Chemical and Protein Quality of Soybean (*Glycine max)* and Tigernut (*Cyperus esculentus)* Based Weaning Food

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Received: March 5, 2012 Accepted: March 20, 2012 Published: May 1, 2012
doi:10.5539/jfr.v1n2p246 URL: http://dx.doi.org/10.5539/jfr.v1n2p246

Abstract

Malnutrition and poverty poses a major challenge to low-income families in developing nations and the twin issues are very critical for a growing infant. Commercially processed weaning foods are expensive for these categories of families; hence the objective was to formulate and evaluate the functional, antinutritional and protein quality of composite weaning food based on soybean and tigernut flour. Soybean and Tigernut seeds were processed into flour and three weaning diets: STF_1 (Tigernut; 75%, Soybean 15%); STF_2 (Tigernut; 65%, soybean 25%) and STF_3 (Tigernut; 55%, Soybean 35%) with 10% full cream milk powder (FCM) addition were produced according to FAO/WHO/UNU recommendations. Commercial weaning food (CB) was used as control. Effect of tigernut flour addition on the functional, antinutritional and protein quality of the formulated blends were evaluated using standard methods. The protein quality was evaluated using rat assay. The functional properties of the samples were significantly ($P<0.15$) different from the commercial sample. STF_3 sample had significantly ($P<0.05$) lower swelling index (SI), Packed bulk density, (PBD), loose bulk density (LBD) and water absorption capacity (WAC) with values of 3.63±0.10, 0.53±0.01 g/cm, 0.32±0.03 g/cm and 187.00 ± 2.10 ml/100g compared to values of 6.14±0.22, 0.55 ± 0.01g/cm, 0.42±0.01g/cm and 374.00 ± 3.40 for commercial sample, respectively. Total oxalic, soluble oxalic acid, phytic acid and tannins values of the diets were significantly ($P<0.05$) higher than CB, and the lowest values were for STF_{S}. Protein quality indices of the samples showed significant ($P<0.05$) difference. The NPU, PER, NPR, TD and BV of STF_3 compared favorably with CB. STF_3 sample supported good growth for the growing rats. The results suggested that STF3 is nutritionally balanced & possessed good growth promoting quality for a growing infant and could be adopted at the house hold-level to curb infant malnutrition and death.

Keywords: Protein quality, Tigernut, Soybean, Weaning food, Functional properties, Antinutritional

1. Introduction

The weaning period is a crucial event in an infant's life due to the inability of the mother's milk to adequately meet nutrient needs (Cameron & Hofvander, 1983; WHO, 2003). Appropriate weaning food is imperative to partially replace the mother's milk during weaning. Nutritional status in children is most critical during the weaning stages when both macro and micronutrients are required in sufficient amount to maintain growth and development. Due to high level of poverty in developing nations like Nigeria, many families cannot afford commercial brands resulting in children being weaned on high starchy gruels, low in proteins and other nutrients. Protein energy malnutrition (PEM), and infant mortality and morbidity are consequently on the increase in these rural households due to inadequacy of nutrients for the infants' nourishment and growth. Consequently, the development of low cost high protein weaning food from underutilized readily available raw materials is a constant challenge for developing nation. Hence, there is growing awareness and concerns about the development of cheap balanced weaning foods from available underutilized crops. Tigernut (*Cyperus esculentus)* is an underutilized crop in the family of cyperaceae, which produce rhizomes from the base and tubers that are somewhat spherical. Tigernut tubers contain about 8% protein and has 20-30% tigernut oil, which is nourishing to the epidermis (Alobo & Ogbogo, 2007). The necessary essential minerals, calcium, magnesium and iron required for bones, tissue repairs, muscles and blood stream, as well as vitamin B, that assist in balancing the central nervous system is contained in tigernut tubers (Oladele & Aina, 2007). Chevallier (1996) also reported that tigernut tubers could be used for the treatment of flatulence, indigestion, diarrhea, dysentery and excessive thirst and contain higher essential amino acids than those proposed in the protein standard by the FAO/WHO

(1985) for satisfying adult needs (Bosch *et al*., 2005). The use of such readily available underexploited crop to complement with legumes such as soybeans in developing a simple household low cost weaning food hold promise for PEM and infant mortality alleviation. The aim of this study was to evaluate the chemical and protein quality of soybean seed and tigernut tubers composite based weaning food.

2. Materials and Method

Mature dried tigernut (Cyperus esculentus), soybean (Glycine max), and full cream milk powder (FCM) were bought from a local market in Calabar, Nigeria. Corn Starch, Sucrose, and casein were bought from a reputable chemical supplier in Calabar. A commercial weaning food brand used as control was purchased from a local superstore.

All the chemical reagent were of anaylical grade purchased from Aldrich (Germany).

2.1 Preparation of soybean and tigernut flour

Soybean seeds were sorted to remove extraneous materials and soaked overnight in portable tap water, drained and then cooked for 30 min with portable tap water twice its volume. The cooked beans were dehulled, washed thoroughly and then dried in an oven (Gallenkamp Plus 11) at 60 $^{\circ}$C to a constant weight. The sample was milled using a hammer mill (Christy & Norris Ltd., Chelmsford, England) to pass through a 60 µm sieve to obtain soybean flour (SF).

The method of Ade-Omowaye *et al*., (2008) was used in the production of tigernut flour. Tigernut tubers were sorted to remove damaged and other extraneous materials, then dried in a cabinet dryer at 60 $^{\circ}$C for 24 h, and milled to pass through 60 µm sieve to obtain tigernut flour (TF). The flours were packed and sealed separately in a high density polyethylene pouches and stored at -4 $^{\circ}$C until analyzed.

2.2 Diet formulation

Three diet formulations: STF_1, STF_2 and STF_3 in duplicates were prepared by mixing varying proportions of the flours with 10 percent full cream powered milk (FCM) as shown in Table 1.

2.3 Analysis

2.3.1 Functional property

The method of Leach *et al*. (1959) was applied to determine Swelling Index (SI). One gram of sample was washed into a beaker and rewashed (W_1). The sample was dispersed in 50 mL of distilled deonized water (ddw) using magnetic stirrer and then heated at temperatures of 40, 50, 60, 70, 80 and 90 ^{o}C for 10 min in a thermostate water bath (Technical and Technical, Texas, USA). The slurry was cooled to room temperature (25 ^{o}C) and then centrifuged at 2200 rpm for 15 min. The residue obtained after centrifugation with the water it retained was rewashed (w_2) and the SI calculated.

Water absorption capacity (WAC) was determined using Solsulki *et al*. (1976) method. Ten milliliter of ddw was added to 2 g sample contained in a 25 ml centrifuge tube and stirred for 30 seconds with a glass rod .The suspension was given a 10min rest interval while the particles adhering to the sides of the tubes were scrubbed down with a glass rod. The sample was stirred seven additional times with each period lasting for 20sec and 10 min rest period between each stirring. The tube was centrifuged (Bench top centrifuge, model: MSE England) at 5100 rpm for 25 min, after which the water was decanted. The percentage of absorbed water was calculated.

The method of Akpapunam & Markakis (1981) was used for the determination of pack bulk density (PBD) and loose bulk density (LBD). Sample was weighed into a 5 mL measuring cylinder (W_1). For PBD, it was gently taped to eliminate air spaces between the flour sample in the cylinder and the volume was noted as the volume of the sample used (W_2). The mass of the sample and the cylinder was recorded. PBD expressed in gram per cm was calculated as the differential in weight. For LBD, space was not eliminated by tapping but the sample contained in the cylinder was left to stand for 10 min before weighing.

2.3.2 Antinutritional factors

Hoff & Singleton (1977) method was used for Tannin determination. Briefly, 0.05 g ground defatted sample was suspended in 5 mL of EtOH in a test tube for 15 min, shaken for 2 min (Gallenkemp Flask Shaker) and centrifuged in a benchtop centrifuge for 5 min at 1500 rpm. Sample extract (1mL) was pipetted into a 100 mL volumetric flask containing 75ddw, then 5 mL of folin-Denis reagent and 10 mL sodium carbonate solution were added. The solution was made up to 100 mL with ddw, shaken properly and allowed to stand for 30 min, after which the absorbance was read in a spectrophotometer (Perking Elmer Lambda 3 B) at 760 nm. Tannin content was read from a standard curve of tannic acid. The combined methods of Makower (1970) and Wheeler & Ferrel

(1971) were used for phytic acid estimation. Briefly, the sample (0.2 g) was extracted four times for 40 min with 3% Trichloracetic acid (TCA) and then centrifuged for 30 min at 5000 rpm. Aliquot (10 mL) of the supernatant was precipitated with 4 mL $FeCl_3$ solution containing 0.2% $FeCl_3$ in 3% TCA. The solution was heated for 45 min in a water bath (Aston VII) at 100 °C and centrifuged at 5000 rpm for 15 min. The $Fe(OH)_3$ obtained was dissolved in 40 mL of hot 3.2 N $HN0_3$ and the Iron determined calorimetrically (Corning Calorimeter, 253). The absorbance of the solution was read in a spectrophotometer (Perking Elmer Lambda 3B) at 480 nm against a reagent blank for each set of sample. The Iron content was calculated from a standard curve. Phytate phosphorus was calculated from determination assuming 4:6 Iron: Phosphorus molecular ratio, while phytic acid contains 28:20% phosphorus.

The method described by Dye (1956) was used for the oxalate determination. Briefly, sample (10 g) was digested in a water bath (Aston VII) for 4 h at 50 °C with 190 mL ddw and 10 mL of 6 N HCl. The digest was centrifuged for 30 min and the filtrate diluted to 250 mL with ddw. Aliquot of 50 mL was taken and evaporated to 25 mL, and the brown precipitate filtered off and washed with hot distilled ammonia until the pink color of methyl red indicator changed to faint yellow. The solution was heated in a water bath to 90 °C, precipitated with 10 mL of 5% $CaCl_2$ solution, allowed to stand overnight and then centrifuged (Bench top centrifuge, MSE, England). The precipitate was washed with hot 25% H_2SO_4 diluted to 125 mL and warmed to 90 °C, then filtered with 0.05 N $KMnO_4$ and the total oxalate calculated. The same procedure was used for soluble oxalate except that 10 g sample was digested in a water bath with 200 mL ddw at 90 °C for 4 h.

2.3.3 Protein quality evaluation

The randomised design was used in the study. Thirty five wistar strain albino rats aged 28-35 days with average initial weight of 33-60 g obtained from the pharmacology Department, University of Calabar, Nigeria were divided into A, B, C, D, E and F. The rats were housed in individual metabolic wire mesh bottomed cages in a room at 25 ± 2 °C with facilities for fecal and spilled food collection. Each group of five replicates was fed a different experimental diet for 28 days and acclimatization for 3 days. Drinking water provided with nipple drinkers and the test diets supplied in troughs were fed to the rats ad libitum. The feed intake was measured individually twice daily and body weight at 3 days intervals. The fecal droppings of the rats were collected daily, dried at 85 °C to a constant weight and then ground into powder for fecal nitrogen determination. Urine samples were collected in sample bottles containing 0.1 N HCl to prevent loss of ammonia and stored in a freezer until analyzed for urinary nitrogen. Data on feed consumption and spilled food were collected by recording the feed measured out for each rat at the beginning and the quantity remaining after feeding. Gain or Loss in weights of the rats was also recorded. At the end of the feeding period, the rats were sacrificed with chloroform and dissected. The carcasses and alimentary tract contents were dried at 85 °C to a constant weight, ground and then stored for carcass nitrogen determination. Faecal and carcass nitrogen of the rats were determined by the Kjedhal method (AOAC, 1990). Protein Efficiency Ratio (PER) was obtained by the method of Bender & Doell (1957), while Net Protein Utilization (NPU), Biological Value (BV), True Digestibility (TD), Net Protein Retention (NPR) were calculated based on the method of Miller & Bender (1955).

2.4 Data analysis

Data generated were analyzed using SPSS Software Program for Analysis of Variance (ANOVA) at 5 percent confidence interval. Mean separation was done by LSD.

3. Results and Discussion

3.1 Functional properties

Table 2 shows the results of the functional properties of the formulated weaning Diets (FWD) and the control. There was a significant difference (P<0.05) in the Swelling Index (SI) values, which ranged from 3.65 ± 0.10 to 6.14 ± 0.22. The control (CB) sample had significantly higher (P<0.05) SI value of 6.14 ± 0.22, while the lowest value was 3.63 ± 0.10 was for STF_3. SI refers to the expansion accompanying spontaneous uptake of solvent. Increase in soybean addition produced a reduction in SI values of the FWD, while SI value decreased as the tigernut flour addition decreased. The effect could probably be due to lose association of amylase and amylopectin in the native granules of tigernut starch and weaker association forces maintaining the granules structures (Adebayo-Oyetoro *et al*., 2011). Among the FWD, STF_1 had the highest SI (4.77 ± 0.30), while the least was STF_3 (3.63 ± 0.10). Swelling causes changes in hydrodynamic properties of the food, thus impacting characteristics such as body, thickening and increase in viscosity to foods. This suggests that among these FWDs, STF_1 with the highest SI will produce a thick viscous gruel compared to STF_3 and STF_1, which may be due to higher carbohydrate content arising from increased level of tigernut flour, than the others with higher soybean substitution level. The SI is an important parameter since it determines the consistency of the diet. Flours with high SI value indicates high water absorption capacity and will therefore hold large volume of water during cooking into gruels, to yield voluminous low energy and nutrient food (Cameroon & Hafvander, 1983). According to WHO (2003), appropriate complementary diet is one which produce a gruel or porridge that is neither too thick for the infant to consume nor so thin that energy and nutrient density are reduced. The FWD with lower SI which compared favorably with CB would therefore deliver more energy and nutrient to the infant. Thus, STF_3 with the lowest value (3.63 ± 0.10) may be more desirable for a complementary diet. Similar trend have been reported by earlier workers (Adebayo-Oyetora *et al*., 2011; Ikpeme -Emmanuel et al., 2009; Sanni *et al*., 1999; Omueti *et al*., 2009).

The water absorption capacity WAC of the samples were significantly different (P<0.05). The CB sample had the highest value of 374.00 ± 3.40 mL/100 g. The WAC values ranged from 187.00 ± 2.10 mL/100 g to 374.00 ± 3.40 mL/100 g. WAC is the ability of a product to associate with water under a condition where water is limiting (Omueti *et al.,* 2009). There was a progressive reduction in WAC values as the level of tigernut flour decreased. The ability of flour to absorb water was reported to have a significant correlation with its starch content (Mbofung *et al*., 2006). Among the FWD, STF_1 had the highest (P<0.05) WAC value of (220.00±2.00 mL/100 g), which may be due to exposure of more damaged starch, which are sites for water binding (Milan-Camilo *et al*., 2000). This could also be that STF_1 contained higher fiber and starch content, (which have been found to cause water binding) because of higher amount of tigernut flour (Ade-Omowage *et al.,* 2008) The significantly higher (P<0.05) WAC values of STF_1 and STF_2 compared to STF_3 may be due to higher tigernut flour content (75%) and 65%), respectively, which resulted in the presence of many exposed hydroxyl groups on the molecules, which were available for water binding (Nelson & Cox, 2000). Our result is in agreement with the reports of earlier workers (Adebayo Oyetora *et al*., 2011; Sanni *et al*., 1999; Ikpeme-Emmanuel *et al*., 2009; Omueti *et al*., 2009). Among the FWDs, STF_3 had the lowest WAC value (187.00 ± 2.10 mL/100 g) which is significant because lower WAC is desirable for making thinner gruels with high caloric density per unit volume. However, the highest value of WAC for CB (374.00 ± 3.40) could be attributable to higher protein content, as proteins are hydrophilic in nature and so absorb and bind more water (Otegbayo *et al*., 2000). The decreasing levels of both WAC and SI with decrease in tigernut flour and increase in soybean flour are a reflection of the level of damaged starch and hemicelluloses contained in these samples (Pomeranz & Moore, 1975). The Bulk Density (BD) is a reflection of the load the sample can carry if allowed to rest directly on one another. The lower the bulk density value, the higher the amount of flour particles that can stay together thereby increases the energy content derivable from such diets (Onimawo & Egbekun, 1998). The Pack Bulk Density (PBD) of the samples were significant (P<0.05) and the values ranged from 0.53 ± 0.01g/cm to 0.59 ± 0.01g/cm. STF_1 had the highest value of 0.59 ± 0.04 g/cm, while the STF_3 had the lowest value of 0.53 ± 0.02 g/cm. Among the FWDs, there was a decrease in the PBD with increase in soybean flour. Similar trend was also reported by Edima *et al*., (2005). The PBD value for STF_1 and STF_2 were significantly higher (P < 0.05) than CB, while the PBD value for STF_3 was lower than the other FWDs as well as CB, thereby making the blend suitable for the formulation of high nutrient dense weaning food (Desikachar, 1979). This is because high bulk limits the caloric and nutrient intake per feed per child and infants are sometimes unable to consume enough to satisfy their energy and nutrient requirements (Omueti *et al*., 2009). Apart from dietary bulk of the gruel or porridge made from the complementary diets, the bulk density is also important in the packaging requirement and material handling of the complimentary diet (Karuna *et al*., 1996). Earlier workers have reported bulk density values of 0.48-0.66 g/mL for raw and malted wheat flour (Magnesia & Wafflemix, 2007) and 0.57 to 0.64 g/mL for tigernut and wheat flour, which are comparable to the values obtained in this study. The Loose Bulk Density (LBD) represents the lowest attainable energy without compression. The LBD values ranged from 0.32 ± 0.03 g/cm to 0.42 ± 0.01 g/cm. The CB had the highest LBD value (0.42 ± 0.01 g/cm), while STF_3 had the least. The LBD is related to the bulk density, the higher the LBD, the higher the bulk density. This is because the LBD indicates the free space between the food when packed. According to Omueti *et al*., (2009), a large free space is undesirable in packaging of foods because it constitute a large oxygen reservoir. The difference between the loose and the bulk densities of FWDs was slight, indicating that the volume of the FWD in a package will not decrease excessively during storage or distribution.

3.2 Antinutritional factors

Table 3 shows the results of the antinutritional factors. The result showed that total and soluble oxalates values obtained for the FWD were significantly higher (P<0.05) than the CB. The total and soluble oxalate levels ranged from 18.75 ± 0.02 mg/100 g to 45.34 ± 0.20 mg/100 g and from 9.57 ± 0.20 mg/100 g to 22.27 ± 0.10 mg/100 g, respectively. The STF_3 had the lowest value for both total and soluble oxalates. There was a progressive reduction in the level of total and soluble oxalate of the FWD with increase in soybean flour substitution and reduction in tigernut flour substitution level. The values were lower than a total oxalate of 366.6 mg/100 g and a soluble oxalate of 250 mg/100 g for a multimix diet and a total oxalate of 128.3 mg /100 g and soluble oxalate of 110 mg/100 g for the commercial brand reported by Okoro (1986). Oxalates in large amounts bind with calcium forming calcium oxalate, which is insoluble and not absorbed by the body. They are therefore considered poisonous at high concentration, but harmless when present in small amounts (Fox & Cameron, 1986). High oxalate level in food has been implicated as the cause of kidney stones because high level of oxalates correlates with increase in calcium absorption in the kidney (Chai & Liebman, 2004).

Tannin has the ability to form insoluble complexes with proteins thereby reducing digestibility of food proteins. The tannin values ranged from 0.06 ± 0.07 mg/100 g to 0.14 ± 0.11 mg/100 g. There was no significant difference ($P<0.05$) between STF_1 and STF_2 and between STF_3 and CB, though all the values were low. This suggests that the processing technique used in this study (soaking, dehulling, and drying) were effective in reducing the tannin contents of the samples. Our values were higher than the tannin values (0.40 to 0.70 mg/100 g) reported by Akaninwor & Okechukwu (2004) for sweet potato and soybean weaning food. Toxicity of tannins absorbed from the gut and interference with the absorption of Iron and a possible carcinogenic effect has been reported (Buttler, 1989). Tannins also inhibit the activities of trypsin, chymotrypsin, amylase and lipase (Griffiths & Mosley, 1980; Delumen & Salamat, 1980). Reduction of tannins during production improve nutritional value of food by increasing protein digestibility (Bassey, 2004) and hence the formulated diet with low tannins levels would have good digestibility.

The phytic acid level was significantly higher ($P<0.05$) in the formulated diets compared to the commercial brands. The levels ranged from 0.99 ± 0.30 mg/100 g to 1.96 ± 0.03 mg/100 g. STF_1 had the highest phytic acid level of 1.96 ± 0.03 mg/100 g, while the least value of 1.79 ± 0.04 mg/100 g was for STF_3 among the FWDs. Phytic acids are insoluble and cannot be absorbed in the human intestine. However the level of phytic acid found in the FWD was very low and would not be injurious to health. The values for all the antinutritional factors in the FWD were low and as such would not cause any harm to an infant.

3.3 Protein quality

Table 4 shows result of the protein quality of the samples. The rats fed with CB gained significantly ($P<0.05$) more weight than others fed on the FWD. Among the FWDs, STF_3 had significantly ($P<0.05$) higher weight gain (31.93 ± 6.45 g) compared to values of 20.57 ± 8.47 g and 25.93 ± 3.97 g, respectively for STF_1 and STF_2. Rats fed on the basal diet lost weight and their body weights was significantly lower ($P<0.05$) than rats fed on other diets. Ayalogu *et al*., (2003) reported similar findings. There was a progressive weight increase from STF_1 fed rats to STF_3 fed rats, which corresponded to increase in protein ingested from STF_3. This implies that STF_3 diet promoted growth better than other FWD. The observed high weight gain of rats fed on CB may be attributable to the addition of sucrose and vanillin to the product by the manufactures, which resulted in better palatability. Rats fed on casein diet had the lowest fecal nitrogen of 0.15 ± 0.01g ($P<0.05$). The FWDs had significantly lower fecal nitrogen than the CB diet. Fecal nitrogen affects digestibility consequently, rats fed on STF_3 had higher nitrogen intake, since it had lower fecal nitrogen value of 0.27 ± 0.02 g. The highest carcass nitrogen content was observed for rats fed on CB ($P<0.05$), followed by rats on STF_3, while the least value was for STF_1 ($P < 0.05$). This might be due to the relative proportion of protein in these diets. The FWD had lower urinary nitrogen ($P<0.05$) compared to the CB diet, which could be due to nutrient-nutrient interaction between soybean and tigernut, resulting in better digestibility with lower urinary nitrogen. NPU is the percentage of nitrogen intake retained as body nitrogen. The values ranged from 50.00 ± 0.10% to 77.25 ± 0.06%. The casein diet had the highest NPU ($P<0.05$), followed by CB diet. Among the FWDs, STF_3 had the highest value ($P<0.05$) of 60.44 ± 0.03%. The NPU values for STF_3 and CB were comparable. PER (Protein Efficiency Ratio) is the weight gained per gram protein consumed. The PER values ranged from 1.36 ± 0.02 to 2.83 ± 0.10. PER of CB diet was higher ($P<0.05$) compared to other samples. This could be that the higher percentage of milk protein was incorporated into the formulation of the CB diet by the manufactures. The FWD had significantly lower ($P<0.05$) PER values, though the STF_3 value (2.26 ± 0.04) was above the 2.1 minimum PER value recommended for such flours by Protein Advisory Group. NPR (Net Protein Ratio) provides information on the ability of proteins to support both maintenance and growth. The values ranged from 1.83 ± 0.03 to 3.47 ± 0.30. NPR value of rats fed on CB diet was significantly higher ($P<0.05$) than for rats fed on other diets. This was followed by NPR value for casein diet which compared favorably with NPR value of rats fed on STF_3 diet. The true disgestibility (TD) values gives information on the percentage of nitrogen intake absorbed by the body. The values ranged from 86.10 ± 0.50% to 98.80 ± 0.02%. TD values of rats fed on casein diet was significantly higher ($P<0.05$), followed by the TD value for the CB diet. The TD values of the FWDs were comparable; however, STF_3 diet had the highest ($P<0.05$) value. The gradual decrease in TD values of the rats fed on the FWDs could be due to higher amounts of antinutrients from STF_3 to STF_1, which are known to reduce protein digestibility and consequently bioavailability. However, TD values of the FWDs were higher than the (85%) values recommended for children (PAG, 1971). Biological value (BV) gives information on how much of the absorbed nitrogen is actually retained or utilized by the body. BV values ranged from 67.29 ± 0.06% to 92.77 ± 0.01% ($P<0.05$). The BV of rats fed on casein diet was higher ($P<0.05$) than for rats fed on other diets. The BV value of rats fed on STF_3 diet was higher ($P<0.05$) than the other FWDs, while BV of CB was highest (90.06 ± 0.03%). This indicates that rats fed on CB had higher nitrogen retention than those on other diets (as was also reflected by high NPR value). This also suggested that the essential amino acids in the product were present in sufficient quantity to meet the needs for growth (Young & Bier, 1987). According to Codex Alimentarius standards, the nutritional composition of the foods indicates their suitability for young children. Our results are in agreements with reports of earlier workers (Ijarotimi & Ayantokun, 2006; Ijarotimi & Olopade, 2009; Gahlawat, 1992; Onweluzo & Nwabugwu, 2009; Essien *et al*., 2010).

4. Conclusion

The study revealed that STF_3 containing 55% tigernut, soybean 35% and milk 10% had good growth promoting quality and therefore would be suitable as a weaning diet because it supported growth in rat models. This would consequently add value to the under-utilized nutrient dense tigernut tubers and so would encourage biodiversification of food crops.

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Table 1. Percentage composition for formulation of tigernut and soybean weaning food

COMPOSITE	PERCENT DRY WEIGHT BASIS (% dwb)		
	TF	SF	FCM
STF_1	75	15	10
STF_2	65	25	10
STF_3	55	35	10

SF = Soybean Flour; Tigernut Flour = TF.

Table 2. Functional properties of soybean and tigernut based weaning food

PROPERTY	DIETS			
	STF_1	STF_2	STF_3	CB
Swelling Index (SI)	4.77 ± 0.30^c	4.03 ± 0.04^b	3.65 ± 0.10^d	6.14 ± 0.22^a
Packed Bulk Density (PBD) (g/cm)	0.59 ± 0.04^d	0.58 ± 0.01^a	0.53 ± 0.02^c	0.55 ± 0.01^b
Loose Bulk Density (LBD) (g/cm)	0.37 ± 0.02^b	0.34 ± 0.02^c	0.32 ± 0.03^d	0.42 ± 0.01^a
Water absorption Capacity (WAC) (ml/100g)	220.00 ± 2.00^b	200.00 ± 1.89^c	187.00 ± 2.10^d	374.00 ± 3.40^a

*Means of three determination. Values not followed by the same letter in the same row are significantly different ($P<0.05$). STF_1 (Tigernut 75%; Soybean 15%), STF_2: (Tigernut 65%, soybean: 25%), STF_3: (Tigernut 55%, Soybean 35%); CB: Commercial Brand (control).

Table 3. Antinutritional contents of soybean and tigernut based weaning food (mg/100 g)

Diets	Oxalic acid		Phytic acid	Tannins
	Total Oxalic acid	Soluble oxalic acid		
STF_1	45.34 ± 0.20[a]	22.13 ± 0.03[a]	1.96 ± 0.03[a]	0.14 ±0.11[a]
STF_2	43.25 ± 0.30[b]	15.25 ± 0.10[b]	1.88 ±0.02[b]	0.11 ± 0.10[b]
STF_3	37.25 ± 0.01[c]	11.73 ± 0.03[c]	1.79 ±0.04[c]	0.08 ±0.01[a]
CB	28.75 ± 0.02[d]	9.75 ± 0.20[d]	0.99 ±0.30[d]	0.06 ±0.02[a]

*Means of three determination; Values not followed by the same letter in the same row are significantly different ($P<0.05$). STF_1 (Tigernut 75%, Soybean 15%), STF_2: (Tigernut 65%, soybean 25%); STF_3: (Tigernut 55%, Soybean 35%); CB: Commercial Brand (control).

Table 4. Protein quality of soybean and tigernut based weaning foods

Parameter	DIETS					
	STF_1	STF_2	STF_3	CB	CD	BD
Weight gain (g)	20.57±8.47[d]	25.93±3.97[c]	31.93±6.45[b]	43.87±7.51a	30.87±7.51[b]	9.85±0.05[e]
Carcass Nitrogen (g)	1.42 ± 0.26[e]	1.53 ± 0.05[d]	1.89 ± 0.21[b]	2.30 ± 0.04[a]	1.76 ± 0.21[c]	0.21± 0.02[f]
Carcass Protein (g)	8.85 ± 0.26[e]	9.69 ± 0.31[d]	11.81±1.30[b]	14.40± 0.28[a]	11.00± 0.08[c]	1.33± 0.14[f]
Fecal Nitrogen (g)	0.47 ± 0.31[d]	0.38 ± 0.02[c]	0.27 ± 0.02[b]	0.53 ± 0.03[a]	0.15 ± 0.01[e]	0.01 ± 0[f]
Urinary Nitrogen (g)	0.08 ± 0.02[e]	0.18 ± 0.02[c]	0.23 ± 0.02[b]	0.40 ± 0.03[a]	0.04 ±0.10[f]	0.11±0.01[d]
Protien Intake (g)	14.07±0.23[d]	14.09±0.11[c]	22.87±0.01[a]	22.19 ± 09[b]	17.03±.47[d]	0.93±0.19*
Nitrogen Intake (g)	2.25 ± 0.03[d]	3.05 ± 0.02[c]	3.66 ± 0.02[a]	3.55 ± 0.02[b]	2.20 ± 0.07[d]	0.15± 0.03[e]
NPU (%)	50.00±0.10[d]	48.85±0.03[e]	60.44±0.03[c]	63.09± 0.10[b]	77.27± 0.06[a]	-
PER	1.40± 0.01[C]	1.36 ± 0.02[d]	2.26 ± 0.04[c]	2.83 ± 0.10[a]	2.46 ± 0.03[b]	-
NPR	1.83 ± 0.03[d]	1.87 ± 0.01[d]	2.16 ± 0.03[c]	2.85 ± 0.01[b]	3.47 ± 0.30[a]	-
TD (%)	86.10±0.50[d]	87.67±0.02[c]	88.14±0.30[c]	90.36± 0.01[b]	98.80± 0.02[a]	-
BV (%)	67.29±.006[d]	65.72±0.04[e]	80.54±0.05[c]	90.06± 0.03[b]	92.77± 0.01[a]	-

*Means of three determinations, values not followed by the same letter in the same row are significantly different ($P<0.05$) $STF_{1.}$ (tigernut 75; soybean 15%); STF_2 (tigernut flour 65%; soybean 25%), STF_3 (tigernut 55%; soybean 35%), CB: Commercial brand; BD: Basal diet (non-protein diet), CD: Casein diet.