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Production and evaluation of sorghum-based complementary foods supplemented with African Yam bean and Crayfish flours

Egbujie Augustine Eseroghene and Okoye Joseph Ikechukwu

Department of Food Science and Technology, Enugu State University of Science and Technology, P.M.B 01660, Enugu, Nigeria

***Corresponding Author:** egbujieae@gmail.com

Abstract

This study was carried out to evaluate the proximate, mineral and sensory properties of nutritive and ready-to-eat complementary foods formulated from blends of sorghum, African yam bean and crayfish flour. The protein, ash, fat and crude fibre contents of the samples increased significantly (p<0.05) with increase in substitution with African yam bean and crayfish flours from 13.56 ± 0.29 – 23.88 ± 0.82%, 2.77 ± 0.02 – 3.67 ± 0.02%, 1.85 ± 0.01-3.64 ± 0.01 and 1.46 ± 0.06 – 2.15 ± 0.02%, respectively, while the carbohydrate and energy contents decreased. The control sample without substitution with African yam bean and crayfish flours (100% malted sorghum flour) had the highest carbohydrate (72.36 + 0.21%) and energy (364.33 ± 0.35KJ/100g) contents. The mineral content of the complementary foods also showed similar increases in calcium (12.68 ± 1.24 – 84.86 ± 7.83mg/100g), iron (2.68 ± 0.03 – 7.99 ± 0.08mg/100mg) and zinc (1.28 ± 0.02 – 1.63 ± 0.13mg/100g) with increase in substitution with African yam bean and crayfish flours, while the phosphorous and potassium contents decreased. The control sample without substitution had the highest phosphorus (257.01 + 41.44mg/100g) and potassium (346.20 + 0.03mg/100g) contents, respectively. The sensory properties of the samples showed that the colour, taste, mouth feel and texture of the control sample were significantly (p<0.05) the most acceptable to the assessors compared to the samples substituted with African yam bean and crayfish flours at different graded levels. Although, the control sample had better consumer's sensory attributes, it was significantly (p<0.05) lower in nutrient contents compared to the formulated samples with the exception of carbohydrate, phosphorus and potassium. The study, therefore, showed that the macro and micronutrient contents of the gruels can be improved by substituting sorghum-based traditional complementary food with African yam bean and crayfish flours at the levels of 5 to 30% and 5 to 20%, respectively in the preparation of complementary foods.

Keywords: African yam bean flour, complementary foods, sorghum flour, crayfish flour.

Introduction

The problems associated with infant feeding include bulkiness and monotony of diet and various processing techniques such as fermentation, dehulling, malting, drying and milling had been employed to combat the problems of bulkiness, acceptability, quality, flavour, texture, viscosity and palatability (Odunfa, 1985; Nnam, 2002; Hotz and Gidson, 2007). These methods create variety that eliminates monotony. The presence of anti-nutrients and food toxicants limit the full utilization of cereal-legume based infant foods. Commercial complementary foods modified to meet infant nutrient requirements are expensive and beyond the reach or out of the reach of most Nigerian families (Nwamarah and Amadi, 2009; Anigo et al., 2010). Hence, many depend on inadequately processed traditional foods consisting mainly of unsupplemented cereal porridges made from maize, sorghum and millet (Nnam, 2002). These problems compromise the health, growth and development of infants thereby predisposing them to protein energy-malnutrition (PEM) and infectious diseases due to lowered immunity. Protein energy-malnutrition results when an infant's body need for energy and protein or both are not satisfied by their diets (Wardlaw and Hampl, 2007).

In Nigeria as in most developing countries, one of the greatest problems affecting millions of people, particularly children (6 months – 5 years) is lack of adequate protein intake in terms of quality and quantity. As cereals are generally low in protein, the supplementation of cereal with locally available legume that is high in protein coupled with the addition of protein from animal source will greatly increase the protein content of cereal – legume blends. Complementary foods are readily consumed and digested by the young children as they provide additional nutrients to meet all their growing needs (Ijarotimi and Bakare, 2006). Complementary foods are mostly produced from locally available food crops which include cereals such as wheat, sorghum, maize, millet and rice, root and tuber crops such as cocoyam, irish potato and sweet potato and legume such as cowpea, soybean, African yam bean, pigeon pea and bambara groundnut etc. The formulation of complementary food can be made by using one or a combination of more than one plant product, cereal with legume (Odumodu, 2008). Complementary foods with low fibre content are very important in the diets of infants since they help in the safety of children because of their stomach capacity since they have to consume more to get satisfied in order to meet their daily energy requirement (Eka and Edijala, 1999). The need for low cost complementary foods which can be prepared easily with adequate processing and appropriate blending of locally available food crops could result in improved intake of macro and micro-nutrients to prevent the problem of protein – energy malnutrition. Sorghum (*Sorghum bicolor*), African yam bean (*Sphenostylis stenocarpa*) and Crayfish *(Euastacus* sp.) are food crops and animal protein source that are readily available in Nigeria. They have promising nutritional attributes. Whole sorghum grain is an important source of complex vitamins and some minerals like iron, phosphorus, calcium and magnesium (Onabanjo et al., 2009). The protein content of sorghum is similar to that of wheat and maize, with lysine as the most limiting essential amino acid (FAO, 2009). African yam bean is an excellent source of protein (21-25%) with the amino acid spectrum similar to that of soybean. It is also rich in phosphorus, iron, potassium and vitamins. African yam bean contains all the amino acids found naturally in plant protein (Alozie et al., 2009). African yam bean is limiting in essential sulphur containing amino acids (methionine and cystine) but are rich in lysine (FAO, 1992). Hence, Africa yam bean could form a good supplement to sorghum which is low in lysine. Sorghum contains high level of dietary fibre (13.2%) but low in trace minerals and ascorbic acid. Therefore, there is need to enrich sorghum-based diets with both protein and micro-nutrient rich foods. Complementary foods in developing countries are often deficient in fat and essential fatty acids, which are required for proper growth and development. Non-breastfed children in developing countries are often at high risk of inadequate fat intake. Animal food products such as crayfish are important for complementary feeding as they provide high quality protein, bioavailable micronutrients and have low levels of anti-nutrients and fibre. However, these are unaffordable for majority of the populace in sub-Sahara African countries like Nigeria. Consequently, most mothers use local alternatives to milk such as sorghum, millet, maize and rice gruels. The micro and macronutrient deficiencies of complementary foods could be responsible for setting up risk factors for ill-health which may include poor school performance, reduced productivity, impaired intellectual and social development or chronic diseases (Nestle et al., 2003). The nutritional potentials of the triple mixes (Sorghum, African yam bean and crayfish) as composites for use as complementary foods during the period of complementary feeding can be of greater benefits especially in solving the problems of protein-energy malnutrition and micronutrient deficiencies by providing nutrition security to infants and young children. This study was, therefore, undertaken to evaluate the proximate, mineral and sensory properties of sorghum-based complementary foods supplemented with African yam bean and crayfish flours.

Materials and methods

The red variety of sorghum (*Sorghum bicolor*), African yam bean (*Sphenostylis stenocarpa*) and crayfish (*Euastacus* sp.) used for the study were purchased from Ogbete Main Market, Enugu, Enugu State, Nigeria.

Preparation of Malted Sorghum Flour

The malted sorghum flour was prepared according to the method of Otunola et al., (2004). One kilogram (1kg) of sorghum grains which were free from dirt and other extraneous materials were thoroughly cleaned and steeped in 3 litres of potable water in a plastic bowl at room temperature (30 ± 2^0C) for 24 h with a change of water at every 6 h to prevent fermentation. After steeping, the grains were drained, rinsed and immersed in 2% sodium hypochlorite solution for 10 min to disinfect the grains. The grains were rinsed repeatedly for five consecutive times with excess water and cast on a damped jute bag, covered with a polyethylene bag and left for 24 h to fasten sprouting. The grains were carefully spread on the jute bag and allowed to germinate at room temperature (30 ± 2^0C) and relative humidity of 95% in the germinating chamber for 96 h. During this period, the grains were sprinkled with water at intervals of 8 h to facilitate germination. Non-germinated grains were handpicked and discarded and the germinated grains were collected, spread on the trays and dried in a tray dryer (Model EU 850D, UK) at 60^0C for 24 h with occasional stirring of the grains at intervals of 30 min to ensure uniform drying. After drying, the malted sorghum grains were cleaned and rubbed in-between palms to remove the roots and the shoots. The dried sorghum malts were milled in a hammer mill and sieved through a 500 micron mesh sieve. The flour produced was packaged in an airtight plastic container, labeled and kept in a refrigerator until needed for further use.

Preparation of Malted African Yam Bean Flour

The malted African yam bean flour was prepared according to the method of Eneche (2006). One kilogram (1kg) of African yam bean seeds which were free from dirt and other extraneous materials were thoroughly cleaned and steeped in 3 litres of potable water in a plastic bowl at room temperature (30±2^0C) for 24 h with a change of water at every 6 h to prevent fermentation. After steeping, the seeds were drained, rinsed and immersed in 2% sodium hypochlorite solution for 10 min to disinfect the seeds. The seeds were rinsed for five consecutive times with excess water and cast on a damped jute bag, covered with a polyethylene bag and left for 24 h to fasten sprouting. The seeds were carefully spread on the jute bag and allowed to germinate at room temperature (30 ± 2^0C) and relative humidity of

95% in the germinating chamber for 96 h. During this period, the seeds were sprinkled with water at intervals of 8 h to facilitate germination. Non-germinated seeds were handpicked and discarded and the germinated seeds were collected, spread on the trays and dried in a tray dryer (Model EU 850D, UK) at 60^0C for 24 h with occasional stirring of the seeds at intervals of 30 min to ensure uniform drying. After drying, the malted African yam bean seeds were cleaned and rubbed in-between palms to remove the roots and shoots along with the hulls. The dehulled African yam bean malts were milled in a hammer mill and sieved through a 500 micron mesh sieve. The flour produced was packaged in an airtight plastic container, labeled and kept in a refrigerator until needed for further use.

Preparation of Crayfish Flour

The crayfish flour was prepared according to the method of Onimawo and Egbekun (1998). One kiligram (1kg) of crayfish was sorted and cleaned to remove dirt and other contaminants. The cleaned crayfish was dried in a tray drier (Model EU 850D, UK) at 60^0C for 12 h with occasional stirring at intervals of 30 min to ensure uniform drying. The dried crayfish was winnowed and milled in a hammer mill and sieved through a 500 micron mesh sieve. The flour produced was packaged in an airtight plastic container, labeled and kept in a refrigerator until needed for further use.

Preparation of Complementary Foods

Sorghum, African yam bean and crayfish flours were mixed thoroughly at different graded proportions of 90:5:5, 80:15:5, 70:20:10, 60:25:15 and 50:30:20, respectively in a rotary mixer (Philips, type HR 1500/A Holland) to produce homogenous complementary food samples. The complementary foods formulated were packaged separately in lidded plastic containers, labeled and preserved in a refrigerator until needed for analysis. The malted sorghum flour without any substitution (100% malted sorghum flour) was used as control.

Chemical Analysis

The moisture, crude protein, fat, ash and crude fibre contents of the complementary food samples were determined in triplicate according to the standard analytical methods (AOAC, 2006). Carbohydrate was calculated by difference. 100% - (% Moisture + % Crude Protein + % Ash and % Fat) according to the method of Onwuka, 2005. The energy content was calculated by multiplying the percentages of protein, fat and carbohydrate by the Atwater factors of 4, 9 and 4, respectively (AOAC, 2006). The calcium, iron, phosphorus, potassium and zinc contents of the samples were determined in triplicate using atomic absorption spectrophotometer (Milton Roy Spectronic 601) according to the method of Abiodun and Akinoso (2014).

Sensory Analysis

The control and the formulated samples of the complementary food were individually prepared into gruels. Sixty gram (60g) of each sample were mixed with 120mL of cold water to produce slurry. Then, 80mL of boiling water was added to each of the slurry with continuous stirring to obtain homogenous gruels. Three gram (3g) of granulated sugar were added to each sample of the gruels. The gruels were evaluated in sensory evaluation booths for attributes of colour, taste, mouth feel, texture and overall acceptability by a panel of twenty (20) semi-trained judges comprising of nursing mothers, staff and students of the Department of Food Science and Technology, Enugu State University of Science and Technology, Enugu, Nigeria. Prior to the sensory test, the gruels were separately coded and served to the assessors in white plastic cups with teaspoons at room temperature (30 ± 2^0C). Clean water was provided to the judges to rinse their mouth in-between testing of the gruels to avoid residual effect. The assessors were instructed to assess and score each sample of the product based on their degree of likeness and acceptance of the gruels using a nine-point Hedonic scale with 1 and 9 representing dislike extremely and like extremely, respectively (Okaka, 2010). Expectoration cups with lids were provided for the judges who did not wish to swallow the samples.

Statistical Analysis

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

Results and discussion

Proximate Composition of Complementary Food Samples

The proximate composition of the complementary food samples are presented in Table 1. The moisture content of the complementary food samples varied significantly ($p<0.05$) from each other. The moisture content ranged from 9.46 to 10.33% with the control sample (100% malted sorghum flour) having the least moisture content (9.46%), while the sample supplemented with 30% African yam bean and 20% crayfish flours had the highest value (10.33%). The moisture contents of all the formulated complementary food samples reported in this study were within the recommended moisture contents of dried foods (Ndife et al., 2011; Bolarinwa et al., 2015). The lower moisture content observed in this study is an indication that the products can be stored at room temperature without any adverse effect on their quality attributes and will also exhibit better shelf stability. The protein content of the samples increased with increase in substitution with African yam bean and crayfish flours in the formulations. The protein contents of all the formulated complementary food products were superior to that of the control (100% malted sorghum flour). The observed increase in protein could be attributed to the inclusion of high amounts of African yam bean and crayfish flours in the blends and this is in consonance with the report that African yam bean and crayfish are good sources of protein (Ekop, 2006; Ibironke et al., 2012). The high protein contents of complementary foods supplemented with high levels of African yam bean and crayfish flours will be of great importance in reducing protein-energy malnutrition resulting from high cost of animal protein and commonly consumed legumes. Protein is important for growth and tissue replacement (Okaka et al., 2006). The fat content of the complementary food samples range from 1.85 to 3.64%. The fat content of the control (100% malted sorghum flour) was significantly ($p<0.05$) lower than the fat contents of all the formulated samples. The fat content of the formulated complementary food samples was relatively higher than the control sample but was within the recommended range of dietary allowance for infants and young children. This could be attributed to the addition of high levels of crayfish flour which has high fat content in the products (Oduro et al*.,* 2007). The high fat contents of the complementary food products may be of interest to consumers interested in the consumption of high fat food products. Fat increases the energy density and also provides essential fatty acids needed in the body for proper neural development (Mariam, 2005). The ash content of the complementary food samples increased significantly ($p<0.05$) with increase in substitution with African yam bean and crayfish flours in the blends. The increase in ash content observed in the samples substituted with African yam bean and crayfish flours at different graded levels may be attributed to the high mineral content of African yam bean and crayfish flours. The ash content of a food material could be used as an index of the mineral constituents of the food (Ishiwu and Onyeji, 2004). The ash content (2.77 - 3.67%) obtained in this study was lower than the ash content (4.25 - 5.81) of complementary food prepared from sorghum and African yam bean flour blends reported by Ijarotimi and Bakare (2006). The crude fibre content of the complementary food samples ranged from 1.46 to 2.15% with the control (100% malted sorghum flour) and the sample substituted with 30% African yam bean and 20% crayfish flours having the least (1.46%) and highest (2.15%) values, respectively. The values obtained in this study were higher than the crude fibre content (0.31-1.82%) of complementary food formulated from fermented maize, soybean and carrot flours reported by Barber *et al*., (2017). The crude fibre content of the complementary food samples was observed to increase as the levels of substitution with African yam bean and crayfish flours increased and this is in consonance with the report that African yam bean and crayfish are rich sources of dietary fibre (Alozie et al*.*, 2009; Fashakin and Ige, 2014). Fibre plays a significant role in the digestion and absorption of food in the human body. The carbohydrate content of the samples ranged from 60.34 to 72.36%. The carbohydrate contents of all the formulated complementary food samples were significantly ($p<0.05$) lower than the control. The increase in carbohydrate content of the control sample could be attributed to the high proportion of sorghum flour used. The carbohydrate levels of all the formulations are of nutritional benefits as children require energy to carry out their rigorous activities as growth continues. The values obtained in this study were lower than the carbohydrate content (69.2 – 74.5%) of complementary foods formulated from malted millet, plantain and soybean flour blends reported by Bolarinwa et al., (2015). The energy content of the complementary food samples ranged from 357.79–364.33KJ/100g. The control sample without any substitution significantly ($p<0.05$) had the highest energy value (364.33KJ/100g), while the formulation substituted with 30% African yam bean and 20% crayfish flours had the least energy value (357.79KJ/100g). The observed differences in the energy levels of the formulations could be attributed to variation in the protein, fat and carbohydrate contents of the samples. The results obtained in this study are similar to the findings of Nzeagwu and Nwaejike (2008) who reported a decrease in the energy content of complementary foods with increasing substitution with groundnut and crayfish flours. The substitution of sorghum-based gruels with African yam bean and crayfish flours greatly increased the nutrient contents of the formulations.

Mineral Composition of Complementary Food Samples

The mineral composition of complementary food samples are presented in Table 2. The calcium, iron and zinc contents of the complementary food samples increased significantly ($p<0.05$) with increase in substitution with African yam bean and crayfish flours with the exception of phosphorus and potassium which act as the major mineral elements present in sorghum grains. The calcium content of the complementary food samples ranged from 12.68 to 84.86mg/100g. The control sample (100% malted sorghum flour) had the least value (12.68mg/100g), while the formulation substituted with 30% African yam bean and 20% crayfish flours had the highest calcium content (84.86mg/100g). The increase in calcium content observed in all the formulations substituted with different proportions of African yam bean and crayfish flours could be attributed to increase in the addition of African yam bean and crayfish flours in the blends. Calcium in conjunction with magnesium, phosphorus and protein are involved in bone formation (Agu and Aluya, 2004). The iron content of the complementary food samples varied significantly from each other. The formulation substituted with 30% African yam bean and 20% crayfish flours had significantly ($p<0.05$) the highest iron content (7.99mg/100g), while the control (100% malted sorghum flour) had the least value (2.68mg/100g). Iron is a component of myoglobin, a protein that provides oxygen to muscles and supports metabolism in humans (Okaka et al., 2006). Regular consumption of food that is rich in iron has the potential to prevent anaemia in infants and young children. The phosphorus content of the complementary food samples ranged from 128.63 to 257.01mg/100g. The control had the highest phosphorus content (257.01mg/100g), while the formulation substituted with 30% African yam bean and 20% crayfish flours had the least value (128.63mg/100g). The values obtained in the study (128.63-291.01mg/100g) are similar to the phosphorus content (196.48-291.01mg/100g) of complementary foods formulated from sorghum, African yam bean and mango mesocarp flour blends reported by Yusufu et al*.,* (2013). Phosphorus is an important nutrient that plays a significant role in the formation of Adenosine Trisphophate (ATP) in the body (Okaka et al., 2006). The potassium content of the complementary food samples which ranged from 293.11 to 346.20mg/100g decreased significantly with increase in substitution with African yam bean and crayfish flours in the blends. The observed decrease in the potassium content is an indication that African yam bean and crayfish are not good sources of potassium (Nzeagwu and Nwaejike, 2008). Potassium is essential in blood clothing and muscle contraction. The zinc content of the complementary food samples ranged from 1.28 to 1.63mg/100g. The formulation substituted with 30% African yam bean and 20% crayfish flours had the highest zinc content (1.63mg/100g), while the control had the least value (1.28mg/100g). The increase in zinc content could be attributed to the inclusion of high proportions of African yam bean and crayfish flours in the blends. Zinc supports normal growth and development during pregnancy, childhood and adolescence. The substitution of sorghum-based gruels with African yam bean and crayfish flours increased the mineral content of the products.

Sensory Properties of Complementary Food Samples

The sensory properties of complementary food samples are presented in Table 3. The sensory scores of the gruels prepared from both the control and formulated samples showed significant ($p<0.05$) differences in colour, taste, mouth feel, texture and overall acceptability. The control sample (100% malted sorghum flour) had significantly ($p<0.05$) the highest scores for colour, taste, mouth feel and overall acceptability compared to the test samples in all the parameters evaluated by the judges. The sample substituted with 5% African yam bean and crayfish flours had no significant ($p<0.05$) difference is taste. The gruels prepared from 100% malted sorghum flour and those made from the formulated samples of complementary blends substituted with 5-30% African yam bean and 5-20% crayfish flours were generally acceptable. The increase in substitution with African yam bean and crayfish flours resulted in decrease in acceptability of the gruels as indicated by the significantly ($p<0.05$) low values for the sample substituted with 30% African yam bean and 20% crayfish flours. The variation in colour observed could be due to increased substitution of the formulations with African yam bean and crayfish flours and the addition of sugar which gave the products a slightly dark colouration. The sample substituted with 30% African yam bean and 20% crayfish flours was also reported to have crumbly texture and a beany flavour, attributed to increased substitution and the beany flavour of African yam bean flour.

However, the gruel made from the sample formulated with 90% sorghum, 5% African yam bean and 5% crayfish flours was described by the panelists as having the best taste, mouth feel and overall acceptability compared to the other test samples. The taste and mouth feel are important parameters while testing the acceptability of formulated foods. The sensory qualities of complementary food formulations which are closely related to food preferences for infants and young children are of the greatest importance in addition to their energy density (Muhimbula et al., 2011). This showed that sensory evaluation should be given adequate attention in the formulation and evaluation of quality attributes of home-made complementary food formulations. The substitution of sorghum flour with 5% African yam bean and 5% crayfish fours could be used to produce nutrient dense and organoleptically acceptable complementary food products.

Table 1 (a & b). Proximate composition (%) of complementary food samples.

Table 1a.

Sample ID	% Substitution SF: AYBF: CF	Moisture	Protein	Fat
A	100 : 0 : 0	$9.46^{e} \pm 0.08$	$13.56^{f} \pm 0.29$	$1.85^{f} \pm 0.01$
B	90 : 5 : 5	$9.61^{d} \pm 0.27$	$18.80^{e} \pm 0.08$	$2.41^{e} \pm 0.01$
C	80 : 15 : 5	$9.70^{c} \pm 0.11$	$21.32^{d} \pm 0.05$	$2.64^{d} \pm 0.01$
D	70 : 20 : 10	$9.73^{c} \pm 0.11$	$22.32^{c} \pm 0.16$	$2.69^{c} \pm 0.13$
E	60 : 25 : 15	$10.28^{b} \pm 0.17$	$22.61^{b} \pm 0.27$	$2.83^{b} \pm 0.01$
F	50 : 30 : 20	$10.33^{a} \pm 0.05$	$23.88^{a} \pm 0.82$	$3.64^{a} \pm 0.01$

SF: Malted Sorghum Flour; **AYBF:** Malted African Yam Bean Flour, **CF :** Crayfish Flour
Values are mean ± standard deviation of triplicate determinations. Means in the same column with different superscripts are significantly different ($p < 0.05$)

Table 1b.

Sample ID	Ash	Fibre	Carbohydrate	Energy (kg/100g)
A	$2.77^{e} \pm 0.02$	$1.46^{e} \pm 0.06$	$72.36^{a} \pm 0.21$	$364.33^{a} \pm 0.35$
B	$2.86^{d} \pm 0.06$	$1.63^{d} \pm 0.01$	$66.31^{b} \pm 0.07$	$362.13^{b} \pm 1.09$
C	$2.88^{d} \pm 0.03$	$1.86^{c} \pm 0.01$	$62.49^{c} \pm 0.37$	$362.09^{c} \pm 0.27$
D	$2.93^{c} \pm 0.01$	$1.87^{c} \pm 0.04$	$61.77^{d} \pm 0.01$	$361.33^{d} \pm 0.83$
E	$3.17^{b} \pm 0.02$	$1.91^{b} \pm 0.01$	$61.61^{e} \pm 0.40$	$360.64^{e} \pm 0.83$
F	$3.67^{a} \pm 0.02$	$2.15^{a} \pm 0.02$	$60.34^{f} \pm 1.06$	$357.79^{f} \pm 0.44$

SF: Malted Sorghum Flour; **AYBF:** Malted African Yam Bean Flour, **CF :** Crayfish Flour
Values are mean ± standard deviation of triplicate determinations. Means in the same column with different superscripts are significantly different ($p < 0.05$)

Table 2. Mineral composition (mg/100g) of complementary food samples.

Sample ID	% Substitution SF: AYBF: CF	Calcium	Iron	Phosphorus	Potassium	Zinc
A	100 : 0 : 0	12.68^{f}±1.24	2.68^{d}±0.03	257.01^{a}±41.44	346.20^{a}±0.03	1.28^{d}±0.02
B	90 : 5 : 5	18.56^{e}±10.01	3.63^{c}±0.32	233.77^{b}±0.01	342.77^{b}±0.02	1.48^{c}±0.48
C	80 : 15 : 5	24.54^{d}±1.07	4.65^{c}±0.34	218.55^{c}±0.01	340.53^{c}±0.01	1.52^{c}±0.37
D	70 : 20 : 10	46.55^{c}±0.02	5.74^{b}±0.27	180.25^{d}±0.00	319.63^{d}±41.20	1.58^{b}±0.57
E	60 : 25 : 15	61.75^{b}±0.04	6.76^{b}±0.02	145.55^{e}±42.44	305.00^{e}±29.27	1.60^{a}±0.17
F	50 : 30 : 20	84.86^{a}±7.83	7.99^{a} ±0.08	128.63^{f}±1.15	293.11^{f}±0.44	1.63^{a}±0.13

SF: Malted Sorghum Flour; **AYBF:** Malted African Yam Bean Flour, **CF :** Crayfish Flour
Values are mean± standard deviation of triplicate determinations. Means in the same column with different superscripts are significantly different ($p< 0.05$)

Table 3. Sensory properties of complementary food samples.

Sample ID	% Substitution SF: AYBF: CF	Colour	Taste	Flavor	Texture	Overall acceptability
A	100 : 0 : 0	7.50^{a}±1.24	7.50^{a}±1.24	7.70^{a}±1.02	7.75^{a}±1.02	7.90^{a}±1.17
B	90 : 5 : 5	6.35^{b}±1.23	7.48^{a}±1.10	6.40^{b}±1.27	7.10^{b}±1.33	7.85^{b}±0.01
C	80 : 15 : 5	5.35^{c}±1.34	6.95^{b}±1.50	6.40^{b}±1.27	6.35^{c}±1.42	6.70^{c}±1.38
D	70 : 20 : 10	5.40^{d}±1.57	6.30^{c}±1.34	5.50^{c}±1.19	5.70^{d}±1.38	6.35^{d}±1.79
E	60 : 25 : 15	5.40^{d}±1.50	4.15^{d}±0.10	4.95^{d}±1.23	5.50^{e}±1.61	6.00^{e}±1.72
F	50 : 30 : 20	4.50^{e}±1.19	4.05^{e}±0.10	4.15^{e}±0.75	4.85^{f}±1.42	5.70^{f}±1.66

SF: Malted Sorghum Flour; **AYBF:** Malted African Yam Bean Flour, **CF :** Crayfish Flour
Values are mean ± standard deviation of twenty (20) semi-trained judges. Means in the same column with different superscripts are significantly different ($p< 0.05$)

Conclusion

The study showed that the substitution of sorghum-based complementary foods with African yam bean and crayfish flours in the formulation of complementary foods improved the protein, fat, carbohydrate, mineral and vitamin contents of the products, thus creating a novel use for African yam bean and crayfish. The complementary foods formulated in this study could be used by nursing mothers to feed their infants and young children during the complementary feeding period. Although the product had high protein, fat, fibre and mineral contents, there is need for further supplementation of the complementation blends with better sources of minerals. The gruel prepared from the sample with 5% African yam bean and crayfish flours substitution had better acceptability than other test samples. The complementary food products developed with locally available and affordable food materials in this study could also help to prevent the problems of protein-energy malnutrition and micronutrient deficiencies among infants and young children in Nigeria and other developing countries of the world.

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