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Original Research Article

Formulation and Nutritional Quality of Complementary Foods Developed from Red Beans, Orange-Fleshed Sweet Potatoes and Peanut Flour

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Abstract: Malnutrition and micronutrient deficiencies during infancy and early childhood are major problems facing developing countries, particularly Cameroon. This study aimed to formulate highly nutritious infant foods from locally available and affordable raw materials: orange-fleshed sweet potato (*Ipomoea batatas* L.), beans (*Phaseolus vulgaris* L.), and peanuts (*Arachis hypogaea* L.) grown in Cameroon. The formulated diets were analysed for their proximate (protein, fat, ash, fibre, carbohydrates), mineral (iron, zinc, calcium, magnesium, phosphorus), and antinutritional contents using standard methods. They were compared with the FAO/WHO standards. A total of two formulations were produced, with compositional proportions calculated based on recommended daily allowances (RDAs) for young children. The formulated ingredient varied 57-58% sweet potato, 23-25% beans, and 18-19% peanut. The linear programming method combined the samples into different formulations to meet FAO/WHO/UNICEF requirements. The results showed that the nutritional composition of the flour on a dry weight basis was as follows: crude protein: 12.66-13.66g/100g, lipid: 8.95-9.13g/100g, carbohydrates: 61.58-63.71g/100g, fibre: 5.58-6.22g/100g, ash: 3.82-4.64g/100g, energy: 381.53-387.65 Kcal, iron 9.45-10.46mg/100g, zinc 3.00-4.24mg/100g. The proximate contents of the formulated flours meet the FAO/WHO standards, except the energy content. The results of the study showed that the formulated diets contain very low antinutritional factors (phytate: 0.12 mg/100g and trypsin inhibitory content 0.30 to 0.35mg/100g). Based on the results, the complementary food formulated from sweet potato, beans, and peanut flour is a good source of protein, iron, and zinc and would contribute to the daily requirements of infants and young children.

Keyword: Sweet Potatoes, Beans, Peanut, Complementary Foods, Nutritional Evaluation, Young Children.

INTRODUCTION

Protein-energy malnutrition and mineral deficiencies remain the most widespread form of malnutrition in developing countries. Preschool children pregnant and lactating women are the most affected (WHO, 2020). In sub-Saharan Africa, it is estimated that 23.2% and 72.4% of the population suffer from protein-energy malnutrition and iron deficiency (WHO, 2019). According to the latest statistics (2018) from the Ministry of Public Health, Cameroon (EDS, 2018), the prevalence of malnutrition among children aged one to five years was 29%, 4%, 11%, and 57% for stunting, wasting, underweight and anemia respectively (EDS, 2018). This prevalence is higher during the food transition (6 to 24 months). Indeed, around the age of 6 months, an infant's need for energy and nutrients starts to exceed what is provided by breast milk alone and complementary foods are required to meet those needs. At this stage of life, an infant is also developmentally ready for other foods. This

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transition is referred to as complementary feeding. If complementary foods are not introduced around the age of 6 months, or if they are given inappropriately, an infant's growth may falter (Martha and Wenaty, 2023).

Complementary feeding is a gradual process of introducing solid foods alongside breast milk to an infant's diet. Complementary foods are anticipated to be high in energy density with adequate protein composition and required vitamins and minerals to meet the nutrient needs of the infant. Poor dietary quality and feeding practices, more often, a combination of the two, are the major challenges during complementary feeding (Nnam *et al.,* 2023). However, in Cameroon, industrial complementary foods for children sold in supermarkets are inaccessible to many of the population due to the high costs (Mvogo *et al.*, 2020). According to many authors, sub-standard food processing techniques and poor hygiene conditions are some of the poor complementary practices that may lead to malnutrition. The quality of the complementary food and its hygiene conditions can be affected by how it is processed (Asoba *et al*, 2019). Cameroonian traditional complementary foods are generally based on starchy staples, typically cereals such as maize, millet, soya, and sorghum. Also, these formulations are done by inexperienced mothers and/or caregivers who do not take into account recommended Dietary Allowances (Azike *et al.*, 2019; Tetanye *et al.*, 2020; Mananga *et al.*, 2022) Unfortunately, such diets are typically provided without enough supplementation with high-quality protein and mineral sources references. These complementary foods in most cases are made from mono cereal gruel and have very low nutritional value due to their deficiency in essential amino acids, particularly lysine, iron, vitamin A, and iodine (Shrimpton *et al.*, 2001). However, the high prevalence of children's malnutrition shows that to date, the various strategies adopted have not been effective. WHO/UNICEF recommends a combination of cereal, tuber, vegetables, and seafood in formulating complementary food may help to make up for the deficiency in essential amino acids and micronutrients in mono-cereal traditional complementary foods (FAO/WHO, 2011). Orange-fleshed sweet potatoes, beans, and peanuts are readily available foods that will cater to the needs of Cameroonian infants.

Orange fleshed sweet potato is an edible tuber belonging to the order *Solanales* and *Convolvulaceae* family. It contains starch, which is the main component, dextrins, β-carotene, and other nutrients in varying amounts. Orange-fleshed sweet potato has been reported to increase vitamin A intake and serum retinol, polyphenols, and carotenoid concentrations in children. Sweet potato may be blanched and processed into flour to avoid the problems associated with the perishability of the raw roots and to preserve its carbohydrate content (Ndangui *et al.*, 2014). Sweet potato makes these foods a healthy complement to young children's diets infant food of more than 20% concentration (w/v) is too thick for an infant's gastric system while if lower than 20% (w/v), might be low in energy and nutrient densities (Walker *et al.*, 2002).

Peanut is a legume crop that belongs to the family of Fabaceae, genus Arachis, and botanically named *Arachis hypogaea*. Peanuts are consumed in many forms such as boiled peanuts, peanut oil, and peanut butter roasted peanuts. Peanuts are considered a vital source of nutrients, particularly fat. Peanuts are rich in calories and contain many minerals (copper, zinc, magnesium), antioxidants (tocopherol, selenium), and vitamins that are essential for optimum health. The basic composition of peanuts is 49.66g proteins 23.68 and carbohydrates 21.51g (Sattaluri *et al.,* 2012).

Among legumes, the common bean plays a significant role in the diet of Cameroonians. It is a good source of protein, fibre, and micronutrients. Processed common beans have been reported to have low levels of antinutrients and a good potential for exploitation as food formulation material for infants and young children. Processing methods revealed protein content ranging from 19.53%-27.66%, fibre from 4.46%-7.99%, carbohydrate from 62.23%-53.28%, and lipids from 5.48%-3.32% (Mananga *et al.*, 2022).

Many studies have indicated that more than 85% of the complementary foods given to infants fail to meet the nutrient density levels recommended by the World Health Organization (WHO), thereby contributing to malnutrition problems. Therefore, this study aimed to formulate and evaluate infant flours using orange-fleshed sweet potato, beans, and peanuts flour.

MATERIAL AND METHODS

Collection Samples

The major food materials used in the study were orange-fleshed sweet potatoes: IRAD-TIB1 (*Ipomea batata* L.), red beans: Feb 192 (*Phaseolus vulgaris L.*), and peanuts: GL24 (*Arachis hypogea* L.). These ingredients were purchased from a local market at Foumbot in the West Region of Cameroon. Then, the bean seeds were identified at the Agricultural Institute of Research and Development of Foumbot station. The peanuts and potatoes were identified at the National Herbarium. These raw materials were chosen because they were rich in the desired nutrients which were plant protein, vitamin A precursor (β-carotene), tocopherol, iron, zinc, and magnesium. These materials are available and affordable locally and during the year. The collected samples were coded, packed, and transported to the Laboratory of Biochemistry University of Douala.

Samples Preparation

Preparation of Orange-Fleshed Sweet Potato Flour

Ten kilograms (10kg) of orange-fleshed sweet potato were processed into flour. Sweet potato samples were divided into two batches and treated differently. One batch was processed raw while the other was peeled, washed with distilled water, and sliced with a kitchen knife. Then, it was immediately immersed in a water bath at 90°C for one minute to prevent enzymatic browning. It was drained and oven-dried at 50°C in a conventional air oven for 12 hrs. After, it was dry-milled into powder packed in ziplock bags, and stored in a desiccator until required for further analysis and formulation of complementary food. They were all used to produce orange-fleshed sweet potato flour following the steps summarized in Figure 1.

Preparation of Bean Flour

Two kilograms (02 Kg) of red bean cultivars (*Phaseolus vulgaris* L.) were sorted by removing dirt and broken beans. Then, they were washed thoroughly, to remove soil and all foreign particles. The seeds obtained were separated into two batches and treated as presented in Figure 2 to produce treated and untreated red bean flours which were packed in ziplock bags and stored in a desiccator until required for further analysis and formulation of complementary food.

Preparation of Peanut Flour

Raw and treated peanut flours were prepared from 200g of peanut seeds as developed in Figure 3 to obtain treated and untreated peanut flours which were packaged in an airtight vessel in readiness for analysis and further infant flour formulations.

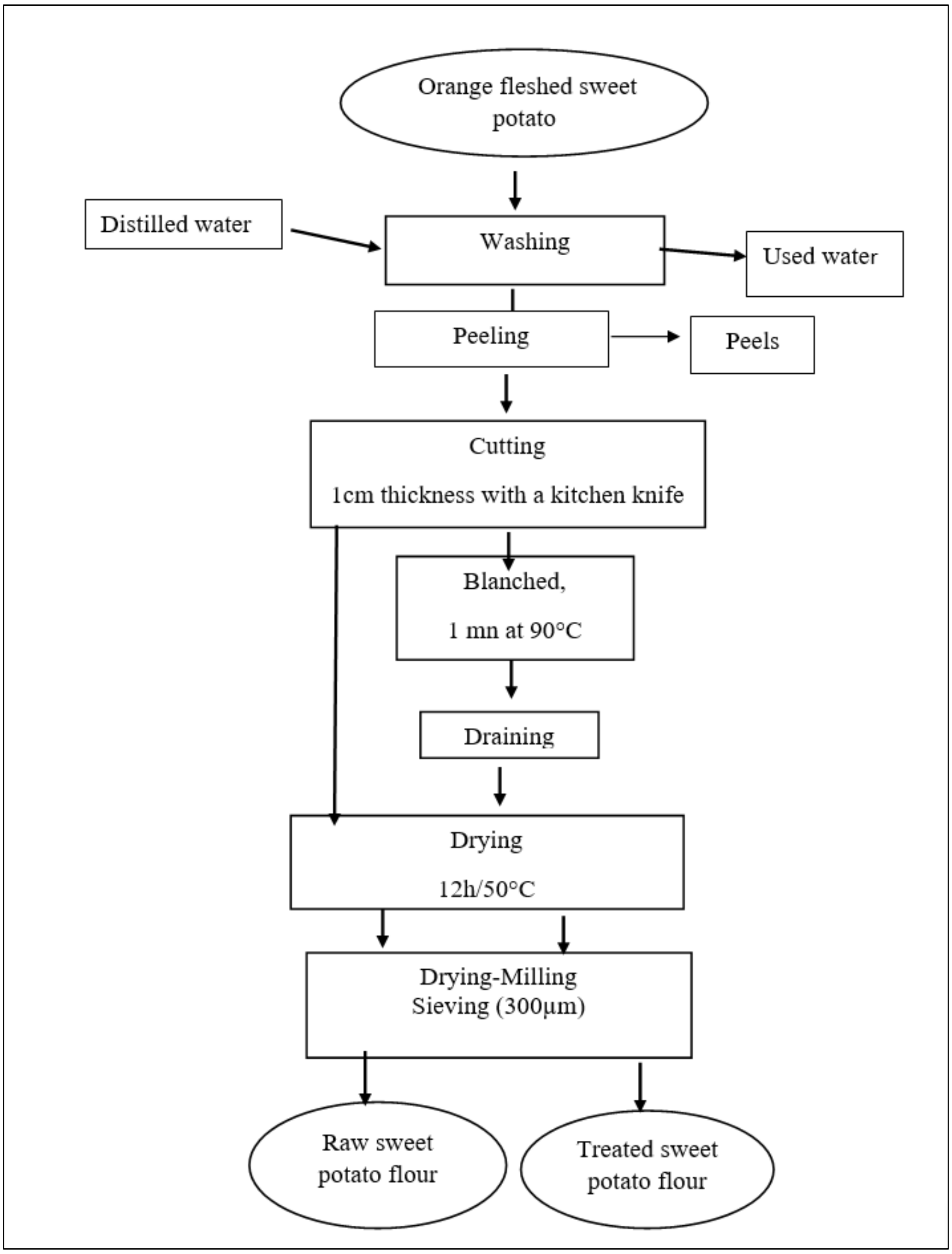

Figure 1: Process diagram of orange fleshed sweet potato flours production

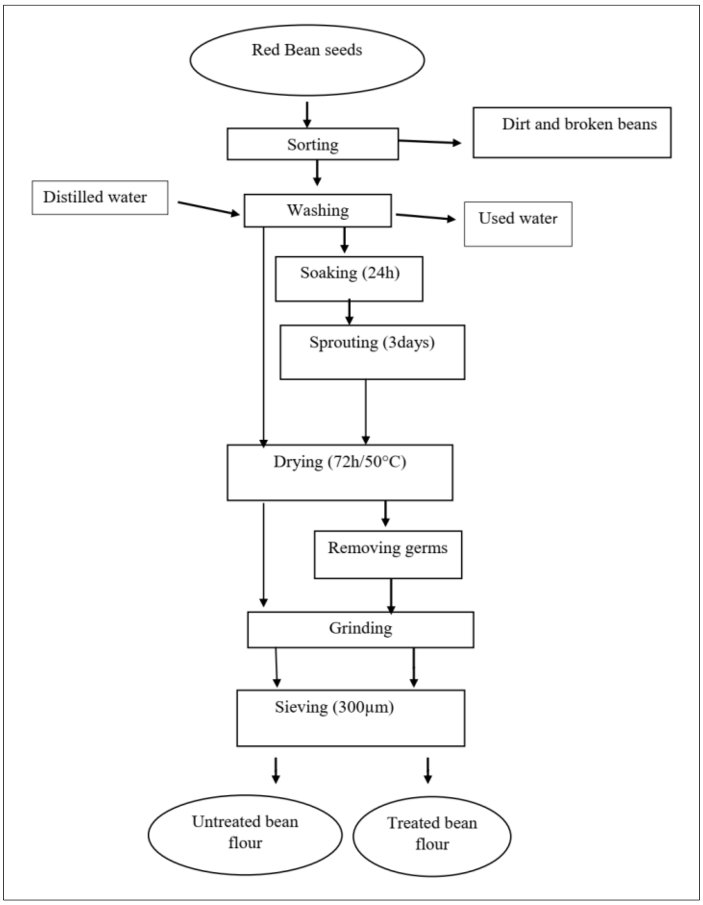

Figure 2: Process diagram of red bean flours production

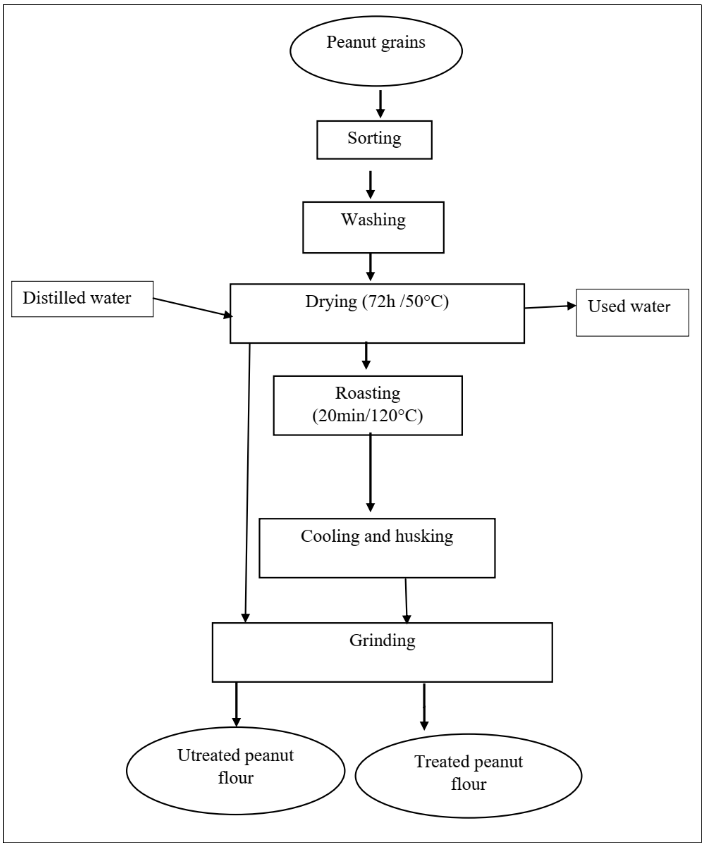

Figure 3: Process diagram of peanut flours production

Formulations of Composite Flours

Flours from red bean, peanut, and orange-fleshed sweet potato were used to formulate the infant diet, and several responses were evaluated. The linear regression method was used to combine the samples into different formulations to meet the FAO/WHO/UNICEF requirements for macro and micronutrients for infants and young children. However, Solver from Excel software was used to design and assess complementary flours. To prevent the issue of malnutrition during the early stages of child growth, these formulations developed must provide at least half of the recommended daily intake of the targeted nutrients, which are carbohydrates at 60- 68%, 12-15% of protein, 7- 10% of lipids and 400Kcal/100g of energy. The samples were formulated as presented in Table 1.

Table 1: Mixing Plan Experimental Matrix

Orange-fleshed sweet potato proportions of flour (%)	Bean flour proportions (%)	Proportions of peanut flour (%)
60	19	21
60	24	16
57	25	18
58	23	19
54	31	15

Determination of Proximate Composition

The proximate composition of the samples including moisture content, fat, protein, ash, and dietary fibre was determined according to AOAC (2005) method. The moisture was determined in an oven set at 105°C, according to standard methods detailed by AOAC (Association of Official Analytical Chemists, 2005) (AOAC, 2005). Protein content was evaluated via two successive methods beginning with mineralization as described by the Kjedahl method followed by titration (Devani *et al.,* 1989). Crude lipid content was evaluated by Soxhlet extraction according to the method described by AOAC (2005) using hexane as the extractor. The ash content was determined by calcination in a furnace at 550°C using the method described by AOAC (2005). The total fibre content was evaluated gravimetrically after delipidation of sample flours using the method shown by AOAC (2005). Total carbohydrate content was calculated by difference:

100 − (% crude protein + % crude fibre + % total ash + % crude fat). The energy value (E) per 100g of flour was obtained using Atwater conversion (Merill et Watt, 1955) factors as follows: E (Kcal)= Proteins (%) x4 + carbohydrate (%) x 4 + fat (%) x 9.

Determination of Mineral Content

The mineral contents (iron, zinc, magnesium, phosphorus, and calcium) of different samples were determined according to the standard method of AOAC (2000). Calcium and magnesium were determined by complexiometric method while total phosphorus concentration was measured by colorimetric spectrophotometer after incubation with Molybdo-vanadate solution. Iron and zinc were evaluated using an atomic absorption spectrophotometer (AAS).

Determination of Antinutrient Content

Trypsin inhibitors were analyzed using the method described by Aina *et al.* (2012). Phytate content was determined by titration with iron III solution after acid digestion (Olayeye *et al.,* 2013).

Statistical Analysis

Data were analyzed using Statistical Package for Social Sciences (SPSS) version 16.0 software statistical package. All analyses were carried out in triplicate. Results were expressed in the form of mean ± SD. Statistical differences between formulated complementary diet samples were determined by Oneway Analysis of variance (ANOVA) and Post-hoc (Tukey's Test) with a significance level of $p < 0.05$ so that significant differences between the created formulations to be observed.

RESULTS AND DISCUSSION

Proximate Composition

Proximate composition results are shown in Table 2. The moisture content of food is an index of its water activity and its knowledge helps in determining the shelf life of food and different forms of storage for later uses (Anshu *et al.,* 2018). Also, high water contents lead to rapid deterioration of food due to microbial activities (Aruah *et al.,* 2016). The moisture content of the treated flour (sweet potato, red bean) samples was significantly higher ($p<0,05$) than the untreated flour samples (Table 2). This is assumed to be caused by the absorption of water during blanching, soaking, and sprouting. On the other hand moisture content of the treated peanut flour was significantly lower than the untreated peanut flour. This could be justified by the roasting process during which the grains lose their water content. However, all the treated flour samples are low in moisture and fall within the acceptable FAO/WHO requirement (FA0/WHO, 2011). Similar results on moisture content in the formulated complementary porridges have been reported in Ethiopia by Fekadu *et al.*, (2020), after going through the same procedures in the preparation of complementary food from maize, pea, and anchote to reduce their moisture content. All the treated flours can be stored for a long period and this underscores its long shelf life and low susceptibility to microbial attack (Mananga *et al.,* 2021). The food matrices (red bean, sweet potato, and peanut) were used as sources of protein, fat, carbohydrate, fibre, crude ah, and a few minerals in formulated flours, the discussion of the findings observed has been focused only on these nutrients.

Protein is a macronutrient necessary for the growth of children. The protein content of the flours (Table 2) showed an increase in protein content from 2.85 to 2.91, from 19.84 to 21.92, and from 24.23 to 28.45 for sweet potato, red bean, and peanut flours respectively after different processes. This could be justified by changes in the association and dissociation properties of proteins caused by germination, blanching, and roasting of red beans, sweet potatoes, and peanuts respectively (Ndangui *et al.*, 2014; Hama *et al.*, 2017). On the other hand, this finding may be due to the synthesis of proteases and especially the activation of endopeptidases which increase after germination of legumes (Laxmi *et al.*, 2015). Similar results were obtained on the same food matrices by Ndangui *et al.*, (2014) for sweet potatoes, by Mananga *et al.* (2021) for beans, and by Hama *et al.* (2017) for peanuts. The protein content observed in red bean flour indicated that bean seeds are good matrices for protein intake in infant formulations.

The fat content of food matrices was 0.84 to 0.93 (red bean), 1.66 to 2.94 (sweet potato), and 45.75 to 46.24 (peanut). All pretreatments applied to red beans, peanuts, and sweet potatoes increased their lipid contents. This augmentation observed in the findings could be explained by the concentration of some nutrients after the evaporation process. Similar observations were made by Makinde and Akinoso (2014) in soaked and roasted soybean and sesame flours. The high lipid content observed in peanut paste indicated that peanuts are good matrices for energy intake in infant formulations.

However, carbohydrate content in our food matrices samples decreased with treatment. Carbohydrate content in the flours varied from 86.51 to 85.69% in sweet potato, 43.63 to 41.69% in red bean, and 13.68 to 13.61% in peanuts. According to Fernandes *et al.* (2010), the reduction in the amount of available carbohydrates could be because carbohydrates the water-soluble compounds, and then, they have been hydrolyzed and diffused in the cooking water. The findings of this study reflect results by Kaushik *et al.*, (2010) that the decrease in carbohydrate content after the pretreatment applied could be due to leaching in the soaking water and blanching of soluble molecules such as soluble sugars. The high carbohydrate content observed in orange-fleshed sweet potato indicated that it is a good matrix for an infant's main fuel source for formulations.

Fibre is the nondigestible polysaccharide residue of plants and plays a major role in increasing the utilization of nitrogen and absorption of some micronutrients (Martha and Wenaty, 2023). Fibre ranged from 2.54 to 2.12%, (sweet potato), 6.63 to 6.15% (red bean) and 8.91 to 5.68% (peanut). All three food matrices were affected by the applied pretreatments. The findings obtained in this study are similar to those of several authors who reported that the combined unit operations of soaking and peeling affected considerably the fibre content in food which is taken away after processing (Baik and Han, 2012; Farah, 2015). Also knowing that the fibre is more localised in the seed coats (Labat, 2013), the peeling operation in peanuts which consisted of removing these coats could justify this sharp reduction in the fibre content in the flours. A significant drop of about 64% in fibre content was also reported in soaked, dehulled, and roasted legume flours.

The crude ash content of the food matrices ranged from 2.36 to 2.23, from 4.57 to 4.52, and from 2.55 to 2.44 respectively for sweet potato, red bean, and peanut flours. The findings also revealed that different pretreatment applied had considerably reduced ash content. A comparable ash value (4.06%) was reported on boiled Telfairia occidentalis seeds by Achu *et al.*, (2021). A decrease in ash content from 4.55 to 4.52 % was recorded for red bean flour samples. This diminution could be explained by the leaching of most minerals during the boiling process, given their higher solubility in the water (Purchas *et al.*, 2018). Ash content indicates the presence of minerals in food matrices (Laryea *et al.*, 2018) and this implies that the formulated complementary foods in this study are potential sources of minerals.

Table 2: Proximate composition (g/100g DW) of the orange-fleshed sweet potato, red bean, and peanut flour.

Ingredients	Moisture	Protein	Carbohydrates	Lipids	Ash	Fibre
Untreated OFSP	95.09± 0.13^{b}	2.85± 0.04^{e}	86.51± 0.2^{a}	0.84±0.02 ^{f}	2.36±0.08 ^{bc}	2.54± 0.04^{e}
Treated OFSP	93.89± 0.02^{c}	2.91±0.01^{e}	85.69±0.02^{b}	0.93±0.02^{e}	2.23±0.03^{c}	2.12±0.01^{f}
Untreated red bean	93.27±0.16^{d}	19.84±0.03^{d}	43.63±0.09^{c}	1.66±0.02^{d}	4.57±0.13^{a}	23.63±0.08^{a}
Treated red bean	92.27±0.17^{e}	21.92±0.04^{c}	41.69±0.04^{d}	2.94±0.01^{c}	4.52±0.03^{a}	21.15±0.07^{b}
Untreated peanut	95.13±0.08^{b}	24.23±0.03^{b}	13.68±0.19^{e}	45.75±0.1^{b}	2.55±0.11^{b}	8.91±0.03^{c}
Treated peanut	96.42±0.07^{a}	28.45±0.03^{a}	13.61±0.19^{e}	46.24±0.05^{a}	2.44±0.03^{bc}	5.68±0.23^{d}

Values are means ± SD of triplicate determinations, DW=dry weight basis. Means within the same column with different superscripts significantly different at $p<0.05$. OFSP = Orange fleshed sweet potato.

Mineral Composition

The mineral composition of the food matrices is summarized in Table 3. All the mineral investigated was significantly affected by the pretreatment applied. The mineral contents of the orange-fleshed potato ranged from 1.99 to 1.20, 0.90 to 0.28, 12.01 to 10.51, 2.59 to 1.52, and 8.94 to 6.61 mg/100g DW for iron, zinc, calcium, magnesium, and phosphorous respectively. The mineral contents of the red bean varied from 3.93 to 3.38, 2.53 to 1.61, 104.67 to 83.40, 302.96 to 291.59, and 502.48 to 486.81 mg/100g DW for iron, zinc, calcium, magnesium, and phosphorous respectively. As far as the mineral content of the peanut flour was (untreated and treated) 5.65 to 4.80, 2.33 to 2.16, 107.01 to 80.04, 170.11 to 168.51, and 376.13 to 298.47 mg/100g DW for iron, zinc, calcium, magnesium, and phosphorous respectively. Iron, zinc calcium, magnesium, and phosphorous have been identified as the problem nutrients from 6 months of age and must be supplemented with the addition of complementary food (Fakadu, 2020). However, the result of this study was lower than the value reported by Haile and Getahun (2018) in the mineral composition of mashed OFSP and haricot bean (0.40.5% and 3.50% for zinc, 0.74 and 1.78% for iron, 39.10 and 58.93 for calcium). The mineral content of the food matrices is used for further infant formulations.

Table 3: Mineral composition (mg/100g DW) of the orange-fleshed sweet potato, red bean, and peanut flour

Flours	Fe	Zn	Ca	Mg	P
Untreated OFSP	1.99±0.03[a]	0.90±0.04[c]	12.01±2.86[d]	2.59±3.30[d]	8.94± 0.09[f]
Treated OFSP	1.20±0.04[b]	0.28±0.05[d]	10.51± 4.08[d]	1.52± 0.25[d]	6.61±0.6[e]
Untreated red bean	3.93±0.23[e]	2.53±0.16[a]	104.67±5.69[a]	302.96±4.94[a]	502.48±3.76[a]
Treated red bean	3.38±0.11[f]	1.61±0.17[b]	83.40±3.14[b]	291.59±3.58[b]	486.81±2.65[b]
Untreated peanut	5.65±0.06[c]	2.33±0.02[e]	107.01±4.59[d]	170.11±0.01[c]	376.13±0.03[d]
Treated peanut	4.80±0.08[d]	2.16±0.02[e]	80.04±0.29[c]	168.51±0.05[c]	298.47±1.07[c]

Values are means ± SD of triplicate determinations, DW=dry weight basis. Means within the same column with different superscripts significantly different at p<0.05. OFSP = Orange fleshed sweet potato.

Antinutrient Content

The antinutrient composition of the food matrices is presented in Table 4. The bean flour was higher in phytate content compared to the peanut flour ($p<0.05$). The trypsin inhibitor content of peanut flour was significantly higher ($p<0.05$) than the red bean flour. However, all the ingredients (bean, peanut), contain very low antinutritional contents. It appeared that all the processing methods led to a significant reduction ($p<0.05$), in the levels of phytates and trypsin inhibitors. Phytate contents of the food matrices ranged from 0.24 to 0.14, and 0.18 to 0.13 for bean and peanut flours respectively. Trypsin inhibitor contents of the food matrices ranged from 0.35 to 0.24, and 2.25 to 1.29 for bean and peanut flours respectively. Trypsin inhibitors strongly inhibit the activity of key pancreatic enzymes thereby reducing digestion and absorption of dietary proteins by the formation of complexes that are indigestible even in the presence of high amounts of digestive enzymes (Gemede and Ratta, 2014). According to many authors, the major concern about the presence of phytate in the diet is its negative effect on mineral uptake. Indeed, minerals concern in this regard include iron, zinc, calcium, and magnesium but also hurt the nutritional value of protein. Phytates can inhibit digestive enzymes (Gemede, 2014). However, the result of this study was lower than the value reported by Eltom and Sulieman (2023) where the level of phytate was 2.20 and 2.07 mg/g on the roasted peanut. The antinutrient content of the food matrices was very low and suggested that these matrices could be used for further infant formulations.

Table 4: Antinutrient composition (mg/100g DW) of the raw and treated ingredient flours.

Flours	Phytate contents	Trypsin inhibitor levels
Untreated red bean	0.24± 0.03[a]	0.35± 0.04[c]
Treated red bean	0.14±0.01 [b]	0.24± 0.03[c]
Untreated peanut	0.18±0.03 [ab]	2.25± 0.11[a]
Treated peanut	0.13± 0.03[b]	1.29± 0.02[b]

Values are means ± SD of triplicate determinations, DW=dry weight basis. Means within the same column with different superscripts significantly different at p<0.05. OFSP = Orange fleshed sweet potato.

Selection of the Best Formulations

Based on the associations indicated in Table 1, five different formulations were obtained by the linear programming method. The analysis of constraints and FAO/WHO (2011) guidelines showed that the best responses obtained were combinations of 58% of orange-fleshed sweet potato, 23% of red bean and 19% of peanut (Diet 1), and 57% of orange-fleshed sweet potato, 25% of red bean and 18% of peanut (Diet 2). These two formulations were validated taking into consideration the recommended daily intake for children (12-15% for protein, 65-68% for carbohydrates, 400Kcal for energy, and 7-10% for fat) (FA0/WHO, 2011).

Proximate Composition of the two Formulated Complementary Diets

The proximate composition of the two formulated diets is shown in Table 5. The moisture content of the two was close to 5% as recommended by the FAO/WHO (2011). According to many authors, moisture content determination is a key factor affecting the storage, shelf life, and safety of foods (Purchas *et al.*, 2018). The two diets can be stored for a long period and have less susceptibility to microbial attack. The fat contents of the diets were 8.95% and 9.13% respectively for diet 1 and diet 2. The recommended value of fat content for infant flour ranged from 7-10% (FAO/WHO, 2011). Among the legumes used for formulation, peanuts had the highest fat content. The results show that increasing the peanut content can improve the fat content of the formulated diet. During infancy and childhood fats are a source of energy and essential fatty acids and fat-soluble vitamins (A, D, E, K). In addition, dietary fats have an important role in promoting good health and enhancing the sensory qualities of foods (Kaushik *et al.*, 2010). However, the results of this study were lower than the value reported by Mbame *et al.* (2021) (9.5%-14%) who formulated complementary foods from ten different proportions of local staples: yellow maize, rice, potatoes, egg whites, soybeans, pawpaw, watermelon, pineapple, and oranges, using standard processing techniques. For the crude protein contents, all the two infant flours were within the recommended range of 12-15% (FA0/WHO, 2011). This could be because the different processes (soaking and sprouting) have improved the protein content of the red bean flours which are the main protein source (21.92 g/100 g DW). Protein makes important nutrient composition in complementary foods. It is vital for the prevention of protein-energy malnutrition (PEM), which is frequently witnessed among children in emerging nations, particularly during weaning (Kaushik *et al.*, 2010). The finding of this study is less than the value reported by Fekadu *et al.*, (2020) (14.92% to 20. 99%) who evaluated nutritional and antinutritional contents of complementary foods from locally available and affordable raw materials (maize, pea, and anchote) grown in Western Ethiopia.

The carbohydrate contents of the two developed complementary foods were within the FAO/WHO requirements of 65-68%. This result suggests that diet 1 and diet 2 can be regarded as good sources of energy to support children's growth. Carbohydrates maintain a healthy body weight in infants and play a main role as a fuel source essential for proper growth and development. The finding is similar to the results reported by Selemani *et al.* (2023) who evaluated complementary food based on dates, millet, orange-fleshed sweet potato, and moringa leaf powder (73-77%). Along the same line, the energy value of diet 1 and diet 2 were within the FAO/WHO requirements of 400kcal. The proximate composition of formulated flours shows that the macronutrient contents and energy value of the 2 flours could be used to fight against protein energy malnutrition (PEM).

Fibre contents in infant formulation samples ranged between 5.58 and 6.22 g/100g respectively for diet 1 and diet 2. FAO/WHO recommends complementary foods containing low fibre as high-fibre products can lead to high water absorption and displacement of nutrients and energy needed for the growth of children less than two years of age (Kaushik *et al.*, 2010). The findings of this study are lower than those obtained by Mbame *et al.* (2021) who formulated complementary foods from ten different proportions of local staples. Like other macronutrients, the ash content of the flour samples was 3.82 and 4.64% for Diet 1 and Diet 2 respectively. FAO/WHO recommends an ash content of 2.9g for every 100g of food sample for complementary foods. The two formulas have ash contents up to 3% but within the acceptable FAO/WHO requirement. Concerning ash, the results are higher than the value (1.88%) reported by Ikese *et al.* (2016) who evaluated the proximate composition of a potential infant food made from wheat and groundnut. Ash content means the presence of minerals in food samples (Laryea *et al.*, 2018), and this denotes that the formulated complementary foods in this study are potential sources of minerals.

Table 5: Proximate composition (g/100g DW), energy value (Kcal/100g DW) of two formulated complementary diets

Formulated diets	Diet 1	Diet 2	Norms (FAO/WHO, 2011
Moisture	5.1 ± 0.16^{a}	4.95 ± 0.08^{a}	5
Protein	12.66 ± 0.11^{b}	13.66 ± 0.09^{a}	12 – 15
Lipid	9.13 ± 0.1^{a}	8.95 ± 0.14^{a}	7 – 10
Carbohydrates	63.71 ± 0.16^{a}	61.58 ± 0.64^{b}	65 – 68
Fibre	5.58 ± 0.16^{a}	6.22 ± 0.37^{a}	<5
Ash	3.82 ± 0.18^{b}	4.64 ± 0.1^{a}	> 2
Energy value	387.65 ± 0.50^{a}	381.53 ± 2.01^{b}	400

Values are means ± SD of triplicate determinations, DW=dry weight basis. Means within the same line with different superscripts significantly different at $p<0.05$.

Proximate Composition of the two Formulated Complementary Diets

The mineral contents and the WHO standard values for each of these micronutrients of the formulated diets are shown in Table 6. Mineral contents of the formulated diet varied from 9.45 to 10.46, 3.00 to 4.24, 303.93 to 304.80, 152.67 to 161.67, and 254.93 to 263.61 for iron, zinc, calcium, magnesium, and phosphorus respectively. These micronutrients are known to be the main problem nutrients from 6 months of age and must be supplemented with the addition of complementary food (Laryea *et al.*, 2018). The mineral content of the study was almost within the requirement of FAO/WHO (2011) except phosphorous and calcium (Table 7). Therefore, the formulated diets can be recommended as good source of iron, zinc, magnesium, phosphorous, and calcium because they provide more than 50% of the nutrients Recommended Dietary Intake (RDI) for feeding children.

Iron is required to carry oxygen throughout the body in the form of hemoglobin and myoglobin. Other hand, it is an integral part of many proteins and enzymes and it also helps in energy metabolism (Anderson and McLaren, 2012). Iron deficiency in infants and young children is associated with anemia and irreversible abnormal functioning of the brain. Also, zinc is a component of more than 300 enzymes in the body and plays a role in the proper functioning of some sense organs such as the ability to taste and smell (Bridgide *et al.*, 2014). Similar to iron, zinc deficiency is associated with stunting and anemia. Calcium is reported to be necessary for the development of teeth and bones in infants and young children (Beto, 2015). As for magnesium, it supports a healthy immune system, maintains normal muscle and nerve function, and is a cofactor in several metabolic pathways (Modamed *et al.*, 2021). Phosphorus plays key roles in the regulation of gene transcription, activation of enzymes, and maintenance of normal pH in extracellular fluid and intracellular energy storage (Chamba *et al.*, 2021). The findings of the study are closely comparable to those of Fekadu *et al.* (2020) in porridge samples where calcium, iron zinc phosphorous potassium, sodium, and magnesium meet the codex standards.

Table 6: Contents of some minerals (mg/100g DM) of developed infant flours.

Formulated diets	Diet 1	Diet 2	Norms (FAO/WHO, 2011)
Iron	10.46 ± 0.61^{ab}	9.45 ± 1.43^{a}	>8.5
Zinc	4.24 ± 0.29^{ab}	3.00 ± 0.73^{a}	4-6
Calcium	304.80 ± 0.32^{a}	303.93 ± 0.35^{b}	400
Magnesium	161.67 ± 5.00^{ab}	152.67 ± 3.4^{a}	100
Phosphorus	263.61 ± 1.55^{b}	254.93 ± 0.82^{a}	281

Values are means ± SD of triplicate determinations, DW=dry weight basis. Means within the same line with different superscripts significantly different at $p<0.05$.

The mineral ratios of the two formulated diets are presented in Table 7. The calcium-phosphorous (Ca/P) ratios of the two formulated diets ranged from 1.16 to 2.47. The recommended Ca/P ratio should be > 0.5. (Jacob *et al.*, 2015). Food is considered as good if the Ca/P ratio is >1 and poor if this ratio is < 0.5 (Alinnor and Oze, 2011). Many studies reported that the Ca/P ratio must be close to 1 for good Ca and P intestinal utilization. Also, higher calcium-phosphorous (Ca/P) levels in foods are required for favorable calcium absorption in the intestine for bone formation (Adeyeye *et al.*, 2012 ; Chandran *et al.*, 2013). The results suggest that the two formulated complementary diets would help calcium absorption in the body and be necessary for infants and young children for bone and teeth formation and maintenance. The iron-zinc (Fe/Zn) ratios of the 2 formulated complementary diets ranged from 1.19 to 3.15. The recommended Fe/Zn ratio should be > 2 to be sure that iron did not impair zinc absorption. The results showed that the iron present in the formulated complementary diets did not impair zinc absorption.

Table 7: Mineral ratios of the two formulated complementary diets

Formulated diets	Ca/P	Fe/Zn
Diet 1	1.16	1.19
Diet 2	2.47	3.15
Standards	>0.5	>2

Antinutrient Contents of the two Formulated Complementary Diets

The antinutrient contents and calculated molar ratios of two formulated complementary diets were presented in Table 8 and Table 9. Phytate contents of the two formulated complementary diets were 0.12 mg/100g. The trypsin inhibitor contents of two complementary diets ranged from 0.30 to 0.35 respectively for diet 2 and diet 1. The presence of antinutritional factors (phytates, trypsin inhibitor) in complementary food has been constituting a brake to the effective utilization of its nutrients in human nutrition. Many authors revealed that phytate levels in complementary foods generally interfere with mineral availability (Anigo *et al.*, 2010). However, the levels of phytate and trypsin inhibitors in this study were reduced through various processes.

Table 8: Antinutrient composition (mg/100g DW) of two formulated complementary diets.

Formulated diets	Diet 1	Diet 2
Phytate	0.12± 0.01[a]	0.12± 0.04[ab]
Trypsin inhibitor	0.35± 0.03[b]	0.30± 0.02[a]

Values are means ± SD of triplicate determinations, DW=dry weight basis. Means within the same line with different superscripts significantly different at $p<0.05$.

The molar ratio of phytate to iron (Phy/Fe) of the two formulated complementary foods ranged from 9,7 $x10^{-4}$ to 1,07 x10-3. According to Siegenberg (Siegenberg *et al.*, 2015) the phytate/iron molar ratios <0.15 is indicative of good iron bioavailability. The result indicated that the complementary diets contain the phytate/iron molar ratios of less than the critical value this implies the good availability of iron. The phytate/calcium molar ratio was $2,4x10^{-5}$ for the two formulations. The values are below the standard value (< 0.24), which implies good calcium bioavailability of the infant flours (Woldegiorgis *et al.*, 2015). The molar ratio of phytate to zinc (Phy/Zn) ranged from $3x10^{-3}$ to $3.96x10^{-3}$ was less than 10, which is the critical molar ratio of Phy/Zn (Morris and Ellis, 1989). This indicates that the two formulated complementary diets have adequate availability of zinc.

Table 9: Calculated molar ratios of the two formulated complementary diets

Formulated diets	(Phytates/Ca)[a]	(Phytates/Fe)[b]	(Phytates/Zn)[c]
Diet 1	$2,4x10^{-5}$	$9,7\ x10^{-4}$	$3x10^{-3}$
Diet 2	$2,4x10^{-5}$	$1,07x10^{-3}$	$3,96x10^{-3}$
Standard value	< 0.24	>0.15	<10

[a]mg of phytate/molecular weight of phytate: mg of calcium/molecular weight of calcium.
[mg] of phytate/molecular weight of phytate: mg of iron/molecular weight of iron.
[c]mg of phytate/molecular weight of phytate: mg of zink/molecular weight of zink.

CONCLUSION

This study revealed that good quality complementary foods could be obtained from orange-fleshed sweet potatoes, red beans, and peanut flour. The macronutrient and the micronutrient contents of the two formulated complementary foods meet FAO/WHO standards. The findings showed that the formulated diets contain low antinutritional factors and high bioavailability of minerals (iron, calcium, and zinc). The molar ratios of the formulated complementary foods were within the standard requirements. This study proves that orange-fleshed sweet potato, red bean, and peanut flour can be used as a solution for infants and young children suffering from protein-energy malnutrition and stop depending on commercial complementary foods (generally expensive). These complementary foods are nutritious and provide sufficient energy and nutrients to support the body's growth, teeth and bones formation and maintenance, brain development, and children's immunity.

DECLARATIONS

Credit Authorship Contribution Statement

DDT: Investigations, methodology, writing the original draft. MFMJ and ENJK: data curation, writing the original draft. DAW, DMA and NTJB: Methodology, data curation, formal analysis. YM and MFC: Investigation and formal analysis. DH and TTS: Methodology, visualization. M-JM and KSMM: Conceptualization, formal analysis, methodology, resources, supervision, writing the original draft, reviewing, and editing.

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