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QUALITY CHARACTERISTICS OF COMPLEMENTARY FOODS FORMULATED FROM SORGHUM, AFRICAN YAM BEAN AND CRAYFISH FLOURS

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ABSTRACT
Low-cost, nutritive and ready-to-eat complementary foods formulated from blends of sorghum, African yam bean and crayfish flour were evaluated for proximate, vitamin and pasting properties. 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 vitamin content of the samples showed that the ascorbic acid, niacin, thiamine, vitamin A and folic acid contents of the blends increased with increase in substitution with African yam bean and crayfish flours from 1.27±0.02–2.66±0.06mg/100g, 0.64±0.00–0.88±0.00mg/100g, 0.36±0.00 – 0.53±0.00mg/100g,2.54±0.08–4.15±0.04mg/100g and 0.24±0.01–0.36±0.03mg/100g, respectively, while the riboflavin content decreased. The control sample had the highest riboflavin (3.17±0.02mg/100g) content. The pasting properties of the samples showed that the control had the highest values for final, breakdown and setback viscosities as well as peak time and pasting temperature, respectively compared to the formulated samples. The sample substituted with 30% African yam bean and 20% crayfish flours recorded the highest values for peak viscosity (113.77RVA) and trough (57.42RVA), respectively. However, the study showed that the nutrient contents and pasting properties of sorghum-based complementary foods could be drastically improved by supplementing sorghum flour with African yam bean and crayfish flours in the preparation of home-made nutrient dense complementary foods that would be used for feeding of infants and young children during complementary feeding period in Nigeria and other developing countries of the world.

Keywords: Complementary foods, supplementation, proximate composition, vitamin content, pasting properties, sorghum flour, African yam bean flour, crayfish flour.

INTRODUCTION
Protein-energy malnutrition is one of the most serious problems that is common in the developing countries. It is usually associated with deficiencies in protein and calories leading to endemic protein malnutrition with its attendant health consequences particularly in infants and young children (WHO, 2009). Complementary foods are foods other than breast milk (liquids, semi-solids and solids) given to an infant to provide nutrients. This refers to the period during which an infant gradually becomes accustomed to foods other than breast milk. They are readily consumed and digested by infants and children as they provide additional nutrients to meet all their growing needs (Ijarotimi and Famurewa, 2006). It has been proved that breast milk is the perfect food for the infant during the first six months of life as it contains all the nutrients and immunological factors an infant requires to maintain optimal health and growth. Furthermore, breast milk also protects infants against the two leading causes of infant mortality, viz: upper respiratory infections and diarrhoea (WHO, 2009). However, after six months, breast milk alone will no longer be sufficient both in terms of quantity and quality to meet the nutritional requirements of the growing child especially for energy and micronutrients notably zinc, iron and vitamin A (UNICEF, 2009). It is therefore necessary to supplement breast milk with other foods as the child grows older. Nutritious complementary foods are therefore introduced, which typically covers the period from six to twenty four months of age in most developing countries. Poor handling during this crucial growth period may lead to undernutrition. Poor feeding practices or short fall in food intake have been identified as the most important direct factors responsible for malnutrition and illness amongst infants and young children in Nigeria. However, in developing countries, nutritious complementary foods can assist in nutritional development of infants and young children, but they are beyond the reach of many Nigerian families. Hence, such families often depend on inadequately processed traditional foods consisting mainly of unsupplemented cereal gruels made from maize, sorghum and millet (Ibe, 2008). These cereals are eaten in large quantities in developing countries and are prepared as gruels and used in feeding infants (Ikujenlola, 2008). Due to their high viscosity on cooling, a large amount of water is used during preparation to obtain the right consistency. The high viscosity characteristics of cereal grain is obviously responsible for young children's inability to fulfill their energy and nutrient requirements (Kikafunda *et al*., 2006). Complementary foods prepared with appropriate processing and blending of locally available food commodities improve the nutrient density and nutrient intake which result in the prevention of malnutrition. This requires adequate knowledge of the nutritive values of a variety of local food commodities indigenous to the affected communities. Therefore, it is essential that infants receive appropriate, adequate and safe complementary foods to ensure the right transition from breast feeding to the full use of family foods (Okoye *et al.,* 2010). Lack of appropriate feeding can set up risk factors for ill-health. The lifelong impact may include poor school performance, reduced productivity, impaired intellectual and social development or chronic disease (Nestle *et al.,* 2003).

Vegetable proteins especially those derived from leguminous sources such as soybean have been put forward as an excellent source of protein for upgrading the nutritional quality of starchy roots and tubers used in the preparation of baby foods (Okaka *et al.,* 2006). Complementary foods commonly used in Nigeria are composed largely of sorghum (Sorghum bicolor) with a limited amount of dried milk powder. However, such mixture have shown to be poor in protein content and quality (Achi, 2005). Complementary foods with low fibre content is very important because it helps in the safety of children considering 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 fortification of complementary foods with a variety of inexpensive vegetable proteins derived from legumes, nuts and oilseeds has received considerable attention from nutritionists and food scientists in several sub-Saharan African countries (Uzogara *et al*., 1990). This is because these grain legumes and oilseeds contain high amount of the essential amino acids that are deficient in most cereals (Asma *et al.*, 2006). Whole legumes generally contain high amounts of protein compared to other foods of plant origin (FAO, 2009). In developing countries like Nigeria, complementary foods are mainly based on starchy tubers like cocoyam, sweet potato and Irish potato or on cereals like maize, millet and sorghum. Children are normally given these staples in the form of gruels that are either mixed with boiled water or boiled with water (Igyor *et al*., 2011).

Sorghum (*Sorghum bicolor)* is an important food crop grown on a subsistence level by farmers in the semi-arid tropics of Africa and Asia. It is the principal crop grown in northern Nigeria (Zakari and Iyang, 2008). Sorghum like other cereals is predominantly starchy. The average starch content of the grain ranged from 56 to 73%. It is relatively rich in iron and phosphorus but do not contain pro-vitamin A (FAO, 2009). African yam bean (*Sphenostylis stenocarpa*) is an underutilized leguminous crop that is predominantly cultivated in West Africa. It produces nutritious pods, highly proteinous seeds and is capable of growing in marginal areas where other pulses fail to thrive (Enwere, 1998). It has the potential to meet the ever increasing protein demands of the people in areas where it is produced in commercial quantity. Crayfish is one of the cheapest sources of animal protein. Generally, fish flesh contains mainly water, protein and fat with traces of carbohydrates, amino acids and other non-protein nitrogenous extracts with various minerals and vitamins (Onimawo and Egbekun, 1998). The fibres of crayfish are shorter than those of other meat, so they are easier to digest. Ideally, the ingredients for low-cost complementary foods must be derived from dietary staples and animal products that are available and affordable in the region of interest.

MATERIALS AND METHODS

The red sorghum grains (*Sorghum bicolor*), African yam bean seeds (*Sphenostylis stenocarpa*) and crayfish (*Euastacus spp.*) 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 kilogramme (1kg) of sorghum grains which were free from dirt and other extraneous materials were thoroughly cleaned and steeped in 2.5litres of potable water in a plastic bowl at room temperature (30±2^{0}C) for 24 h with occasional change of water at intervals of 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 then rinsed for five consecutive times with excess water and cast on a moistened jute bag, covered with a polyethylene bag and left for 24 h to fasten sprouting. The grains were then spread carefully on the jute bag and allowed to germinate at room temperature (30±2^{0}C) for 96 h. During this period, the grains were sprinkled with water at intervals of 6 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^{0}C for 24 h with occasional stirring of the grains at intervals of 30 min to ensure uniform drying. After drying, the roots and shoots of the malted sorghum grains were removed by rubbing them in-between palms. The dried sorghum malts were milled in a locally fabricated attrition mill and sieved through a 500 micron mesh sieve. The flour produced was packaged in an airtight plastic container, labeled and stored in a refrigerator until needed for the formulation of complementary foods.

Preparation of Malted African Yam Bean Flour

The malted African yam bean flour was prepared according to the method of Eneche (2006). One kilogramme (1kg) of African yam bean seeds which were free from dirt and other extraneous materials were thoroughly cleaned and steeped in 2.5litres of potable water in a plastic bowl at room temperature (30±2^{0}C) for 24 h with a change of water at intervals of 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 then rinsed for five consecutive times with excess water and cast on a moistened jute bag, covered with a polyethylene bag and left for 24 h to fasten sprouting. The seeds were spread on the jute bag and allowed to germinate at room temperature (30±2^{0}C) for 96 h. During this period, the seeds were sprinkled with water at intervals of 6 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^{0}C for 24 h with occasional stirring of the seeds at intervals of 30 min to ensure uniform drying. The dried malted African yam bean seeds were cleaned and rubbed in-between palms to remove the roots and shoots along with the hulls. The dehulled malted seeds were milled in a locally fabricated attrition mill and sieved through a 500 micron mesh sieve. The flour produced was packaged in an airtight plastic container, labeled and stored in a refrigerator until needed for the formulation of complementary foods.

Preparation of Crayfish Flour

The crayfish flour was prepared according to the method of Onimawo and Egbekun (1998). One kilogram (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^{0}C for 12 h with occasional stirring at the crayfish 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 the preparation of complementary foods.

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 in a rotary mixer (Philips, type HR 1500/A Holland) to produce homogenous complementary food samples. The complementary foods formulated were separately packaged in airtight 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 ascorbic acid, niacin, and folic acid contents of the samples were determined by the methods of AOAC (2006). The thiamine, riboflavin and vitamin A contents of the samples were determined according to the flourimetric methods of Onwuka (2005).

Pasting Properties of Complementary Foods
The pasting properties of the complementary food samples was determined using Rapid Visco Analyzer (RVA); (Model Newport Scientific Pty. Ltd., Warne-wood NSW 2012, Australia) according to the method of AACC (2000). Three grams (3g) of each sample of the flour were weighed into a dried empty canister and 30mL of distilled water was dispensed into each canister containing the sample to form the slurry. The slurry was thoroughly mixed in each case and each canister was fitted into the Rapid Visco Analyzer. The slurry was individually heated from 50^{0}C to 95^{0}C with a holding time of 2 min followed by cooling to 50^{0}C with 2 min holding time. The rate of heating and cooling was maintained at a constant rate of 11.25^{0}C per min. The viscosity was expressed in centipoise (cP). The parameters measured (RVA unit) were: Breakdown viscosity (The difference between the peak viscosity and the minimum viscosity at the end of the heating stage). Final viscosity (The viscosity at the end of the cooling stage). Peak time (min) (The time taken for the paste to reach the peak viscosity). Pasting temperature (^{0}C) (The temperature at which there is a sharp increase in viscosity of the flour suspension after the commencement of the heating stage). Set back viscosity (The difference between the maximum viscosity during cooling and the minimum viscosity during heating). Trough (The minimum viscosity which measures the ability of paste to withstand breakdown during cooling). Peak viscosity (Highest viscosity during the heating stage).

Statistical Analysis
The data generated were subjected to one-way analysis of variance (ANOVA) using Statistical Package for Social Sciences (SPSS, Version 20) software. Significant means were separated using Duncan's New Multiple Range Test (DNMRT). Differences were considered significant at $p < 0.05$ and results were expressed as mean $\pm$ 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 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*., 2016). 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 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). 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 agreement 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 the 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 ranged from 1.85 to 3.64%. The fat content of the control sample (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. The increase could be attributed to the inclusion of high levels of crayfish flour which has high fat content in the products (Oduro *et al.,* 2007). The high fat content 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 acid 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 sample substituted with African yam bean and crayfish flours at different graded levels may be attributed to 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 Famurewa (2006). The crude fibre content of the complementary food samples ranged from 1.46 in the control sample to 2.15% in the sample substituted with 30% African yam bean and 20% crayfish flours, respectively. The values obtained in this study were higher than the 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 agreement with the report that African yam bean and crayfish are rich sources of dietary fibre (Alozie and Udofia, 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 content 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 in 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.* (2016). 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 content (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 were similar to the findings of Nzeagwu and Nwaejike (2008) who reported a decrease in the energy content of supplementary 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 content of the formulations.

Vitamin Composition of Complementary Food Samples

The vitamin composition of complementary food samples are presented in Table 2. The ascorbic acid, niacin, thiamine, vitamin A and folic acids contents of the samples increased with increase in substitution with African yam bean and crayfish flours except for riboflavin. The increase in the vitamin content of the formulations confirms the beneficial effect of complementation (Lutter and Dewey, 2003). The ascorbic acid content of the complementary food samples varied from 1.27 to 2.66 mg/100g with the control and the formulation substituted with 30% African yam bean and 20% crayfish flours having the least (1.27mg/100g) and highest (2.66mg/100g) values, respectively. The increase in ascorbic acid content observed in all the formulated samples could be attributed to the addition of high proportions of African yam bean and crayfish flours in the blends. Africa yam bean and crayfish have been known to be good sources of ascorbic acid (Muhimbula *et al.,* 2011). Ascorbic acid is important in the prevention of scurvy and development of healthy immune system in infants and young children (Michaelsen *et al*., 2000). The niacin content of the complementary food samples varied significantly ($p<0.05$) from each other. The sample substituted with 30% African yam bean and 20% crayfish flours had significantly ($p<0.05$) the highest value (0.88mg/100g), while the control sample had the least niacin content (0.64mg/100g). The niacin contents of the complementary foods produced in this study were lower than the niacin content (3.43 - 4.56mg/100g) of high protein weaning food prepared from maize, peanut and soybean flours reported by Plahar *et al*. (2003). Niacin is a component of the respiratory co-enzyme (NAD) that is responsible for tissue oxidation in the body. The thiamine content of the formulations varied from 0.36 to 0.53mg/100g with the control and the sample substituted with 30% African yam bean and 20% crayfish flours having the least (0.36mg/100g) and highest (0.53mg/100g) values, respectively. Thiamine functions as a co-enzyme in energy metabolism. It also helps in the treatment of beriberi and in the maintenance of healthy mental attitude in infants and young children (Okaka *et al*., 2006). The riboflavin content of the complementary food samples decreased significantly ($p<0.05$) with increase in substitution with African yam bean and crayfish flours in the products. The control sample had the highest riboflavin content (3.17mg/100g), while the formulation substituted with 30% African yam bean and 20% crayfish flours had the least riboflavin value (0.35mg/100g). Riboflavin, which is commonly known as vitamin B_2 is also necessary for growth and development in infants and young children (Okwu, 2004). The Vitamin A content of the formulations which ranged from 2.54 to 4.15mg/100g increased significantly ($p<0.05$) with increase in substitution with African yam bean and crayfish flours in the blends. The sample substituted with 30% African yam bean and 20% crayfish flours had the highest vitamin A content (4.15mg/100g), while the control sample had the least value (2.54mg/100g). Vitamin A, which is a fat soluble vitamin plays a vital role in the maintenance of good sight (Okaka *et al*., 2006). The folic acid content of the samples increased significantly ($p<0.05$) from 0.24 mg/100g in the control sample to 0.36 mg/100g in the formulation substituted with 30% African yam bean and 20% crayfish flours. The observed increase in the folic acid content of the samples is an indication that African yam bean and crayfish are good sources of folic acid (Okafor and Usman, 2013). Folic acid plays a significant role as a co-enzyme in the body. The substitution of sorghum-based gruels with African yam bean and crayfish flours generally enhanced the vitamin content of the products and would be therefore recommended for use in the preparation of good quality gruels.

Pasting Properties of Complementary Food Samples

The pasting characteristics of complementary food samples are presented in Table 3. The peak viscosity of the complementary food samples ranged from 94.63 to 113.77 RVA with the control sample having the lowest peak viscosity (94.63 RVA), while the formulation substituted with 30% African yam bean and 20% crayfish flours had the highest value (113.77 RVA). The observed increase in the peak viscosity of the samples could be attributed to the addition of African yam bean and crayfish flours in the mixes which do not contain degraded starch. The increase in the peak viscosity of the complementary foods is generally not advantageous because the gruels prepared from them would not be watery and more solids will not be added, hence this will discourage the addition of more nutrients and energy constituents which are much needed by the growing children (Onweluzo and Nwabugwu, 2009). The trough ranged from 34.61 to 57.4 RVA with the control sample having the highest value (57.42 RVA). The decrease in the trough of the samples could be attributed to the addition of African yam bean and crayfish flours in the blends. Trough is the minimum viscosity which measures the ability of paste to withstand breakdown during cooling (Bolarinwa *et al*., 2015). The breakdown viscosity of the complementary food samples ranged from 40.62 to 69.72 RVA with the sample substituted with 30% African yam bean and 20% crayfish flours having the least breakdown viscosity (40.62 RVA). The breakdown viscosity is essentially a measure of the degree of paste stability or starch granules disintegration during heating (Oluwalana *et al*., 2012). The sample substituted with 30% African yam bean and 20% crayfish flours which had relatively low breakdown viscosity (40.62 RVA) will form a more stable paste during heating than the control sample which had the higher breakdown viscosity (69.72 RVA) (Farhat *et al*., 1999). However, the inclusion of African yam bean and crayfish flours in the mixes tends to generally reduce the breakdown viscosity, thereby making the paste more stable during heating. The ability of starch to withstand heating at high temperature and shear stress is an important factor in many processes. Elofsson *et al*. (1997) noted that the formation of gels by the proteins in foods results from a two-step process involving, firstly, the partial denaturation of individual proteins to allow more access to the reactive side groups within the protein molecules and secondly, the aggregation of these proteins by means of reactive side groups into a continuous three dimensional network structure capable of retaining significant amount of water and also exhibiting same structural rigidity. This phenomenon is of great importance in foods since it contributes significantly ($p<0.05$) to the textural and rheological properties of various foods. The final viscosity of the complementary food samples ranged from 76.82 to 9.42 RVA with the sample substituted with 30% African yam bean and 20% crayfish flours having the least final viscosity (78.82 RVA). The inclusion of African yam bean and crayfish flours in the formulations was generally observed to cause reduction in the final viscosity. The final viscosity is usually regarded as an indication of the stability of the cooked paste (Ragaee and Abdel-Aal, 2006). The setback viscosity of the formulations ranged from 49.37 to 64.83 RVA with the control sample having the highest setback viscosity (64.83 RVA). The setback viscosity decreased with increase in substitution with African yam bean and crayfish flours in the blends. The higher the substitution level, the more the retrogradation level during cooling and the higher the staling of the products made from the flour (Adeyemi and Idowu, 1990). A high setback viscosity value is associated with a cohesive paste while a low value is an indication that the paste is not cohesive (Oduro *et al*., 2000). This phase is commonly described as the setback region and is related to retrogradation and reordering of starch molecules. The reduction in setback viscosity of the samples is an indication of low rate of starch retrogradation and syneresis of the gel. The setback viscosity is usually regarded as an index of retrogradation tendency of the paste prepared from a starchy food (Sandhu *et al*., 2007). The peak time of the complementary food samples ranged from 4.93-6.12 min with the control sample having the highest peak time (6.12 min). The addition of African yam bean and crayfish flours in the formulations resulted in a decrease in the peak time. The peak time is usually regarded as an indication of the total time taken by each sample to attain its respective peak viscosity. Therefore, complementary food sample with a lower peak time will cook faster than that with a higher peak time. The pasting temperature of the samples ranged from 82.62 - 85.42^{0}C with the sample substituted with 30% African yam bean and 20% crayfish flours having the lowest pasting temperature (82.62^{0}C). The substitution of the formulations with African yam bean and crayfish flours resulted in a reduction in the pasting temperature. The differences in the pasting temperature of the complementary food samples revealed that the formulations exhibited different gelatinization temperatures (Newport–Scientific, 1996). The pasting temperature provides an indication of the minimum temperature required to cook a given sample, which can also have implications on energy usage (Ragaee and Abdel-Aal, 2006).The ability of protein to form gel and provide a structural matrix for holding water, flavour, sugar and food ingredients is useful in food application. Protein gel formation usually requires prior heating which lead to the denaturation or unfolding of the polypeptide chains. The relatively low peak viscosity observed in this study is an indication that the inclusion of African yam bean and crayfish flours in the formulated samples would be more suitable for products that require low gel strength and elasticity (Ishiwu and Onyeji, 2004). However, the inclusion of African yam bean and crayfish flours in the developed complementary foods could be regarded as appropriate due to the exhibited characteristics of relatively low final and setback viscosities and pasting temperature.

Conclusion

The study showed that the substitution of sorghum flour with African yam bean and crayfish flours in the formulation of complementary foods improved the nutrient content of the products, thus creating a novel use for African yam bean and crayfish. The high protein, energy and vitamin contents of the samples coupled with their unique pasting properties showed that the formulations will enhance the growth, development and wellbeing of infants and young children, in addition to the affordability of the products. Generally, the supplementation of sorghum-based complementary foods with African yam bean and crayfish flours could be regarded as appropriate due to their ability to reduce the final and setback viscosities as well as peak time and pasting temperature of the formulated samples.

Table 1: Proximate composition (%) of complementary food samples

Sample ID	% Substitution SF:AYBF:CF	Moisture	Protein	Fat	Ash	Fibre	Carbohydrate	Energy (KJ/100g)
A	100:0.0	$9.46^e \pm 0.08$	$13.56^f \pm 0.29$	$1.85^f \pm 0.01$	$2.77^e \pm 0.02$	$1.46^e \pm 0.06$	$72.36^a \pm 0.21$	$364.33^a \pm 0.35$
B	90:5:5	$9.61^d \pm 0.27$	$18.80^e \pm 0.08$	$2.41^e \pm 0.01$	$2.86^d \pm 0.06$	$1.63^d \pm 0.01$	$66.31^b \pm 0.07$	$362.13^b \pm 1.09$
C	80:15:5	$9.70^c \pm 0.11$	$21.32^d \pm 0.05$	$2.64^d \pm 0.01$	$2.88^d \pm 0.03$	$1.86^c \pm 0.01$	$62.49^c \pm 0.37$	$362.09^c \pm 0.27$
D	70:20:10	$9.73^c \pm 0.11$	$22.32^c \pm 0.16$	$2.69^c \pm 0.13$	$2.93^c \pm 0.01$	$1.87^c \pm 0.04$	$61.77^d \pm 0.01$	$361.33^d \pm 0.83$
E	60:25:15	$10.28^b \pm 0.17$	$22.61^b \pm 0.27$	$2.83^b \pm 0.01$	$3.17^b \pm 0.02$	$1.91^b \pm 0.01$	$61.61^e \pm 0.40$	$360.64^e \pm 0.83$
F	50:30:20	$10.33^a \pm 0.05$	$23.88^a \pm 0.82$	$3.64^a \pm 0.01$	$3.67^a \pm 0.02$	$2.15^a \pm 0.02$	$60.34^f \pm 1.06$	$357.79^f \pm 0.44$

Values are mean ± standard deviation of triplicate determinations. Means in the same column with different superscripts are significantly different ($p < 0.05$)

SF - Malted Sorghum Flour, AYBF - Malted African Yam Bean Flour, CF - Crayfish Flour

Table 2: Vitamin composition (mg/100g) of complementary food samples

Sample ID	% Substitution SF:AYBF:CF	Ascorbic Acid	Niacin	Thiamine	Riboflavin	Vitamin A	Folic acid
A	100:0.0	$1.27^{f}\pm0.02$	$0.64^{d}\pm0.00$	$0.36^{d}\pm0.00$	$3.17^{a}\pm0.02$	$2.54^{f}\pm0.08$	$0.24^{c}\pm0.01$
B	90:5:5	$1.73^{e}\pm0.01$	$0.67^{d}\pm0.00$	$0.41^{c}\pm0.00$	$2.88^{b}\pm0.03$	$2.86^{e}\pm0.01$	$0.27^{b}\pm0.02$
C	80:15:5	$1.86^{d}\pm0.01$	$0.71^{c}\pm0.00$	$0.43^{b}\pm0.00$	$2.86^{b}\pm0.06$	$3.53^{d}\pm0.11$	$0.29^{b}\pm0.02$
D	70:20:10	$1.94^{c}\pm0.01$	$0.71^{c}\pm0.00$	$0.47^{b}\pm0.00$	$2.77^{c}\pm0.02$	$3.62^{c}\pm0.03$	$0.31^{b}\pm0.01$
E	60:25:15	$2.37^{b}\pm0.02$	$0.77^{b}\pm0.00$	$0.47^{b}\pm0.00$	$0.38^{d}\pm0.00$	$3.77^{b}\pm0.04$	$0.33^{a}\pm0.01$
F	50:30:20	$2.66^{a}\pm0.06$	$0.88^{a}\pm0.00$	$0.53^{a}\pm0.00$	$0.35^{d}\pm0.00$	$4.15^{a}\pm0.04$	$0.36^{a}\pm0.03$

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

Table 3: Pasting Properties of complementary food samples

Sample ID	% Substitution SF:AYBF:CF	Peak Viscosity (RVA)	Trough (RVA)	Breakdown Viscosity (RVA)	Final Viscosity (RVA)	Set back viscosity (RVA)	Peak time (min)	Pasting Temperature (^{0}C)
A	100:0.0	$94.63^{f}\pm0.04$	$34.61^{e}\pm0.01$	$69.72^{a}\pm0.03$	$92.42^{a}\pm0.03$	$64.83^{a}\pm0.04$	$6.12^{a}\pm0.02$	$85.42^{a}\pm0.03$
B	90:5:5	$98.44^{e}\pm0.05$	$35.61^{e}\pm0.01$	$68.46^{b}\pm0.06$	$87.48^{b}\pm0.04$	$63.76^{b}\pm0.04$	$6.06^{b}\pm0.03$	$84.73^{b}\pm0.04$
C	80:15:5	$98.75^{d}\pm0.04$	$39.41^{d}\pm0.01$	$68.32^{c}\pm0.02$	$85.77^{c}\pm0.01$	$62.74^{b}\pm0.06$	$5.78^{c}\pm0.03$	$84.73^{b}\pm0.04$
D	70:20:10	$105.89^{c}\pm0.01$	$45.23^{c}\pm0.04$	$67.48^{d}\pm0.04$	$85.64^{d}\pm0.05$	$60.28^{c}\pm0.04$	$5.45^{d}\pm0.02$	$84.44^{c}\pm0.01$
E	60:25:15	$108.56^{b}\pm0.02$	$48.78^{b}\pm0.04$	$65.32^{e}\pm0.02$	$78.05^{e}\pm0.06$	$59.71^{d}\pm0.01$	$5.28^{e}\pm0.04$	$83.28^{d}\pm0.03$
F	50:30:20	$113.77^{a}\pm0.02$	$57.42^{a}\pm0.02$	$40.62^{f}\pm0.45$	$76.82^{f}\pm0.02$	$49.37^{e}\pm0.01$	$4.93^{f}\pm0.04$	$82.62^{e}\pm0.03$

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

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