fiber (%)	1.96±0.03^{a}	3.01±0.18^{d}	2.71±0.06^{c}	3.07±0.13^{d}
Carbohydrate (%)	62.38±0.11^{b}	66.92±0.11^{bc}	66.83±0.62^{bc}	64.23±0.33^{a}
Energy (kcal/100g)	374.5±5.21^{a}	403.8±2.91^{ab}	408.9±0.64^{b}	406.6±2.48^{b}

Values are means of trplicate determination. Mean values in the same row with different superscript are significantly different ($p< 0.05$).

SC: Control sample; SFR: Fermented-Roasted maize-millet-soybean flour; SGR: Germinated-Roasted maize-millet-soybean flour; SGFR: Germinated maize-Germinated millet-Fermented soybean.

Fermentation-roasting significantly increased ($p<0.05$) protein content of the raw food materials (control sample) to processed samples from 14.2 to 14.7 g/100g, while germination-roasting significantly increased protein content of the control sample from 14.19g/100g to 17.08g/100g in processed samples. This agrees with the work of Ariahu *et al*. (1999) which reported that germination and fermentation improve the protein content of complementary foods. This in essence indicated that complementary foods with suitable protein combination can be formulated from locally available plant sources using fermentation or germination with roasting method.

The fat content of the complementary food samples ranged from 7.69% in SC to 8.77% in SGFR and provides about 31.59% of the energy value, The Codex Alimentarius guidelines for formulated complementary foods for older infants and young children (FAO/WHO, 1991) propose an energy density of at least 5.4g/100g crude fat (i.e. 13% energy from crude fat). All the complementary foods in this study supply more than the recommended value of 13% (energy from fat) for old infant and young children. The ash content of the complementary food samples ranged from 1.50% in SFR (fermented-roasted) to 1.84% in SC (control). There is significant difference ($p<0.05$) in total ash content of the complementary food samples however, it is still within the recommended value of ≤5% Codex Standard (FAO/WHO/UNU, 1985) and Zlotkin *et al*. (2010). Ash content of a food material represents the inorganic or mineral constituents of the foods. Proteins from animal foods are good sources of ash in that they contains adequate supply of calcium, phosphorus and iron, which are essential for the formation of bones, teeth and blood components (Onabanjo, 2007). The ash contents obtained in this study is lower that the recommendation of 5% (FAO/WHO/UNU, 1985) Codex Standard and Wadud *et al*. (2004) but are higher than the values (0.6 – 1.0g/100g) of ash content of complementary foods reported by other authors (Asiedu *et al*., 1994; Singh *et al*., 2003). This result is in agreement with the work of Igyor *et al*. (2010) which reported that simple traditional processing (fermentation and roasting or germination and roasting) methods do not usually cause any significant difference in crude fats and ash contents of soybean based complementary food.

The crude fiber level of samples ranged from 1.96% in the SC (control) to 3.07% in SGFR (germinated-fermented-roasted) sample. The crude fiber content of the complementary foods in the present study was low but within the recommendation of less than 5% for formulated complementary foods according to

FAO/WHO/UNU (1985), which also is similar to values reported by other workers (Sanni *et al.*, 1999; Onuorah and Akinjide, 2004; Asma, *et al*., 2006).

The carbohydrate content of the complementary foods is relatively similar and falls within the range (60 – 70%) approved by the FAO/WHO/UNU (1985) Codex standard for complementary food formulation. The carbohydrate content of the complementary foods obtained in this study was within the range of 60 – 70% which can be correspondingly reduced as the proportions of fat and protein increase i.e. if the calculation is based only on carbohydrate value of the complementary flour. The energy value of the complementary food samples ranged from 374.5kcal/100g in SC (control) to 408.9 kcal/100g in SGR sample. Energy values of the complementary foods are in agreement with the recommendations of the Codex Alimentarius guidelines for formulated supplementary foods for older infants and young children (FAO/WHO, 1991) which propose an energy density of at least 400 kcal / 100g of dry food. In this study, the energy density of the multiple processed samples (SFR, SGR, SGFR) complementary foods is slightly above the FAO/WHO (1991) Codex standard. The energy values obtained in the present study are also higher than values reported by Sanni *et al.* (1999), Agu and Aluyah, (2004), Asma *et al.* (2006) but are lower than the values reported by Annan and Plahar (1995).

Chemical Composition of Maize-Millet-Soybean Complementary Foods

The chemical composition of the complementary food samples are as shown in Table 2. The total sugar ranged from 5.87% in SC (control) to 8.39% in SFR (fermented-roasted), while the starch content of the complementary food samples ranged from 46.63% in SGFR (germinated-fermented-roasted) to 48.89% in SC (control) sample. There were significant increase ($p<0.05$) in the total sugar, while starch content of the complementary food samples are compare to SC (control) as a result of combined processing methods. In this present study, the free (soluble) sugar was quantified separately from starch and was found to be very high in values (5.87 – 8.39%) while soluble sugar of the processed samples was higher than the control as a result of partially hydrolyzation of insoluble carbohydrate into soluble (free) sugar and starch due to the application of processing methods employed.

The amylose of the complementary food samples ranged from 9.18% in SFR (fermented-roasted) to 12.85% in SC (control), while their corresponding amylopectin contents are 90.28% and 87.15% respectively.

Table 2: Chemical composition of maize-millet-soybean complementary foods

Parameter	SC	SFR	SGR	SGFR
Sugar (%)	5.87 ± 0.16^{a}	8.39 ± 0.13^{f}	7.93 ± 0.10^{ef}	7.05 ± 0.01^{cd}
Starch (%)	48.89 ± 0.27^{c}	47.35 ± 0.24^{ab}	47.71 ± 0.52^{b}	46.63 ± 0.03^{a}
Amylose content (%)	12.85 ± 0.16^{g}	9.18 ± 0.06^{c}	11.62 ± 0.42^{e}	9.79 ± 0.30^{d}
Amylopectin (%)	87.15 ± 0.16^{a}	90.82 ± 0.01^{e}	88.38 ± 0.42^{c}	90.21 ± 0.30^{d}
pH $\log_{10}$	6.21 ± 0.14^{c}	6.43 ± 0.21^{c}	5.70 ± 0.14^{a}	6.94 ± 0.14^{b}
Titratable Acidity (%)	0.21 ± 0.01^{a}	0.27 ± 0.04^{a}	0.52 ± 0.06^{b}	0.45 ± 0.03^{b}

Values are means of trplicate determination. Mean values in the same row with different superscript are significantly different ($p< 0.05$).

SC: Control sample; SFR: Fermented-Roasted maize-millet-soybean flour; SGR: Germinated-Roasted maize-millet-soybean flour; SGFR: Germinated maize-Germinated millet-Fermented soybean.

Matz (1984) as cited by Akinsola (2003) reported that amylose content of starch in complementary flours should be between 5 – 20% in order to give acceptable texture with adequate crispness. The percentage amylose content of the complementary foods falls within the values of 7.95 – 12.85% which is still within the recommended value. Amylopectin have been reported to contribute to swelling of starchy foods, whereas amylose and lipids inhibit swelling and that the higher the amylopectin of a complementary flour the better its swelling power (Tester and Morrison, 1990).

The pH values ranged from 5.70 in SGR (germinated-roasted) sample to 6.94 in SGFR samples. The pH values of flours in water suspension are important since some functional properties such as solubility are highly affected by pH changes (Akinsola, 2003). The pH value of the formulated complementary foods falls within 5.70 – 6.94. The pH level has been reported to affect solubility of food products and formulation, firmness and characteristics of protein gels (Ikegwu, 2010). However, there was a significant difference ($p<0.05$) in pH of the processed complementary foods as compared to the control sample (SC). This might have been as a result of further roasting of some of the blended flours [SFR, SGR, and SGFR] after mixing individual flours together. The results obtained in this study showed that all the complementary flours have low pH values and hence would have low solubility value. It could be deduced from the study that all the complementary foods are low acid food. The titratable acidity values ranged from 0.21% to 0.52% in SC to SGR (germinated-roasted) sample, respectively.

There were significant differences ($p<0.05$) in the TTA values of the control sample and processed samples. Titratable acidity (% lactic acid) of all the germinated samples (SGR, SGFR) was higher than all the fermented-roasted (SFR) and control (SC) samples. The result shows that germination increased titratable acidity of the complementary foods than other processing methods. The titratable acidity values obtained in the study for the complementary foods are very low but in agreement with the work of Adeyemi (1983). The study reported that dry-milled sorghum-ogi had lower titratable acidity than wet-milled ogi which could be as a result of moisture content, processing method employed and method of analysis of the study results.

Storage Stability of Maize-Millet-Soybean Complementary Foods

Table 3 shows the result of the storage stability and shelf life of the complementary food samples.

The results of shelf life studies obtained for the complementary flours were significant difference ($p<0.05$). The values of estimated shelf life using moisture content of the complementary food samples ranged from 2 months 8 days to 13 months 5 days in SC (control) and SFR (fermented maize-millet-soybean) samples respectively. The rate of water adsorption in the complementary food samples shows a significant difference ($p<0.05$) for the storage period. The gradual uptake of moisture by all the complementary flours, with the exception of SC (control) sample, throughout the storage period agreed with other workers finding in respect of soybean based complementary food formulation (Wadud *et al*., 2004; Solomon, 2005).

The increase in moisture content of stored complementary flours could be attributed to the air permeability of the packaging film as well as the characteristics of the packaging materials (polyethylene) which allow the movement of certain gases across the film (Daramola, *et al*., 2010).

This explains why air-tight lacquered metal cans or composite (double-packaging) material are often used for packaging by the manufacturer of commercially produced complementary foods.

The estimated shelf life values using peroxide value ranged from 13 months 6 days in SC (control) to 16 months 8 days in SGR (germinated maize-millet-soybean) sample.

Table 3: Linear Regression Models for estimating shelf-life of the complementary foods during storage

Dependant Variable	Sample	Storage equation [y = bx + c]	R^2	Estimated Shelf Life/Month[ESL
Moisture Content	SC	0.02x + 10.65	0.9716	2.25
	SFR	0.02x + 6.23	0.9531	9.61
	SGR	0.02x + 5.42	0.9800	10.96
	SGFR	0.02x + 5.14	0.9054	11.43
Free Fatty Acid	SC	0.02x + 2.57	0.9187	-1.78
	SFR	0.02x + 1.28	0.8730	0.36
	SGR	0.02x + 2.64	0.9785	-1.90
	SGFR	0.02x + 2.06	0.8106	-0.93
Peroxide Value	SC	0.02x + 2.08	0.9036	13.20
	SFR	0.02x + 0.30	0.9243	16.16
	SGR	0.02x + 0.24	0.9902	16.26
	SGFR	0.02x + 1.45	0.8144	14.25

Mean values in the same row with different superscript are significantly different ($p< 0.05$).
SC: Control sample; SFR: Fermented-Roasted maize-millet-soybean flour; SGR: Germinated-Roasted maize-millet-soybean flour; SGFR: Germinated maize-Germinated millet-Fermented soybean.

There was a significant difference in the peroxide value of the complementary flours during the shelf-life studies, though marginal compared to its initial values at the end of the storage period. There was a gradual increase in the peroxide value (PV) of the blended flours during the storage period and this explains the slightly noticeable change in the flavour of the complementary foods towards the end of the storage period. This is in agreement with the work of Solomon (2005) that peroxide formulation during storage of cereal and legume based complementary food is slow at first during an induction period which varies from a few weeks to several months depending on the particular oil/fat, air, and room temperature. According to Solomon (2005) and Keku (2006), rancid taste often begins to be noticeable when PV is between 10 – 15 mEq/kg depending on the individual threshold and oil/fat present. Keku (2006) reported that rancidity was accompanied by FFA formation and is often used as a general indication of the condition and edibility of oil-containing products; flours containing more than 15% FFA are considered unsuitable for use. The FFA values of the complementary food samples at the end of storage therefore do not imply the onset of rancidity in the formulation that could result in spoilage of the flours.

4. CONCLUSIONS

The crude protein results obtained in this study showed that the formulated complementary foods based on maize-millet-soybean were nutrients dense and would possess good growth promoting quality for old infants and young children. Processing methods such as fermentation-roasting and germination-roasting could easily be adapted to prepare complementary foods from maize-millet-soybean with an optimum mixing ratio. The processing methods are found not only to improve sensory quality, but also increase crude fat, crude fiber, and crude protein of the complementary diet and stored more than the control. The results from this study also

indicated that the adoption of fermentation and roasting processing methods in the production of maize-millet-soybean complementary foods would not only bring about generally improved complementary foods, it will also give rise to the production of complementary foods that is nutritious, shelf stable for a longer period.

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