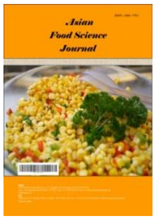

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Proximate Composition, Mineral and Sensory Properties of Orange-Flesh Sweet Potato Starch, Soybean and Groundnut Flour Complementary Food

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study was aimed at formulating and evaluating the proximate, mineral and sensory properties of complementary food from blends of orange flesh sweet potato (*Ipomea batata*) starch, soybean (*Glycine max*) and groundnut (*Arachis hypogea*) flour.
Methodology: Orange flesh sweet potato starch (OFSP), soybean flour (SB) and groundnut flour (GN) were blended in the ratio of (OFSP:SB:GN): 90:5:5, 85:10:5, 80:15:5, 75:20:5, 70:25:5, 65:30:5, 60:35:5, 55:40:5, 50:45:5 and designated as PSG1 – PSG9, while 100% OFSP served as control. Evaluations were carried out following standard analytical methods.
Results: Moisture, fat, ash, crude fibre and carbohydrate contents varied significantly (P<0.05) from 7.53 – 10.74, 1.33 -17.22, 1.20 – 1.94, 4.34 – 19.58 and 53.10 – 70.53% respectively. Protein content (7.62 – 21.91%) of the blends will meet >75% of safe level of protein intake for infants and children. Energy ranged from 339.45 – 373.07 Kcal/100g and will meet >55% of energy requirement for infants at 6 months. Ca, Cu, Fe, Mg and Zn varied respectively, from 0.68 - 6.07, 0.28 - 0.62, 4.40 - 11.94, 1.87 - 2.04, and 1.26 – 2.10 mg/100g. PSG complementary food in comparison to the recommended intake of minerals was found to be excellent in Cu, adequate in Fe and Zn but low in Mg and inadequate in Ca. Degrees of likeness for the sensory attributes:

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aroma, appearance, colour, taste, texture and overall acceptability varied from 5.00 - 7.00, 3.80 - 7.56, 5.04 - 7.20, 3.84 - 7.33, 3.88 - 7.56 and 4.29 - 6.96 respectively. These degrees of likeness from 3.84 - 7.56 indicated dislike moderately to like moderately. PSG7and PSG8 had significantly (P<0.05) the highest degrees of likeness for all attributes except for texture in PSG7 with neither liked nor disliked.

Conclusion: This work showed that enriching orange flesh sweet potato starch by substituting with soya bean and groundnut, increased nutritional composition of the complementary food and addition of soybean flour up to 35 and 40% was acceptable to the assessors. This implies that this complementary food can be recommended as diet for newly weaned and older children.

Keywords: Complementary food; orange flesh sweet potato; soybean; groundnut; proximate; mineral and sensory properties.

1. INTRODUCTION

Majority of the under-five infant and children mortality every year in developing countries are thought to be related to malnutrition [1]. Malnutrition is linked to protein-energy and micronutrient deficiencies. Protein-energy malnutrition is caused by a diet that is low in protein and energy [2], while micronutrient deficiencies comprise deficiency of minerals and it affects more than 50% of the population with children and women being most affected in developing countries [3]. Malnutrition can trigger risk factors for ill-health and severe malnutrition can cause premature death, permanent disability and fragility in face of many deadly diseases [4]. Acceptable ways to check malnutrition in infants is exclusive breastfeeding for the first 6 months of followed by adequate complementary feeding.

Complementary foods are foods other than breast milk or infant formulas required during the second part of the first year of life for both nutritional and developmental reasons and also to enable transition from milk feeding to family foods [5]. After 6 months of age, breast milk is not usually enough to meet the macro- and micronutrient requirements of infants [5,6]. Infants also develop the ability to chew; hence, develop interest for foods other than milk, therefore, there is the need to introduce healthy complementary foods. In Nigeria, complementary foods are cereal-based, mostly formulated with maize, sorghum, millet as the major ingredient and sometimes complemented with soybean, cowpea and/or groundnut. The cereal-based complementary foods are prepared in form of porridges or gruels that are very bulky and usually diluted with water to obtain the consistency for ease of swallowing by the infants and children. This dilution with excess water lowers the nutritional quality per serving of the food often given in lesser amounts. For adequate nutrition, complementary foods should be appropriate in nutritional quality and energy to prevent mortality and enhance children development [7]. There is the need therefore for enrichment with available and affordable raw materials such as, soybean, cowpea, orange flesh sweet potato, groundnut etc.

Sweet Potato is a potential energy contributor and considered as fifth essential crop (fresh weight basis) after rice, wheat, maize, and sorghum [8]. Sweet potato is high in energy content and other micronutrients such as vitamin A and C, potassium, iron and zinc, however, it is low in protein and fat; hence, the need to complement it with legumes and/or cereals when being used in complementary foods. Orange flesh sweet potato (OFSP) is a bio-fortified sweet potato that is rich in nutrients [9]. It is a good source of non-digestible dietary fiber, minerals (Ca, Fe, P, K, Na, Mg and Zn) different vitamins (vitamins A, B and C) and antioxidants [10,11,12]. It possesses a unique sweet taste and attractive yellow to orange colour which is preferable to children in comparison with white-fleshed sweet potato [13].

Soybean (*Glycine max*) is an annual leguminous crop grown to provide food for humans, feeds for animals and raw materials for industries [14]. It is an excellent source of protein (35-40%) and has become popular in the West African sub-region for that reason [15]. In addition to its rich protein content, soybean contain unsaturated, cholesterol free fatty acids, minerals and vitamins A, B, C and D which meet the nutritional needs of humans and other animals [16], and contain numerous antioxidants that are beneficial to human health [17].

Groundnut (*Arachis hypogaea*) which is also known as peanut is a legume considered as an oilseed crop grown primarily for oil production.

Groundnut is rich in vitamins (niacin, folates), minerals (phosphorus, potassium, magnesium, copper) and several bioactive compounds like *procyanidins* and *catechins*, phytoster and flavonoids, that offer several health benefits [18]. It can serve as a cheap source of protein in developing countries where protein-energy malnutrition is prevalent and protein of animal sources are not within the means of the majority of the populace [19,20]. Groundnut has been processed into flour and incorporated into many foods for its high protein content, bland flavour and light tan colour [21,22]

In developing countries, complementary foods are mainly starch based as they are basically made from cereals like maize, rice, wheat, sorghum, millet, and tubers like cocoyam, potatoes, cassava etc. The incorporation of seed proteins, especially from leguminous sources such as soybean and groundnut, are potential sources of protein for nutritionally upgrading the starch-based complementary foods. This work was therefore aimed at the formulation of complementary food from blends of orange flesh sweet potatoes, soybean and groundnut flour and to evaluate the proximate, mineral and sensory properties of the blends.

2. MATERIALS AND METHODS

2.1 Materials

Orange flesh sweet potato (OFSP) tubers (*Ipomea batata*), Soybeans (*Glycine max*) and raw groundnut (*Arachis hypogea*) used in this study were purchased from the fruit garden market, D'line, Port Harcourt.

2.1.1 Production of orange flesh sweet potato starch, soybean and groundnut flour

The OFSP starch was extracted according to the method described by Nath-*et al.,* [23]. The OFSP tubers were washed, pealed, grated, sieved to remove fibre, allowed to sediment for 12 h, dewatered, the wet mash was dried in a hot air oven (model QUB 305010G, Gallenkamp, UK) at 50^{0}C for 1 h and then milled to obtain dry starch. Production of soybean and groundnut flour was according to the method by Dewey and Brown [24]. The soya tester was dehulled after washing and soaking in water for 6-18 h. The dehulled soybean was boiled for 20 min, oven dried at 50^{o}C for 24 h, and roasted in a pan over an open gas flame for 10 min. Thereafter it was milled and sieved to obtain soybean flour. Washed groundnuts were sundried for 6 h, toasted in an oven at 70^{o}C for 10 mins, peeled and then milled to flour. The OFSP starch, soybean and groundnut flour were stored separated in airtight polyethylene bags till required for blending and analysis.

2.1.2 Formulation of the orange flesh sweet potato starch, soybean and groundnut flour complementary food blends

The composition of the OFSP starch, soybean and groundnut flour (OFSP/SB/GN) complementary food blends are shown in Table 1. OFSP starch served as the main carbohydrate source, with varying quantities of soybean (SB) flour and constant quantity of groundnut (GN) flour. The OFSP starch, flour of soybean and groundnut were homogenized in a rotatory mixer (Philips, HR1500/A, Holland), package in air tight plastic containers and stored in the refrigerator until required for analysis.

2.1.3 Proximate analysis of OFSP starch, soybean and groundnut flour complementary food blends

Proximate analysis was carried out using standard AOAC, [25] methods. Carbohydrate content was determined by difference: 100% - (% MC +% Ash +% Crude protein +% Fat +% Crude fibre). Energy (Kcal/g) was calculated using the Atwater factor of 4.0 Kcal/g for protein and carbohydrate and 9 Kcal/g for fat.

2.1.4 Determination of Mineral Content of OFSP starch, soybean and groundnut flour complementary food blends

The sample was subjected to in-vitro pepsin and pancreatin digestion as described by Ikeda [26]. Briefly, to 0.5 g of the sample was added 20 ml of pepsin enzyme solution (1.6%) in phosphate buffer (pH 7.5). The sample suspension was incubated at 37^{o}C for 3 h using a shaker bath. The pH was adjusted using phosphate buffer (pH_8). Few drops of Toluene were added to prevent growth of microorganisms. The mixture was incubated for 20 h at 37^{o}C. Thereafter, the suspension was placed in ice-cold vessel to halt enzymatic action and clarified by centrifugation at 500 rpm for 40 min. The calcium (Ca), Copper (Cu), Magnesium (Mg), Iron (Fe) and Zinc (Zn) content of the supernatant was determined using the Atomic Absorption spectrophotometer (Buck Scientific AAS-210VGP-USA).

Table 1. Composition (%) of orange flesh sweet potato (OFSP) starch, soybean and groundnut flour complementary food blend (OFSP/SB/GN)

Samples	OFSP starch	Soybean flour (SB)	Groundnut flour (GN)
Control	100	0	0
PSG1	90	5	5
PSG2	85	10	5
PSG3	80	15	5
PSG4	75	20	5
PSG5	70	25	5
PSG6	65	30	5
PSG7	60	35	5
PSG8	55	40	5
PSG9	50	45	5

PSG = OFSP:SB:GN Complementary food blends

2.1.5 Sensory evaluation of OFSP starch, soybean and groundnut flour complementary food blends

The gruel samples for sensory analysis were prepared by homogenizing 5 g of each sample in 10 ml of water to obtain a slurry. About 55 ml of boiling water was added to the slurry with vigorous stirring for a lump free gruel, that was heated for 10 s to allow for a properly cooked gruel. The evaluation was carried out following the procedure of Watts [27] using 20 untrained adult panelists consisting of mothers amongst staff and students of the Department Food Science and Technology. A 9 – point hedonic scale with rating expressed as follows: 1 - Dislike extremely, 2 - Dislike very much, 3 - Dislike moderately, 4 - Dislike slightly, 5 - Neither like or dislike, 6 - Like slightly, 7 - Like moderately, 8 - Like very much and 9 - Like extremely was used.

2.2 Statistical Analysis

All experiments and analysis were carried out in duplicates. Data obtained were subjected to Analysis of Variance (ANOVA) using Minitab (Release 18.0) Statistical Software English (Minitab Ltd. Coventry, UK). Means were separated using Tukey's pairwise comparison test, at a significance level of P<0.05.

3. RESULTS AND DISCUSSION

3.1 Proximate Composition and Energy Content of OFSP Starch, Soybean and Groundnut Flour Complementary Food Blends

Proximate composition of the OFSP starch, soybean and groundnut flour complementary food blends are shown in Table 2. Moisture content of formulated complementary foods ranged from 7.53 – 10.74%. There was significant (P<0.05) decreased in moisture with increase in the level of substitution of soybean. The control had significantly (P<0.05) the highest moisture content while PSG9 had the least. This finding is in agreement with the report of Oguizu *et al.,* [28] who reported moisture content of 7.0 – 8.19% for complementary foods formulated with blends of OFSP and groundnut. The observed moisture values were lower than 11.00 – 12.00% reported by Owiredu *et al.,* [29] for complementary food formulated with OFSP, soybean and millet. Low moisture content of food, is an indication of good keeping quality as the higher the moisture contents of food the lower the shelf life stability [30]. High moisture content favour the development of contaminating microorganisms, whose growth and activities caused spoilage in food products. The low moisture content observed for all the formulated complementary food samples is a better indicator of their potential to have long shelf life and material like flour and starch based products containing more than 12% moisture has less storage stability than those with lower moisture content [31].

Protein is the major structural component of cells and is responsible for the building and repair of the body tissues, and provide the essential amino acids required for metabolism [32]. Protein content of the formulated complementary food samples varied significantly (P<0.05) from 7.62 - 21.91%. PSG9 with 50% soybean flour had significantly (P<0.05) the highest protein content and PSG1 had the least. Increase in protein content of the formulated complementary food was probably due to increase in the substitution of soybean and groundnut. The protein content was comparable with the report of 10.00 – 16.90%, and 16.00 – 19.82% presented respectively, by Pobee *et al*., [33] and Oguizu *et al*., [34] for OFSP-based complementary foods. However, the result was higher than 2.02 - 6.00% and 2.1 – 6.2%, reported by Gezahegn *et al*., [35] and Adepoju and Adefila [36] for complementary food formulated with cereals, potato and soybean. According to the Joint FAO/WHO/UNU Expert Consultation on Protein and Amino Acid Requirements in Human Nutrition [37] the safe level of protein intake for infant male and female aged 0.5 and weighing 7.8 and 7.2 kg respectively is 1.31 g/kg/day. For the ages of 2 years with body weight of 12.3 kg for male and 11.8 g for female the safe level of protein intake is 0.97 and 0.90 g/kg/day. The protein content of the formulated OFSP starch, soybean and groundnut flour complementary food will meet 75 – 126% of safe level of protein intake for the male and 81 – 137% for female of 6 months old. For the ages of 2 years, the values will meet 64 – 108% and 67 – 113% for male and female respectively. Protein is important, especially during the weaning period to prevent protein energy malnutrition (PEM), which is usually observed among children in developing countries [38]. The values obtained in this study meets over 60% of the safe level of protein intake and can be recommended for infant feeding.

Fat content of the formulated complementary food varied significantly (P<0.05) from 1.33 - 17.22%. Control sample with 100% OFSP had significantly (P<0.05) the least and PSG9 with 50% soybean flour substitution had the highest. The fat content of the formulated complementary food samples increased significantly (P<0.05) with increase in level of substitution with soybean. This was probably due to the high fat content of soybean and groundnut. The fat content of the formulated complementary foods was in line with 8.71% fat reported by Oguizu *et al*., [34], but higher than 1.09 – 1.99% reported by Amagloh and Coad [39] for complementary food produced with maize, groundnut and soybean. Low fat content in a dry product is advantageous in increasing the shelf life of the product by decreasing the chances of rancidity but it will result to low energy value while high fat product will enhance the energy value of the product [40]. Fat is important in the diets of infants and young children as it provides essential fatty acids, facilitates absorption of fat soluble vitamins, enhances dietary energy density and sensory qualities and the prevention of undesirable weight gain in infants [41].

Ash content of the formulated complementary foods ranged from 1.14 - 1.94% for PSG1 and PSG7 respectively. The ash content of the formulated products was in line with reports on some OFSP-based complementary foods [33,42,43] but lower than the report by Oguizu *et al*., [34]; Amagloh *et al*., [44] and Adenuga [45]. Several factors including the variety of the raw materials and experimental conditions could be responsible for such difference. Ash is the inorganic residue and an indication of minerals present in the food.

Table 2 Proximate composition (%) of complementary food from ofsp starch, soya bean and groundnut flour

Samples	Moisture	Ash	Fat	Fiber	Protein	CHO
Control	10.74 ± 0.62^{a}	1.48 ± 0.30^{bc}	1.33 ± 0.00^{i}	4.34 ± 0.00^{i}	11.59 ± 0.00^{f}	70.53 ± 0.91^{a}
PSG1	9.72 ± 1.70^{ab}	1.14 ± 0.07^{c}	6.31 ± 0.03^{h}	4.90 ± 0.00^{h}	7.62 ± 0.00^{j}	70.32 ± 1.66^{a}
PSG2	9.65 ± 1.32^{ab}	1.15 ± 0.08^{c}	6.33 ± 0.00^{h}	7.51 ± 0.01^{g}	12.33 ± 0.00^{e}	63.03 ± 1.27^{bc}
PSG3	9.25 ± 0.40^{abc}	1.24 ± 0.21^{c}	8.17 ± 0.00^{g}	8.68 ± 0.00^{f}	7.84 ± 0.00^{i}	64.83 ± 0.20^{b}
PSG4	9.31 ± 0.18^{abc}	1.41 ± 0.10^{bc}	9.18 ± 0.00^{f}	11.25 ± 0.01^{e}	10.49 ± 0.00^{g}	58.36 ± 0.29^{d}
PSG5	8.85 ± 0.88^{bc}	1.35 ± 0.01^{bc}	9.90 ± 0.00^{e}	12.14 ± 0.01^{d}	8.25 ± 0.00^{h}	59.52 ± 0.94^{cd}
PSG6	7.98 ± 0.80^{bc}	1.34 ± 0.07^{bc}	12.29 ± 0.00^{c}	14.53 ± 0.01^{c}	13.62 ± 0.00^{d}	50.24 ± 0.74^{e}
PSG7	8.15 ± 1.16^{bc}	1.94 ± 0.07^{a}	12.33 ± 0.00^{c}	17.45 ± 0.02^{b}	18.67 ± 0.00^{c}	41.47 ± 1.11^{f}
PSG8	9.48 ± 0.71^{ab}	1.63 ± 0.21^{ab}	13.62 ± 0.00^{b}	19.58 ± 0.01^{a}	20.60 ± 0.00^{b}	35.10 ± 0.52^{g}
PSG9	7.53 ± 0.65^{c}	1.20 ± 0.13^{c}	17.22 ± 0.00^{a}	19.53 ± 0.01^{a}	21.91 ± 0.00^{a}	41.61 ± 0.80^{f}

Values are mean ± standard deviation of triplicate samples; Values bearing different superscripts in the same column differ significantly (P<0.05); Control = 100 (OFSP): 0 (Soybean flour): 0 (Groundnut flour); PSG1 = 90 (OFSP): 5 (Soybean flour): 5 (Groundnut flour); PSG2 = 85 (OFSP): 10 (Soybean flour): 5 (Groundnut flour); PSG3 = 80 (OFSP): 15 (Soybean flour): 5 (Groundnut flour); PSG4 = 75 (OFSP): 20 (Soybean flour): 5 (Groundnut flour); PSG5 = 70 (OFSP): 25 (Soybean flour): 5 (Groundnut flour); PSG6 = 65 (OFSP): 30 (Soybean flour): 5 (Groundnut flour); PSG7 = 60 (OFSP): 35 (Soybean flour): 5 (Groundnut flour); PSG8 = 55 (OFSP): 40 (Soybean flour): 5 (Groundnut flour) ;PSG9 = 50 (OFSP): 45 (Soybean flour): 5 (Groundnut flour)

Crude fibre content (4.34 - 19.58%) of the complementary food samples were significantly (P<0.05) different. There was significant (P<0.05) increase with increase in substitution of soybean such that the control and PSG9 with 50% soybean flour had respectively the least and the highest crude fibre contents. Fiber is one of the non-digestible carbohydrates, that provides fecal bulkiness and less intestinal transit time, lowers cholesterol level, encourages the growth of intestinal microflora and helps to trap cancer-causing agents [46–50]. Fibre also plays a role in the increased utilization of nitrogen and absorption of some other micronutrients [41]. The low fibre content is also desirable as high fibre can lead to high water absorption and displacement of nutrient and energy needed for the growth of children less than two years [51].

Carbohydrate content calculated by difference showed significant (P<0.05) difference between the control and the formulated PSG complementary food. Values ranged from 35.10 - 70.53%. The carbohydrate content of the control sample was significantly (P<0.05) higher and it did not vary from PSG1 while PSG8 had significantly (P<0.05) the least. The carbohydrate content was comparable with the reported by Oguizu *et al*., [34]; Gezahegn *et al*., [35]; Bonsi *et al*. [42] and Haque *et al*. [43] but lower than 88.8 - 90.89% reported by Anigo *et al*. [22] for complementary food produced with guinea corn, soybean and groundnut. Carbohydrate contributes towards the energy content in complementary foods. Its content could be high but must be digestible enough for infants and young children to obtain the energy required or needed [52].

Figure 1 showed the energy content of the OFSP starch, soybean and groundnut flour complementary food. The value ranged from 339.45– 373.07 Kcal/100g. PSG9 had significantly (P<0.05) the highest energy value and the control had the least. This energy value is comparable with values reported by Barber *et al*. [53] for complementary food formulated from different blends of maize, soybean and carrot flour. Infants need energy from food for activity, growth, and normal development. Energy comes from foods containing carbohydrate, protein, or fat. The number of kilocalories (often termed "calories") needed per unit of a person's body weight expresses energy needs [54]. The energy requirement for infant male (body weight of 7.8 kg) and female (body weight of 7.2 kg) aged 6 months and involved in moderate activities is 335 and 340 KJ/Kg/day respectively, and 348 and 334 KJ/Kg/day for ages 2.5 years with body weight of 12.5 and 11.8 kg for male and female respectively) [37]. The energy value of this OFSP starch, soybean and groundnut complementary food will meet about 54.51 – 59.74 and 58.18-63.76% of the requirements for male and female at 6 months of age respectively. For ages of 2.5 years, the energy value will meet about 32.75 – 35.88 and 36.14 – 39.60% of the requirement for male and female respectively. These values are for the consumption of 100 g of the sample which may be consumed more than once along with the breast milk, or other family main meals. This formulation could be said to be a good source of energy as energy deficiency won't be an issue with the consumption of this food alone or along with the breast milk and other meals. The energy requirement for the day can therefore be met.

3.2 Mineral Content of OFSP Starch, Soybean and Groundnut Flour Complementary Food Blends

The mineral content (Ca, Cu, Fe, Mg and Zn) of the OFSP starch, soybean and groundnut flour complementary food blends are shown in Table 3. The blends varied significantly (P<0.05) in their mineral content and there was significant (P<0.05) increase with increase in soybean flour substitution. The control had significantly (P<0.05) the least content of all the elements except for Mg where PSG1 was significantly (P<0.05) the least and it didn't vary significantly (P<0.05) from the control. PSG8 (with 40% soybean flour) had significantly (P<0.05) the highest content of Ca and Zn while Cu and Mg content of PSG6 was significantly (P<0.05) the highest and PSG5 was the highest in Fe content.

The OFSP starch, soybean and groundnut flour complementary food blends had calcium content of 0.68 - 6.07 mg/100g. PSG1 had significantly (P<0.05) least Ca content that did not differ significantly (P<0.05) from the control, while PSG8 had the highest. These values were lower than the report for OFSP rice complementary food [33]. Calcium plays a major role in muscle function, formation and strengthening of bones, teeth, conducting nerve impulses, blood clotting, and maintaining a normal heartbeat [55]. The RNIs for infants between 7 – 12 months and 1 - 3 years is 400 and 500 mg/day respectively. The formulated OFSP, soybean, groundnut complementary food will meet 0.3 – 9.6% of this minimum CODEX requirement, and 0.2 - 6.3 and 0.1 – 5.0% of RNIs respectively for infants between 7 – 12 months and 1 - 3 years. This implies that formulated OFSP starch, soybean and groundnut flour complementary food are not adequate for Ca supplies for infants.

Copper (Cu) content of the OFSP starch, soybean and groundnut flour complementary food blends ranged from 0.28 – 0.62 mg/100g. PSG6 was significantly (P<0.05) the highest in Cu content while the control was the least. Copper like Fe and Zn is involved in regulation of gene expression. It is a cofactor of many enzymes and an important component of one of the mitochondrial respiratory enzymes. The deficiency of Cu is anemia, poor wound healing, increased plasma cholesterol, neutropenia, twisted and kinky hair [56]. The DRI of Cu for infants 6 -12 months and 1 – 3 years old as stated by CODEX is 0.22 and 0.34 mg/day. The formulated OFSP starch, soybean and groundnut flour complementary food blends is an excellent source of copper as the Cu content will meet 127 – 282 and 82 – 182% of the DRI respectively for the stated age groups.

Iron (Fe) content of the OFSP/Soybean/ groundnut complementary foods varied 4.40 – 11.94 mg /100g. The control sample had significantly the least Fe content while PSG5 had the highest. This Fe content is greater than the value of 0.51 – 1.49 mg/100g reported for OFSP-rice complementary food [33]. The increase in Fe content could be attributed to the addition of soybean and groundnut. Iron serves as an integrated part of important enzyme systems in various tissues, carrier of oxygen by red blood cell haemoglobin and a transport medium for electrons within cells, hence it is very vital in the mental and physical well-being of infants and children [57]. Iron has also been reported as an important nutrient for the improvement of the cognitive function of children [58]. The required Fe intake at a bioavailability of 15% for infants and children between 6 – 12 months and 1 - 3 years respectively is 6.2 and 3.9 mg/day, while at a bioavailability of 5% the requirement is 18.6 and 11.6 mg/day. The consumption of 100 g of the formulated OFSP/soybean/groundnut complementary food will meet 71 – 192 and 113 -306% of the intake at 15% bioavailability for 6 – 12 months and 1 - 3 years respectively, while at 5% bioavailability about 24 – 64 and 38 - 108% will be met. This formulated OFSP/soybean/groundnut complementary food is adequate for the Fe requirement for infants as infants have no iron stores and relies on dietary supplies.

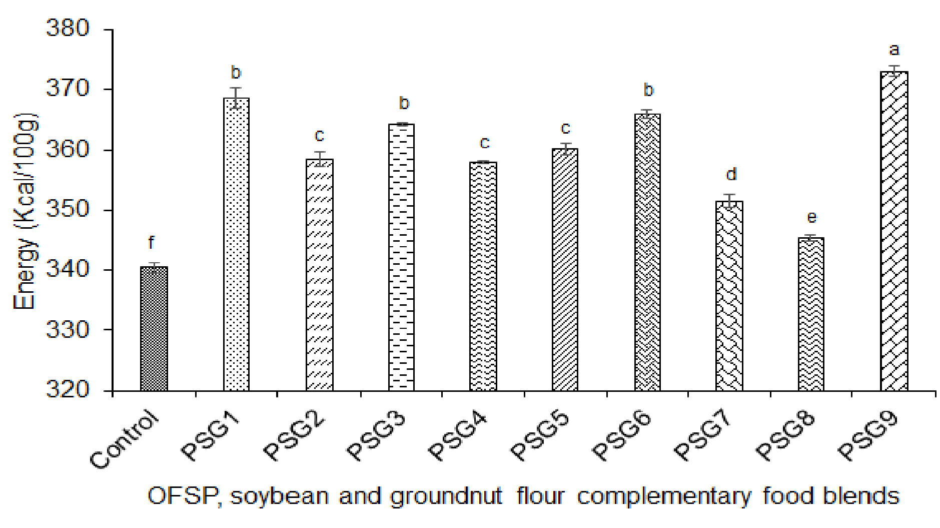

Fig. 1. Energy content (kcal/100g) of Complementary food from OFSP starch, soya bean and groundnut flour blends

Bars and error bars represent the mean and standard deviation of triplicate samples; Bars bearing different letters differ significantly (P<0.05); Control = 100 (OFSP): 0 (Soybean flour): 0 (Groundnut flour); PSG1 = 90 (OFSP): 5 (Soybean flour): 5 (Groundnut flour); PSG2 = 85 (OFSP): 10 (Soybean flour): 5 (Groundnut flour); PSG3 = 80 (OFSP): 15 (Soybean flour): 5 (Groundnut flour); PSG4 = 75 (OFSP): 20 (Soybean flour): 5 (Groundnut flour); PSG5 = 70 (OFSP): 25 (Soybean flour): 5 (Groundnut flour); PSG6 = 65 (OFSP): 30 (Soybean flour): 5 (Groundnut flour); PSG7 = 60 (OFSP): 35 (Soybean flour): 5 (Groundnut flour); PSG8 = 55 (OFSP): 40 (Soybean flour): 5 (Groundnut flour) ;PSG9 = 50 (OFSP): 45 (Soybean flour): 5 (Groundnut flour)

Table 3. Mineral Content (mg/100g) of OFSP starch, soybean and groundnut flour complementary food blends

Samples	Zn	Cu	Fe	Mg	Ca
Control	1.26 ± 0.07^{h}	0.28 ± 0.07^{f}	4.40 ± 0.07^{i}	1.87 ± 0.21^{e}	0.74 ± 0.14^{h}
PSG1	1.31 ± 0.07^{g}	0.44 ± 0.07^{d}	7.45 ± 0.00^{e}	1.97 ± 0.00^{c}	0.68 ± 0.07^{i}
PSG2	1.37 ± 0.07^{f}	0.58 ± 0.00^{b}	8.47 ± 0.14^{c}	2.01 ± 0.07^{abc}	2.95 ± 0.07^{f}
PSG3	1.44 ± 0.07^{de}	0.60 ± 0.00^{ab}	8.46 ± 0.00^{c}	2.00 ± 0.07^{bc}	3.13 ± 0.14^{e}
PSG4	2.01 ± 0.07^{bc}	0.53 ± 0.07^{c}	9.09 ± 0.00^{b}	2.02 ± 0.07^{ab}	3.21 ± 0.00^{d}
PSG5	1.47 ± 0.07^{d}	0.43 ± 0.00^{de}	11.94 ± 0.00^{a}	2.00 ± 0.00^{bc}	3.25 ± 0.14^{d}
PSG6	$1.99 \pm 0.14_{c}$	0.62 ± 0.14^{a}	6.81 ± 0.07^{h}	2.04 ± 0.14^{a}	4.84 ± 0.14^{c}
PSG7	2.03 ± 0.07^{a}	0.54 ± 0.14^{c}	7.10 ± 0.00^{f}	2.02 ± 0.00^{ab}	5.48 ± 0.00^{b}
PSG8	2.10 ± 0.00^{a}	0.53 ± 0.14^{c}	6.92 ± 0.14^{g}	2.03 ± 0.00^{ab}	6.07 ± 0.14^{a}
PSG9	1.42 ± 0.00^{e}	0.40 ± 0.07^{e}	7.85 ± 0.14^{d}	1.92 ± 0.00^{ab}	1.23 ± 0.00^{g}

Values are means ± standard deviation of duplicate samples; Mean values bearing different superscripts in the same column differ significantly (P<0.05); Control = 100 (OFSP): 0 (Soybean flour): 0 (Groundnut flour); PSG1 = 90 (OFSP): 5 (Soybean flour): 5 (Groundnut flour); PSG2 = 85 (OFSP): 10 (Soybean flour): 5 (Groundnut flour); PSG3 = 80 (OFSP): 15 (Soybean flour): 5 (Groundnut flour); PSG4 = 75 (OFSP): 20 (Soybean flour): 5 (Groundnut flour); PSG5 = 70 (OFSP): 25 (Soybean flour): 5 (Groundnut flour); PSG6 = 65 (OFSP): 30 (Soybean flour): 5 (Groundnut flour) ; PSG7 = 60 (OFSP): 35 (Soybean flour): 5 (Groundnut flour); PSG8 = 55 (OFSP): 40 (Soybean flour): 5 (Groundnut flour); PSG9 = 50 (OFSP): 45 (Soybean flour): 5 (Groundnut flour)

Magnesium content of the OFSP starch, soybean and groundnut flour complementary food blends varied from 1.87 - 2.04 mg/100g for the control and PSG6 respectively. Magnesium is an important cofactor of many enzymes involved in energy and calcium metabolism, protein synthesis, nucleic acid (RNA and DNA) synthesis and stability, maintenance of the electrical potential of nervous tissues and cell membranes, and the regulation of potassium fluxes [57]. Deficiency of Mg is characterized by muscle spasms, twitching, tremor, personality changes, anorexia, nausea, vomiting and in acute cases convulsion and lapse into coma [56]. The Recommended Nutrient Intake (RNI) of Mg for infants of 7 -12 months weighing 9 kg is 6.0 mg/kg while for infants between 1 - 3 years weighing 12 kg, the RNI is 5.5mg/kg [57]. The consumption of 100 g of the complementary food will respectively, meet only 3.46 – 3.78 and 3.11 – 3.40% of the recommended RNI of Mg for infants of 7 -12 months and 1 - 3 years old. These values are low though soybean has been reported to be a rich source of Mg. It implies that there is the need for consumption of other foods rich in Mg as reliance on this complementary food alone may lead to deficiencies.

Zinc (Zn) content of the complementary food ranged from 1.26 – 2.10 mg/100g). PSG8 and the control had significantly (P<0.05) the highest and the least Zn content respectively. This result was in line with 1.01 – 2.3 mg/100g reported by Oguizu *et al*. [34] for *OFSP*/soybean complementary food. Root crops are low in minerals such as iron and zinc but the addition of legumes can improve the iron content. As evidenced, in this study, the increase in soybean substitution led to significant (P<0.05) increase in the Fe and Zn content. Zinc is a vital micro-mineral required for the metabolism of macronutrients and other micro-minerals, and the maintenance of cell and organ integrity through the stabilization of muscular structure and membranes [57]. Its deficiency results in stunted growth, skin lesion and delay in bone maturation in infants. According to WHO [57], the RNIs for dietary zinc for infants of 7 – 12 months weighing 9 kg and infants of 1 - 3 years old with body weight of 12 kg is 4.1 mg/day for foods with moderate bioavailability of Zn, the Zn content of the OFSP, soybean and groundnut complementary food will meet 30.73 – 51.23% of the RNIs. Complementary foods that are able to meet at least 50% of the recommended intake are said to be adequate in the provision of such nutrient, the higher substitution of soybean therefore makes the OFSP/Soybean/groundnut complementary food adequate in Zn. The body depends on a regular zinc supply provided by the daily diets and improvement of zinc in the diet as obtained in the formulated complementary foods may help decrease the prevalence of stunting.

3.3 Sensory Properties of OFSP Starch, Soybean and Groundnut Flour Complementary Food

The sensory properties of the OFSP starch, soybean and groundnut flour complementary

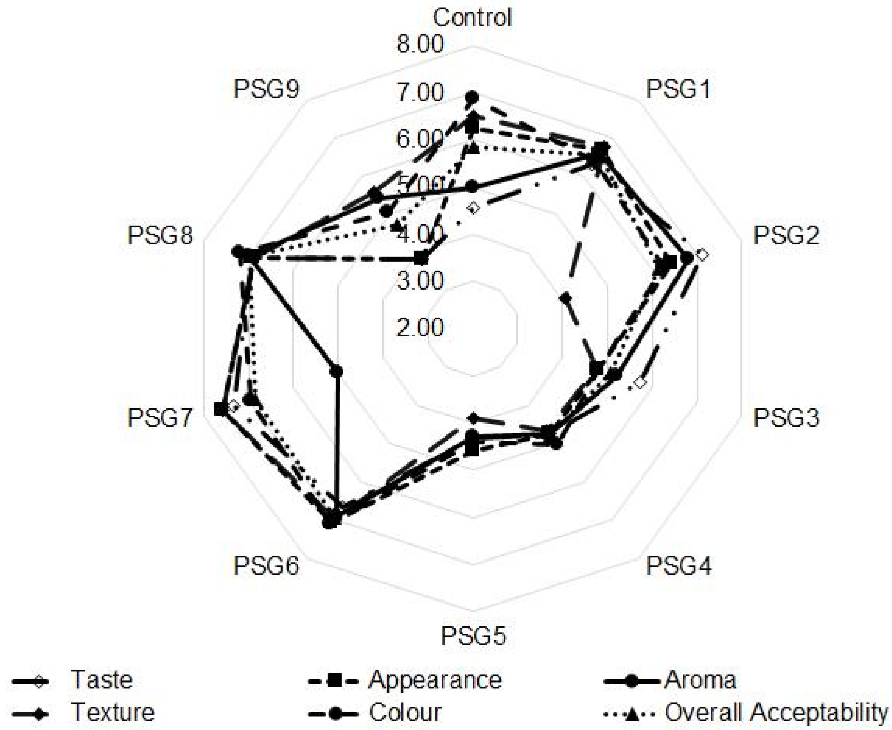

Fig. 2. Sensory properties of the OFSP starch, soybean and groundnut flour complementary food

Control = 100 (OFSP): 0 (Soybean flour): 0 (Groundnut flour); PSG1 = 90 (OFSP): 5 (Soybean flour): 5 (Groundnut flour); PSG2 = 85 (OFSP): 10 (Soybean flour): 5 (Groundnut flour); PSG3 = 80 (OFSP): 15 (Soybean flour): 5 (Groundnut flour); PSG4 = 75 (OFSP): 20 (Soybean flour): 5 (Groundnut flour); PSG5 = 70 (OFSP): 25 (Soybean flour): 5 (Groundnut flour); PSG6 = 65 (OFSP): 30 (Soybean flour): 5 (Groundnut flour) ; PSG7 = 60 (OFSP): 35 (Soybean flour): 5 (Groundnut flour) ;PSG8 = 55 (OFSP): 40 (Soybean flour): 5 (Groundnut flour); PSG9 = 50 (OFSP): 45 (Soybean flour): 5 (Groundnut flour)

food is shown in Fig. 2. assessors' degree of likeness for the sensory attributes: Aroma, Appearance, colour, taste, texture and overall acceptability varied from 5.00 - 7.00, 3.80 - 7.56, 5.04 - 7.20, 3.84 - 7.33, 3.88 - 7.56 and 4.29 - 6.96 respectively. Degrees of likeness for the sensory attributes: Aroma, Appearance, colour, taste and texture varied from dislike slightly to like moderately, while that of overall acceptability was dislike slightly to like slightly. PSG5 had significantly ($P<0.05$) the least degree of likeness for all attributes. PSG8 was liked the most in terms of aroma, appearance, colour and overall acceptability while PSG7 was liked the most in taste and texture. Color and appearance are important sensory attributes which affect the perception of other attributes, such as aroma, taste and flavor [59]. Colour, aroma and taste can affect the way children perceive food. Parents often determine sensory attributes on behalf of their children, and may know whether food will be liked or disliked by their children [33]. The degree of likeness for PSG7 and PSG8 for all attributes was that of moderate likeness except for texture in PSG7 that was neither liked nor disliked. This indicated that the substitution of soybean flour up to 35 and 40% was acceptable and liked the most be the assessors.

4. CONCLUSION

Enriching OFSP starch in complementary food formulation, by substitution with soybean and groundnut flour, significantly ($P>0.05$) increased the protein, fat, ash and fibre content of the blends with decrease moisture and carbohydrate. About 50 - 100% of the safe level of protein requirement for infants of 6 months to 2.5 years old will be met by the consumption of 100g of the formulated complementary food. The energy content will meet >55 – 64% of energy requirements for infants of 6 months old and >33 – 40% for those of 2.5 years old, who may have other family meals to make up for their energy requirement. The mineral content of the blends increased significantly (P<0.05) with increase in soybean flour substitution. The PSG complementary food in comparison to the recommended intake of minerals was found to be excellent in Cu, adequate in Fe and Zn but low in Mg and inadequate in Ca. The Assessors' degrees of likeness of the sensory attributes: aroma, appearance, colour, taste, texture and overall acceptability of PSG7 and PSG8 were significantly (P<0.05) the highest and was that in the range of like moderately to like very much. With the increased nutrient and mineral content of the formulated complementary food, and the assessors' degree of likeness of the higher substitution levels, addition of soybean flours up to 35 and 40% can be recommended as diet for infants and children.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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