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Physicochemical, functional and economic analysis of complementary food from cereal, oilseed and animal polypeptide

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Abstract

In this work, ready-to-eat complementary foods were formulated from cereal (maize), oilseed (sesame) and animal polypeptide (crayfish). Proximate, physicochemical, functional, amino acid composition, sensory and economic evaluations were carried out on the formulated food blends. The results showed that protein content ranged from 20.78-28.09%, moisture (3.60-5.55%), fat (13.26-17.97%), fibre (6.30-8.24%), and carbohydrate (33.89-50.54%). The physicochemical and functional analyses showed that packed bulk density ranged from 0.61-0.69, water absorption capacity (39-96%), oil absorption capacity (8.81-23.13%), pH (6.06-6.09), gelling temperature (65-71^{o}C), swelling index (129-131.75%). The amino acid compositions showed that all the essential amino acids were present in the three formulated diets and appreciable number of them met the Food and Agricultural Organization reference values. The sensory evaluations showed mean scores range: taste (6.01-7.02), aroma (6.51-7.11), colour (6.51-7.53), Mouth feel (4.91-7.31), consistency (7.61-7.72) and overall acceptance (6.81-7.22). Economic analyses showed that the total cost of the formulated food blends ranged from N62.40 to N70.20 per 100 g, which resulted into 49.86%-55.43% cost reduction when compared to the commercial product (cerelac). The research indicated that complementary food products formulated from cereal, oilseed and animal polypeptide can meet the macro nutritional needs of infants and young children. Formulated diets had nutritional superiority over the control cerelac in terms of protein, ash, fat and total energy (kCal) composition. The formulated complementary food can be used to substitute the more expensive proprietary formula product (cerelac), which can be used to combat the problem of malnutrition among infants and children in Nigeria and other developing countries.

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Introduction

Breast milk provides all the nourishment a baby needs for the first six months of life. However, once an infant reaches 6 months, there is need to introduce semi-solid or solid foods into the infant diet both for the infant nutrition and development. A complementary food is any suitable food given to older infants and young children once breast-milk or infant formula alone can no longer meet a growing child's nutritional needs corresponding to a healthy development. Complementary foods are generally introduced between the ages of six months to three years old as breast feeding is discontinued (Ojinnaka *et al*., 2013). Most infants suffer from malnutrition, not mainly because of the economic status but also due to inability to utilize the available raw materials to meet their daily requirements (Annan and Plahar, 1995; Ojinnaka *et al*., 2013). Complementary feeding period is the period when malnutrition starts in many infants contributing significantly to the high prevalence of malnutrition in children less than 5 years of age worldwide (Daelmans and Saadeh, 2003; Ojinnaka *et al*., 2013). Infant feeding and rearing practices have a major effect on short term and long term nutritional status of children as most of under nutrition is associated with faltering practices that occur in weaning period. Faulty feeding practices as well as lack of suitable weaning foods are responsible for under nutrition (Huffman and Martin, 1994).

Maize and sesame, the cereal and oilseed of choice in this study have the potential of giving a nutritious complementary food when blended. Malting could improve the nutrient availability as well as reduce antinutritional factors that may affect the utilization of their nutrients and the health of the consumers (Oluwamukomi *et al*., 2003). Crayfish is classified as an animal polypeptide, accounts for

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36-45% of crude protein, is a freshwater crustacean resembling small lobster, was reported to have high nutritive value with a superior biological value, true digestibility, net protein utilization, high content of amino acid, and protein efficiency is favourable compared to casein (WHO, 2002; Ibironke *et al*., 2012; Ibironke *et al*., 2014). This study investigated formulation of complimentary diet from maize, sesame and crayfish flours at different substitution levels as well as evaluated the properties of the food blends.

Materials and Methods

Raw materials

Yellow maize grains (cereal), sesame seeds (oilseed) and crayfish (animal polypeptide) were purchased from Eke Market in Okposi, Ebonyi State, Nigeria. Also Nestle cerelac (a product of Nestle Nigeria PLC) was obtained from the same market.

Preparation of malted maize flour

The maize grains was sorted and malted. Malting was carried out using the method described by Ariahu *et al.* (1995). Maize grains were washed in 5% (w/v) sodium chloride (NaCl) solution to disinfect the grains. The grains were then soaked in potable water at ambient temperature using a ratio of 1:3 (w/v, grain: water), in a plastic container. The steep water was changed every 4 h for a total steeping period of 12 h, followed by draining and the grains were spread in a single layer moistened jute bag and allowed to germinate at ambient temperature for 72 h while spraying with water at intervals of 12 h. The germinated grains were removed, washed and dried.

Preparation of sesame and crayfish flours

Sesame seeds were sorted and soaked in salt solution (3% sodium chloride) for 18 h. After soaking, the grains were dehulled, washed and dried. The dried seeds were roasted at 70^{0}C for 30min and was milled. The obtained flour was sieved and packaged in an air – tight container for further processing. Crayfish was also cleaned, sorted and all extraneous materials carefully removed, washed and dried.

Formulation of complementary food

Maize, sesame and crayfish flours were mixed homogenously to make complementary blends of ratios (maize: sesame: crayfish): 55:30:15; 60:27.5:12.5; and 65:25:10, which were labeled blend 1, blend 2 and blend 3, respectively.

Proximate analysis

Protein, moisture, fat, crude fibre, ash and carbohydrate were determined using AOAC (2000).

Physicochemical and functional analyses

Packed bulk density was determined by the method of Okezie and Bello (1988). Loose bulk density was determined according to the method described by Yusuf (2013). The water absorption capacity (WAC) was determined at room temperature and at temperatures ranged between 60^{O}C and 90^{O}C using a combination of methods (Sosulski , 1962; Rutkowski and Kozlowka, 1981; AACC, 1995). Oil absorption capacity of the formulated samples was determined by the centrifugal method elicited by Beuchat (1977) with slight modifications. One gram of sample was mixed with 50 ml of pure edible palm olein oil for 60s; the mixture was allowed to stand for 10min at room temperature, centrifuged (0502 – 1 Hospibrand , USA) at 4000 x g for 30 min. The oil that separated was carefully decanted and the tubes were allowed to drain at a 45^O angle for 10 min and then weighed. Oil absorption was express as percentage increase of the sample weight. Emulsifying capacity was determined using the method elicited by Onwuka (2005). Swelling index was done using the method of Ukpabi and Ndimele(1996) with slight modifications. A 10 g of the sample was transferred into a clean, dried, calibrated measuring cylinder. The sample was gently leveled by tapping and the initial volume recorded. A 50 ml of distilled water was added to the tube containing the sample and allowed to stand for 4h before observing the level of swelling. The value of swelling index (SI) was taken as the multiple of the original volume. Gelatinization temperature was determined using the method of Attama *et al*. (2003). The pH of the sample was determined using the method of AOAC (2000). Foam capacity was determined using the method of Omojola *et al.* (2010) with modifications. Sample (1g) was weighed and homogenized in 100 ml distilled water using a blender (master chef, MC-BL-2999) for 5 min. The homogenate was poured into a 500 ml measuring cylinder and the volume recorded after 30 s. The foam capacity was expressed as the per cent increase in volume.

Amino acid determination

Amino acid composition was determined using S433 Amino Acid Analyzer (SYKEM, Germany). Samples were freeze- dried and then hydrolyzed for 24 h at 110ºC with 6N HCl (Blackburn, 1978). After hydrolysis, the samples were stored frozen in sodium citrate buffer at pH 2.2. When ready for analysis a

50 µl of the hydrolysate was injected for analysis. Tryptophan was determined separately by hydrolysis of the sample with sodium hydroxide. Cysteine and methionine were determined after performic acid oxidation prior to hydrolysis in 6N HCl, and measured as cysteic acid and methionine sulphone respectively (Blackburn, 1978).

Sensory evaluation

Sensory evaluation was conducted for the complementary food sample by a 20 member semi-trained panelists consisting of staff and student of Akanu Ibiam Federal Polytechnic Unwana Ebonyi State Nigeria, among whom were nursing mothers. The method of Larmond (1977) was used for the sensory evaluation. Fifty grams each of the complementary food samples were reconstituted with 250 ml of water (warm), 45 g of milk and 5 g of sugar were added. The samples were rated using a 9 point hedonic scale with 9 indicating "liked extremely", 5 indicating "neither liked nor disliked" and 1 indicating "disliked extremely". The samples were evaluated for taste, aroma, colour, mouth feel, consistency and overall acceptability. The panelists were given water to rinse their mouth after each sampling. The evaluation was carried out in a lit room (Sensory Evaluation Laboratory in Department Food Technology, Akanu Ibiam Federal Polytechnic Unwana, Nigeria).

Economic analysis

The economic analyses of the formulated complementary products were evaluated, which included materials costs and production costs. The values obtained were compared to the commercial product (cerelac).

Data analysis

Statistical differences among samples were determined by analysis of variance (ANOVA) using SPSS version 16.0 (SPSS, Chicago, IL, USA). Mean were separated using Duncan's Multiple Range Test.

Results and Discussion

Proximate composition

The proximate compositions of the sesame-maize-crayfish food blends are presented in Table 1. The moisture content ranged from 3.60–5.55%; the food blends are significantly different ($p<0.05$) from one another. Blend 1(55% maize + 30% sesame + 15% crayfish) had the highest moisture content (5.50%) and significantly different ($p<0.05$) from the control, which had value of (2.50%). The low moisture level obtained is in agreement with the report of Yusuf *et al*. (2013) for complementary food and Igyor *et al.* (2011) for dried fura powder. High moisture content in food has been shown to encourage microbial growth (Temple *et al*., 1996). The values obtained in this study were within the range reported to have no adequate effect on the quality attributes of the product (Kure *et al.*, 1998). Sanni and Oladapo (2008) reported that the lower the moisture content of a product to be stored, the better the shelf stability of the food product. However, low residual moisture content in food is advantageous in that microbial proliferation is reduced and storage life may be prolonged, if stored inside appropriate packaging materials under good environmental conditions. The protein content of the formulated complementary food ranged from 20.78–28.09%; and significantly different ($p<0.05$) from the control (cerelac), which recorded 15%. Blend 1(55% maize + 30% sesame + 12.5% crayfish) recorded the highest value (28.09%) while blend 3 (60% maize + 27.5% sesame + 12.5% crayfish) recorded the least value (20.78%). There was no significant difference ($p>0.05$) between blend 1 and blend 2. A significant increase in protein quantity of the complementary food was observed as the quantity of crayfish increased. The protein content of all the food blends are superior to that of the control (cerelac). The observed increase in the level of protein was attributed to the crayfish and sesame flours added and this is in agreement with the report that crayfish is a good source of protein (Emovon, 1987; Oti and Akobundu, 2008). The protein contents in this study were higher than values reported elsewhere (Okoye *et al*., 2010; Yusuf *et al*., 2013). The fat content ranged from 13.26-17.97%. The cerelac (9.25%), which is the control is significantly lower compared to other blends. There was significant difference ($p<0.05$) among the fat content of samples. The fat content of the formulated food blends was relatively higher than the control (cerelac) and also meet the recommended dietary allowance. This could be attributed to the inclusion of oil dense sesame flour in the complementary food. This attribute tends to agree with the recommended FAO/WHO (1998), that high oil content in food meant for infants and children will not only increase the energy density, but also be a transport vehicle for fat soluble vitamins. The fat can also provide essential fatty acids like that of n – 3 and n - 6 Polyunsaturated Fatty Acids (PUFA's) needed to ensure proper neural development (Mariam, 2005). In terms of ash content, all the three samples were significantly ($p<0.05$) superior to the control. Blend 2 and blend 3 were statistically not different ($p>0.05$). The ash content of a food material could be used as

Table 1. Proximate composition and energy value of complementary food blends per 100g

Nutrient	Blend 1	Blend 2	Blend 3	Celerac*
Protein (g)	28.09^{a}	25.50^{a}	20.78^{b}	15.00^{c}
Moisture (g)	5.55^{a}	4.35^{b}	3.60^{c}	2.50^{d}
Fibre (g)	6.30^{c}	7.20^{b}	8.24^{a}	2.95^{d}
Ash (g)	4.53^{a}	3.47^{b}	3.58^{c}	2.60^{d}
Fat (g)	17.97^{b}	25.59^{a}	13.26^{c}	9.00^{d}
Carbohydrate (g)	37.56^{c}	33.89^{d}	50.54^{b}	67.37^{a}
Energy(kcal)	424.33^{b}	467.87^{a}	404.62^{d}	410.48^{c}

Mean with the same superscript all in the same row are significantly not different (p>0.05)
Blend 1 = 55%maize + 30%sesame + 15%crayfish; Blend 2 = 60%maize + 27.5%sesame + 12.5%crayfish; Blend 3 = 65%maize + 25%sesame + 10%crayfish
*Values as indicated by the manufacturer

an index of mineral constituent of the food because ash, the inorganic residue remaining after water and organic matter have been removed by heating in the presence of oxidizing agent. An increase in the ash content was noted as the quantity of crayfish flour used increased. The crude fibre content ranged from 6.30-8.24% with the control (2.95%) being significantly different from other blends (p>0.05). Fiber is part of the food that cannot be digested and absorbed by human or produce energy. An increase in crude fiber content was noted as the quantity of maize flour used increased. The carbohydrate content of the complementary blends ranged from 33.89–67.37%. All samples are significant different (p<0.05) from the control. The increase in total carbohydrate content is principally due to increase in maize flour used. The carbohydrate levels are necessary as children require energy to carry out their rigorous playing and other activities as growth continues. The formulated diet were nutritional adequate to prepare a complementary food and meet the estimated daily nutrient requirements for complementary food (FAO/WHO, 1998; Akubor *et al*., 1999; Ibironke *et al*., 2012).

Physicochemical and functional properties

The results of the physicochemical and functional properties of the complementary food blends are presented in Table 2. Complementary foods formulated in this study compared favourably with the commercial formula used as control (cerelac). There was no significant difference (p > 0.05) in the swelling index property among samples. However, complementary foods do not require high swelling index as the food would absorb more water and have less solid resulting in low nutrient density for the infant. Samples with least swelling index are preferred for a complementary food thus blend 1 (55% maize + 30% sesame +15% crayfish) and blend 3 (65% maize + 25% sesame + 10% crayfish) with lower swelling index values are preferred. The loose bulk density ranged from 0.37±0.01-0.40±0.01g/ml. There was no significant difference (p>0.05) in the loose bulk density value but the result for packed bulk density showed a significant difference (p<0.05). The packed bulk density (PBD), which is the highest attainable density with compression ranged between 0.61 ± 0.01 and 0.69 ± 0.01. The loose bulk density (LBD), which is the lowest attainable density without compression was relatively constant among the samples. This low density values of the complementary food samples implies that more of the samples could be prepared using a small amount of water yet giving the desirable energy nutrient density and semi-solid consistency which can easily be fed to an infant (Mosha and Lorri, 1987). The results obtained for the bulk density were slightly higher than one reported by Yusuf *et al*. (2013) for complementary food. The lower the bulk density value, the higher the amount of flour particles that can stay together and thus increasing energy content that could be derived from such diets (Onimawo and Egbekun, 1998). 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. The water absorption capacity (WAC) ranged between 39±0.41% and 96±0.41%. There is significant difference (p<0.05) in WAC among sample blends. Yusuf *et al.* (2013) reported a range of 50-70.67% for complementary food from sorghum, African yam bean and mango blends. The WAC of the complementary food was

Table 2. Physicochemical and functional properties of complementary food blends

Parameter	Sample		
	Blend 1	Blend 2	Blend 3
PDB (g/ml)	0.62±0.01^{b}	0.61±0.01^{b}	0.69±0.01^{a}
LBD (g/ml)	0.40±0.01^{a}	0.39±0.00^{a}	0.37±0.01^{a}
Porosity (%)	37.00±0.01^{b}	38.50±0.71^{b}	44.50±1.12^{a}
pH	6.09±0.0^{a}	6.06±0.02^{b}	6.08±0.00^{a}
WAC (%)	39.00±0.41^{c}	73.50±0.71^{b}	96.00±0.41^{a}
OAC (%)	237.50±0.4^{b}	222.50±2.12^{b}	255.50±0.71^{a}
GT (°C)	65.00±0.12^{b}	68.00±0.41^{a}	71.00±0.06^{a}
FC (%)	8.81±0.02^{c}	21.65±0.15^{b}	23.13±0.03^{b}
SI (%)	129.00±0.41^{a}	131.75±0.35^{a}	129.50±0.70^{a}
EC (%)	65.55±0.13^{a}	56.50±0.17^{b}	35.50±0.12^{c}

Mean value with the same superscript within the same row are significantly not different ($p > 0.05$).
Blend 1= 55% Maize: 30%Sesame:15% Crayfish; Blend 2= 60% Maize: 27.5%Sesame:12.5%Crayfish; Blend 3 = 65%Maize: 25%Sesame: 10%Crayfish; LBD= loose bulk density; PBD= packed bulk density; TTA= titratable acidity; WAC= water absorption capacity; OAC= oil absorption capacity; GT= gelling temperature; FC= foam capacity; SI= swelling index; EC=emulsifying capacity

higher than those reported for native red (24%) and white (26%) sweet potato flour (Osundahunsi *et al*., 2003), but lower than those reported for fermented maize flour (271.7%) by Fasasi *et al.* (2007) and bambarra groundnut flour (227%) by Sirivongpaisal (2008). The results obtained for the WAC in this formulation is in agreement with the earlier report by Igyor *et al.* (2011) that protein functions in binding water and fat while retaining them. Thus, the availability of sesame protein has increased its ability to absorb water. The water absorption capacity of the complementary food blends increased with increasing temperature. However, all the food blends swelled at all temperatures of investigation in this study. The water absorption capacity as influenced by temperature of the food blends ranged from 38-289%. Increase in water absorption capacity of the food blends may be as a result of increase in carbohydrate content. The higher carbohydrate content in blend 1 may be responsible for its higher absorption capacity. Due to protein rich components of the food blends (Sesame and Crayfish), the high WAC may be due to some intrinsic factors affecting water binding food protein such as amino acid composition, protein conformation and surface polarity /hydrophobicity (Barbut, 1999; Kanu *et al.*, 2007). The oil absorption capacity (OAC) showed that there is no significant difference ($p>0.05$) between blend1 and blend 2. The foam capacity ranged from 8.81-23.13%. There was no significant difference ($p>0.05$) between blend 2 and 3. The pH values of the complementary food blends ranged from 6.06 to 6.09. There was no significant difference ($p>0.05$) in the pH of blend 1 and blend 3. The high pH values obtained show that the formulated complementary food falls within weak acid foods. The gelling temperatures obtained for the formulated food blends ranged between 65°C and 71°C. Gelation is an important functional property of food materials, which affects its texture. The gelatinization process is a property of the starch granule found in cereals and tuber crops. The emulsifying capacity of the samples ranged from 35.5-65.55%. The emulsifying properties are influenced by many factors which include solubility and pH. The varying emulsifying and stabilization capacity may be due to different compositions and stresses to which these products are subjected (Nelson and Cox, 2000). The high emulsion capacity reported in this study may be as a result of high concentration of protein in the food. Oyarekua and Adeyeye (2009) reported that high value of emulsion capacity acts as flavor retainer and enhances the mouth feel and taste of food.

Amino acid composition

The amino acids composition of the complementary food blends are presented in Table 3. Amino acid content of complementary foods is very important in infant feeding, where Protein-

Table 3. Amino acid profile of the complimentary food blends (g/100g)

Amino Acid	Blend 1	Blend 2	Blend 3	FAO Ref. Value*
Thr	1.89	1.03	0.91	2.80
Cys	1.73	1.65	1.22	2.00
Tyr	3.91	2.18	2.07	2.80
Val	4.80	4.09	3.68	4.20
Phe	5.77	4.98	4.11	2.80
Trp	3.68	2.97	2.30	1.40
Lys	4.70	3.65	2.78	4.20
Met	1.88	1.21	0.97	2.20
Arg	5.93	5.33	4.89	-
Leu	3.95	2.81	2.06	4.20
Iso	4.31	3.92	3.19	4.20
Asp	5.08	4.85	4.32	-
Glu	7.14	5.77	4.60	-
Pro	0.86	0.49	0.18	-
Gly	1.98	1.25	0.92	-
Ala	2.56	2.01	0.97	-
Ser	3.72	3.10	2.45	-
His	1.48	0.97	0.36	-

*Food and Agricultural Organization (FAO/WHO, 1998)

Table 4. Sensory evaluation for the complimentary food blends

Sample	Taste	Aroma	Colour	Month Feel	Consistency	Overall Accept.
Blend 1	7.22 ± 0.03^{b}	6.31 ± 0.01^{c}	7.11 ± 0.01^{b}	7.11 ± 0.01^{b}	7.22 ± 0.03^{b}	7.72 ± 0.02^{a}
Blend 2	$6.81 \pm 0.01'$	6.01 ± 0.01^{d}	6.92 ± 0.03^{c}	6.51 ± 0.01^{c}	6.91 ± 0.01^{c}	7.61 ± 0.01^{b}
Blend 3	7.02 ± 0.02^{c}	7.02 ± 0.02^{a}	6.71 ± 0.01^{d}	7.53 ± 0.04^{a}	7.31 ± 0.01^{a}	7.62 ± 0.03^{b}
Control	7.31 ± 0.01	6.52 ± 0.02^{b}	7.92 ± 0.03^{a}	3.71 ± 0.01^{d}	4.22 ± 0.02^{d}	6.41 ± 0.01^{c}

Mean value with the same superscript within the same row are significantly not different ($p > 0.05$).
Blend 1: 55% maize + 30% Sesame + 15% crayfish; Blend 2: 60% maize + 27.5% sesame + 12.5% crayfish; Blend 3: 65% maize +25% sesame +10% crayfish; Control: Nestel cerelac

Energy-Malnutrition (PEM) has continued to pose challenges in the research area. This is due to poor feeding practices and low quality protein commonly associated with plant-based single diets (Badamosi *et al*., 1995; Temple *et al*., 1996; Mariam, 2005). All the essential amino acids were present in the three formulated diets and appreciable number of them meet the FAO reference values (Table 3). Tyrosine (Blend 1), valine (Blend 1), phenylalanine (all blends), tryptophan (all blends), lysine (Blend 1), isoleucine (Blend 1) met FAO reference values. Other amino acids such as cystine, methionine and leucine met over 50% of the FAO reference values. According to FAO/WHO (1998), diets composed of cereals/legumes mixed with some animal protein source (10-20%) have been reported to be sufficiently high in amino acids to meet nutrient intakes. This was observed in blend 1, which contained about 20% crayfish and showed highest amino acid contents than the other two blends.

Sensory evaluation of the complementary food blends

The results for the organoleptic properties of the complementary food are shown in Table 4. The data show average likeness of the formulated complementary foods with respect to taste, aroma, colour, mouthfeel, consistency and overall acceptability. The mean scores ranges of attributes evaluated were: taste (6.01-7.02), aroma (6.51-7.11), colour (6.51-7.53), Mouth feel (4.91-7.31), consistency (7.61-7.72) and overall acceptance (6.81-7.22). Taste is an important parameter when evaluating sensory attribute of food. The product might be appealing and having high energy density but without good taste, such a product is likely to be unacceptable. Appearance is important attribute in

Table 5. Economic analysis of complementary food blends per 100 g

Sample	Material Cost (₦)	Production Cost (₦)	Total Cost (₦)	Cost Ratio	% Cost Reduction (₦)
Blend 1	54	16.20	70.20	0.5014	49.86
Blend 2	50	15.00	65.00	0.4643	53.57
Blend 3	48	14.40	62.40	0.4457	55.43
Control	-	-	140.00	1.0000	0

Blend 1: 55% maize + 30% Sesame + 15% crayfish; Blend 2: 60% maize + 27.5% sesame + 12.5% crayfish; Blend 3: 65% maize +25% sesame +10% crayfish; Control: Nestel cerelac

food choice and acceptance. 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). According to Muhimbula *et al.* (2011), in addition to a sufficient energy density, sensory qualities of complementary food formulations correspond to food preferences for infants and young children are of the highest importance. Sensory evaluation is easy in its principle but its implementation in the field is often complicated because of low literacy among the rural mothers' and the difficulty for them to understand some sensory testing methods. Roasting of the oilseed had an important improvement on the aroma of the formulations.

Economic analysis

The results of the economic analysis carried out on the complementary food blends were presented in Table 5. The results showed that material cost per 100g ranged from N48 to N54 per 100 g. The Total cost ranged from N62.4 to N70.2 per 100 g. The market price for cerelac as at the time of this work was N140 per 100 g. The percentage cost reduction for the formulated complementary food blends ranged between 49.86% and 55.43%. Blend 3 had the highest % cost reduction (55.43%) while blend 1 had the least % cost reduction (49.86%). The results obtained indicated that all the three food blends are cheaper compared to the control (cerelac).

Conclusion

This study examined the formulation, proximate, physicochemical, amino acid, and functional properties of complementary food blends from mixture of maize, sesame and crayfish. The research shows that ready – to – eat complementary food products formulated from cereal, oilseed and animal polypeptide can meet the macro nutritional needs of infants and young children. These products are believed to be easily affordable. The cost analysis showed that the percentage cost reduction for the formulated diets ranged between 49.86% and 55.43%, which indicated that all the three food blends are cheaper when compared to the control (cerelac). The low swelling index, low WAC, low loose and bulk density values in this work indicated that higher amount of the flour particles can stay together and thus increasing energy content that could be derived from these diets. More also, the complementary food blends can be used to substitute the more expensive proprietary formula product (cerelac), which can be used to combat the problem of malnutrition among infants and children in Nigeria and other developing countries. This complementary diet is also recommended for adult consumers.

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References

AACC 1995. Approved Methods of AACC (19th ed., Vols. 1 and 2). St Paul, MN: American Association of Cereal Chemists.

Annan, N. T. and Plahar, W. A. 1995. Development and Quality Evaluation of a Soy-Fortified Ghanaian Weaning Food. United Nations University Pressm Tokyo.

AOAC 2000. Association of Official Analytical Chemists. Official Methods of Analysis. 17th Edition., AOAC International, Washington, DC, USA.

Ariahu, U.G., Lopez, J., Hernandez, J., Fernandez, M., Moreu Mc, Farias, J., Diaz-Pollan, C., Prodano, M. and Vidalvelverde, C. 1995. Nutritional Assessment of Raw, Heated & Germinated Lentils. Journal of Agriculture and Food Chemistry 45: 1871-11877.

Attama, A.A., Nnamani, P.O., Mbonu, I.K., and Adiku, M.U. 2003. Effect of Hypochlorite Oxidation on the Physicochemical properties of gladiolus Starch; Journal of Pharmaceutical and Allied Science 1(1):

28-35.

Badamosi, E. J., Ibrahim, L. M., and Temple, V. J. (1995). Nutritional Evaluation of a Locally Formulated Weaning Food, JUTH-PAP. West African Journal of Biological Science 3: 85-93.

Barbut, S. 1999.Determining Water and Fat Holding. In: methods of Testing Protein Functionality. Hall, G.M. (Eds.). Blackie Academic and Professional. New Yolk.

Beuchat, LR. 1997. Functional and Electrophoretic Characteristics of Succinylated Peanut flour protein. Journal of Agriculture and Food Chemistry 25: 258-261.

Blackburn, S. 1978. Sample Preparation and Hydrolytic Methods. In: Amino Acid Determination Methods and Techniques. Blackburn, S (ed.) pp. 7–37. Marcel Dekker. New York.

Delmans, B. and Saadeh, R. 2003. Global Initiatives to Improve Complementary Feeding. In: SCN Newsletter: Meeting the challenge to improve complementary feeding. United Nations System Standing Committee on Nutrition, Moreira, A.D. Ed. Lavenhem Press, UK pp: 10-17.

Emovon, E. 1987. Training Workshop on Utilization of Soy – bean; March 14th 1987, Abu Zaria.

FAO/WHO 1998. Preparation and use of Food-Based Dietary Guidelines. Report of a Joint FAO/WHO Consultation. WHO Technical Report Series 880. Geneva.

Fasasi, OS., Adeyemi, IA., Faggbenro OA. 2007. Functional and Pasting Characteristics of Fermented Maize and Nile tilapia *(Oreochromis niloticus)* Flour Diet Pakistan Journal of Nutrition 6(4): 304-309.

Huffman, S. L. and Martin, L. H. 1994. First Feeding of Infants and Toddlers. Nutrition Reserves 14: 127-159.

Ibironke, S. I., Fashakin, J. B. and Ige, M. M. 2004. Nutritional Quality of Animal Polypeptide (Crayfish) Formulated into Complementary Foods. American Journal of Food and Nutrition 2(3): 39-42.

Ibironke, S. I., Fashakin, J. B. and Badmus, O. A. 2012. Nutritional Evaluation of Complementary Food Developed from Plant and Animal Protein Sources. Nutrition and Food Science 42(2): 111-120

Igyor, M. A., Yusuf, P. A. and Sengev, I. A. 2011. Functional and Sensory Properties of Fermented Fura Powder Supplemented with Soy. Nigerian Food Journal 29: 113-121.

Kanu, P.J., Kerui,Z.K., Ming, Z.H., Haifeng, Q., Kanu, J.B. and Lexue, Z. 2007.Sesame protein 11: Functional properties of Sesame (*Sesamum indicum* L.) Protein Isolate as Influence by pH, Temperature, Asian Journal of Biochemistry 2(5): 289-301.

Kure, O. A, Bahoya E. J and Daniel 1998. Studies in the Proximate Composition and Effect of Flour Particles Size on Acceptability of Biscuit Produced from Blend of Soya – bean and Plantain Flours. Namida Techscope pp 17 – 21.

Larmond, E. 1977. Methods for Sensory Evaluation of Food. Food Research Institute, Central Experimental Farm, Ottawa, Canada pp 1637.

Mariam, S. 2005. Nutritive Value of Three Potential Complementary Foods Based on Cereals and Legumes. African Journal of Food and Nutrition Series 5(2): 1-14.

Muhimbula, H. S., Issa-Zacharia, A. and Kinabo, J. 2011. Formulation and Sensory Evalution of Complementary Foods from Local, Cheap and Readily Available Cereals and Legumes in Iringa, Tanzania. African Journal of Food Science 5(1): 26-31.

Mosha,A.C. and Lorri,W.S.M. 1987. High-Nutrient-Density Weaning Foods from Germinated cereals. In: Alnwick, D., S. Moses and O.G. Schmidt (Eds.), Improving Young Child Feeding in Eastern and Southern Africa. IDRC, UNICEF, SIDA, Nairobi, New Yolk, Stockholm pp 288-299.

Nelson, D.I.and Cox M.M.2000. Lehninger Principles of Biochemistry. Replika Press, PVT Ltd, India pp 117-124.

Nnam, N.M. 2000. Evaluation of Complementary Foods Based on Maize, Groundnut, pawpaw and mango flour Blends. Nigerian Journal of Nutrition Science 22 & 23: 8-18.

Ojinnaka, M. C., Ebinyasi, C. S., Ihemeje, A. and Okorie, S. U. 2013. Nutritional Evaluation of Complementary Food Gruels Formulated from Blends of Soybean Flour and Ginger Modified Cocoyam Starch. Advance Journal of Food Science and Technology 5(10): 1325-1330

Okezie, BO. Bello 1988.Physicochemical and Functional Properties of Winged Bean Flour and Isolate compared with soy Isolate. Journal of Food Science 53: 450-454.

Oluwamukomi, M. O., Eleyemi, V. N. and Atofarati, S. O. 2003. Nutritional, Physicochemical and Sensory Evaluation of Sorghum and Cowpea based Weaning Formulations. Nigerian Food Journal 21: 11-17.

Omojola, M.O., Akinkunmi,Y.O., Olufunsho, K.O., Egharauba, H.O and Martin E.O.(2010). Isolation and Physicochemical Characterization of Cola-starch. African Journal of Food, Agriculture, Nutrition and Development 10(7): 2884-2900.

Onimawo, A. I. and Egbekun, K. M. 1998. Comprehensive Food Science and Nutrition. Macmillan Press, Ibadan pp228

Onwuka, G. L. 2005. Food Analysis and Instrumentation, Theory and Practice. Naphtali Prints, Lagos Nigeria.

Osundahunsi, of, Fagbemi, TN, Kesselman E., Shimoni E. 2003. Chemical Comparison of the Physicochemical Properties and Pasting Cultivars. Journal of Agriculture and Food Chemistry 51: 2232-2236.

Oti, E. and Akobundu, E. N. T. 2008. Potentials of Cocoyam-Soybean-Crayfish Mixtures in Complementary Feeding. Nigerian Agricultural Journal 39(2): 137-145.

Oyarekua, M. A. and Adeyeye, E. I. 2009. Comparative Evaluation of the Nutritional Quality, Functional Properties and Amino Acid Profile of Co-Fermented Maize/Cowpea and Sorghum/Cowpea Ogi as Infant Complementary Food. Asian Journal of Chemistry and Nutrition 1: 31-39

Pearson, D. 1970. The Chemical Analysis of Foods. 8th ed. J and A Churchill, London p 499.

Ruthkowski, A., Koziowska, H. 1981. Preparaty Zywnosciowe Bialka Roshinnego.(Food Preparations from plant protein),Warszawa, Poland pp 318-334.

Sanni, O and Oladapo, F.O. 2008. Chemical, Functional and Sensory Properties of Instant Yam Bread Fruit Flour. Nigerian Food Journal 26:2-12.

Sirivongpaisal, P. 2008. Structure and Functional Properties of starch and flour from Bambara groundnut. Songklanakarin Journal of Food Science and Technology 30(1): 51-56.

Sosulsaki, F. W. 1962. The Centrifuge Method for Determining Water Absorption in Hard Red Spring Wheats. Cereal Chemistry 39: 333-337.

Temple, V.J, Badamosi, E.J, Ladeji, O, Solomon, M. 1996. Proximate Chemical Composition of Free Locally Formulated CFs. West African Journal of Biological Science 5: 734-743.

Ukpabi, U.J., and Ndumele, U. 1996. Evaluation of the quality of garri produced in Imo State. Nigerian Food Journal 8: 103-110.

WHO 2002. World Health Organization. Complementary Feeding of Young Children in Developing Countries: A Review of Current Scientific Knowledge, Geneva, Switzerland.

Yusuf, P. A., Egbunu, F. A., Egwujeh, S. I. D., Opega, G. L. and Adikwu, M. O. 2013. Evaluation of Complementary Food Prepared from Sorghum, African Yam Bean *(Sphenostylis stenocarpa)* and Mango Mesocarp Flour Blends. Pakistan Journal of Nutrition 12(2): 205-208.