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Preparation of Ready to Use Supplementary Food for Treating Moderate Acute Malnutrition in Children Aged 6 to 59 Months

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ABSTRACT

Children with moderate malnutrition have a high risk of mortality and MAM is associated with a high number of nutrition-related deaths. If some of these children suffering from MAM do not receive adequate support, they may progress towards severe acute malnutrition (SAM), which is a life-threatening condition. Therefore, the management of MAM should be a public health priority

A well-balanced diet was prepared based on the recommendation of WHO for the treatment of moderate acute malnourished children aged 6 -59 months. According to the formulae, nine products of RUSF were prepared using cereals, legumes, seeds, oil, sugar, and vitamin and mineral premix. Three products of RUSF MSPe, PBPe, and ISPe were found to be better among the nine products by the mothers after sensory evaluation.

Based on sensory evaluation in children, RUSF MSPe was found to be the best among the three products. The product was analyzed for proximate composition, mineral, vitamin, digestibility of protein. The protein, fat, carbohydrate, dietary fiber, total ash, vitamin C, Vitamin A, iron, calcium and zinc of 100 g of the product were found to be 15.9g, 33.7g, 44.3g, 6.6g, 2.2g, 54.6 mg, 855 µg, 14.1 mg, 66.6 g and 12.4 µg respectively. The diet can supply 544.5 Kcal/100 g. The energy contributed by the protein, fat, and carbohydrate was found to be 11.68%, 55.7%, and 32.62% of total Kcals respectively. The protein digestibility adjusted to the chemical index PDCASS was 0.95.

Hence, the prepared RUSF is in accordance with the specification given by WHO which could be effective in the treatment of moderate acute malnourished children after the clinical trial.

Introduction

Malnutrition is a prevalent condition in many developing countries and a predisposing factor to various forms of long-term health conditions. In underdeveloped communities, where they are heavily dependent on high carbohydrate foods with inadequate supplies of proteins and essential vitamins, the aged, pregnant women, the sick, and children are the most vulnerable to malnutrition. With regards to children, undernourishment directly affects their mental growth and development which have adverse effects on their ability to learn and process information when they grow into adults. Undernourishment also impairs the immune system of children leaving them more susceptible to infection [1]. Undernutrition in children includes both Moderate acute malnutrition (MAM) and severe acute malnutrition (SAM). Moderate acute malnutrition affects many children in developing countries. Children with moderate malnutrition have a high risk of mortality and MAM is associated with a high number of nutrition-related deaths. If some of these children suffering from MAM do not receive adequate support, they may progress towards severe acute malnutrition (SAM), which is a life-threatening condition. Therefore, the management of MAM should be a public health priority [2].

The prevalent number of children in developing countries from suffering MAM is increasing daily and this has significant cost implications for their treatment. Standard Ready to use supplementary foods (RUSF) has been developed and used in the international setting for management and treatment of MAM but cost considerations usually prohibit its use in African countries [3].

Supplementary feeding programs have been designed to manage the home-based treatment of MAM reason being that the treatment of children with MAM is not always possible in hospitals or nutrition rehabilitation centers in Africa and most developing countries [4]. Nowadays, supplementary feeding programs have been established in some African countries such as Congo, Ethiopia, Malawi and Niger to treat MAM. Fortified blended flours, such as corn-soya blend (CSB), prepared as a porridge, are the most widely used foods in supplementary feeding programs. The goal of supplementary feeding programs is to treat children with MAM and prevent children from deteriorating and developing SAM [5]. In Cameroon, there is no commercial production of RUSF instead it is imported from countries like France and supplementary feeding programs for the treatment moderate acute child malnutrition has not been fully exploited. However, WHO recommends the use of locally available foods in the production of RUSF for the treatment of MAM children [6]. The main objective of this work is to prepare ready to use supplementary food (RUSF) using locally available raw material such as maize, soy, beans, peanuts, Irish potatoes, cowpeas, and potatoes in accordance with WHO recommendations.

MATERIALS AND METHODS

Raw materials

Taking into consideration of the locally available food in our study areas, the following raw materials used for supplementary food formulation were procured; Maize, potato, Irish potato, peanuts, beans, cowpeas, soybeans, vegetable oil, sugar, Milk powder and Vitamin and mineral premix

Treatments of ingredients

Potato and Irish potato

Two varieties of potato were manually selected, clean of foreign bodies, washed several times, peeled, boiled, dried, and milled to flour.

Maize

Maize was cleaned to remove impurities such as stones and other grains. The cleaned maize was cooked into the water and later dried. The dried maize was milled into flour. The flour was sieved put into airtight containers.

Peanuts

Peanut was clean of foreign bodies, roasted, peeled, dried, and ground to paste.

Beans and cowpea

Beans and cowpea were cleaned and soaked in water at room temperature and then boiled, dried, Milled into flour. The flours were sieved and stored into airtight plastic bags.

Soybean

Soybean was cleaned, steeped, cooked, peeled, dried, and ground into flours. The flours were sieved and stored into airtight plastic bags.

Physico-chemical analyses of processed raw materials

The different ingredients selected were analyzed before and after pre-treatment. After formulation, the resulting food was also analyzed. Moisture, total ash, crude protein, crude fat and crude fibre content of the pre-treated ingredients were determined in triplicates according to the standard methods of AOAC [7]. Available sugars were determined by analysis of reducing sugars using Fisher and Stein's 3,5-dinitrosalicylic acid (DNS) method [8]. The amino acid composition was determined according to the waters Pico Tag method described by Bidlingmeyer, Cohen, and Tarvin [9]. Protein quality was determined using the concept of protein digestibility adjusted to the chemical index (PDCASS) and calculated by multiplying the chemical index by the digestibility measured in vitro by the pH-stat method. The mineral content (calcium, iron, magnesium, phosphorus, potassium, sodium, zinc, copper, selenium, and iodine) were determined using atomic absorption spectrometry after mineralization of the samples. Vitamin A and vitamin E were determined according to AACC Method 86-06 (AACC, 2000). Vitamin B6 was determined by a microbiological method using Saccharomyces uvarum (Method AACC 86-31). Vitamin B12 was determined by AACC Method 86-40. Folic acid was determined by the AACC 86-47 method (AACC, 2000). Niacin was determined by AACC Method 86-51. Vitamin C was determined by AACC Method 86-10.01. Thiamine was determined by AACC 86-8.01. Thiochrome was extracted in iso-butanol and its fluorescence measured at 435 nm after excitation at 365 nm. Riboflavin was determined by AACC Method 86-70.01. Riboflavin was extracted in 0.25 N sulphuric acid and its fluorescence measured at 510 nm. The phytate content was determined by the colorimetric method of Vaintraub and Lapteva [10] modified by Gao [11].

Formulation

The preparation of supplementary food was done based on the specification of the basic nutrient composition of F100 (energy density of 550 Kcal/100g of the finished product, with 45-65g of carbohydrate, 10-35g of protein, 20 – 35g of lipid/100g of finished product) as established by the WHO. The formulation process was done using WinFeed software. The amounts of ingredients were calculated on a dry weight basis. Legumes were taken as the source of protein, the cereals as the staple source peanuts and vegetable oils were chosen as a source of energy and to maintain the level of essential fatty acids. The amount of vitamin and mineral premix was added to achieve vitamins and mineral level in the supplementary food. The data obtained from the software made it possible to develop nine different formula mixes which, after nutritional and sensory evaluation, were adjusted to obtain the final recipe.

Acceptability tests

Sensory evaluation of supplementary foods was conducted using a 9 hedonic scale (lowest point 1 = extremely dislike and the highest point 9 = like) by the panel of 20 adults. The three best supplementary foods selected from this sensory evaluation were further subjected to another acceptability test carried out by 10 children.

Statistical analysis

The statistical data analysis was done using SPSS 10.1 software. All measurements were performed in triplicate, the Student test was used to compare the observed difference between pre-treatment (uncooked) and post-treatment (cooked) foods. The level of significance ($p<0.05$) was used in this study.

Nutritional analysis of ready to use supplementary food

The final ready to use supplementary food were evaluated for their moisture, fat, protein, ash, fiber content using AOAC [12] standard procedures Available sugars were determined by analysis of reducing sugars using Fisher and Stein's 3,5-dinitrosalicylic acid (DNS) method Fisher and Stein[8].

The mineral contents were determined using an Atomic Absorption Spectrophotometer (PerkinElmer, model A Analyst 400). Vitamin content was determined as per AACC 2000.

The calorie content of food was determined using One of the methods specified by (Food and drug administration) FDA. This uses the general factors of 4, 4, and 9 calories per gram of protein, total carbohydrate, and total fat, respectively. Total energy = energy from carbohydrate + energy from protein + energy from fat [13].

RESULTS AND DISCUSSION

Physicochemical properties of the main ingredients

Table 1 shows the Physicochemical composition of the main ingredients. It can be observed that there was no significant difference ($p >0.05$) in protein and fat contents among the uncooked and cooked ingredients. Whereas the difference was significant ($p<0.05$) in carbohydrate attributes of soybean, cowpea beans, and corn. This could be due to leaching when cooking these ingredients in water.

Table 1: Physicochemical of the main ingredients

Samples	Moisture	Ash	Protein	Lipid	Total sugar	Fibre	Calories (Kcal)
Peanuts							
Uncooked peanuts	2.7±0.17^{a}	0.3±0.01^{a}	24.6±0,73^{a}	49.9±0.14^{a}	21.8±0.79^{a}	0.7±0.06^{a}	631.1
Cooked Peanuts	3.4±0.23^{b}	0.2±0.03^{b}	24.4±0,59^{a}	49.5±0.15^{a}	21.7±1.08^{a}	0.8±0.07^{b}	629.9
Soybean							
Uncooked soybean	4.2±0.45^{a}	0.4±0.04^{a}	38.1±0.91^{a}	22.6±1.05^{a}	34.1±0.43^{a}	0.6±0.02^{a}	492.2
Cooked soybean	5.5±0.33^{b}	0.3±0.07^{a}	37.8±0.85^{a}	21.9±0.03^{a}	33.9±1.03^{b}	0.6±0.02^{a}	483.9
Bean							
Fresh bean	6.1±0.58^{a}	0.3±0.08^{a}	22.6±0.61^{a}	0.6±0.12^{a}	69.6±0.17a	0.8±0.07^{a}	372.2
Cooked bean	7.0±0.29^{b}	0.2±0.04^{a}	22.2±0.16^{a}	0.7±0.07^{a}	69.1±0.98^{b}	0.8±0.06^{a}	371.5
cowpea							
Uncooked cowpea	4.1±0.59^{a}	0.6±0.1^{a}	23.4±0.48^{a}	1.4±0.07^{a}	69.8±0.84^{a}	0.7±0.05^{a}	385.4
Cooked cowpea	6.2±0.15^{b}	0.5±0.14^{b}	23.1±0.37^{a}	1.5±0.05^{a}	68.1±0.53^{b}	0.6±0.03^{b}	378.3
Maize							
Uncooked maize	6.1±0.53^{a}	0.8±0.04^{a}	9.7±0.61^{a}	4.2±0.33^{a}	78.4±0.15^{a}	0.8±0.03^{a}	390.2
Cooked maize	7.0±0.26^{b}	0.9±0.06^{a}	8.7±0.56^{a}	3.3±0.36^{a}	79.4±0.19^{b}	0.7±0.02^{b}	382.1
Irish potato							
Uncooked irish potato	10.5±0.27^{a}	0.1±0.05^{a}	2.4±0.28^{a}	0.4±0.09^{a}	85.5±1.29^{a}	1.1±0.04^{a}	355.2
Cooked irish potato	9.4±0.39^{b}	0.2±0.04^{b}	3.3±0.19^{a}	0.3±0.06^{a}	85.9±0.82^{a}	0.9±0.03^{b}	359.5
Potato							
Uncooked Potato	9.7±0.09^{a}	0.4±0.03^{a}	2.4±0.07^{a}	0.7±0.02^{a}	85.9±1.51^{a}	0.9±0.02^{a}	359.5
Cooked Potato	10.1±0.06^{b}	0.5±0.01^{b}	2.5±0.03^{a}	0.6±0.03^{a}	85.6±1.44^{a}	0.7±0.01^{b}	357.8

Means were calculated from triplicate measurements; Means with different superscripts across columns are not significantly different (P<0.05)

Phytate content of ingredients before and after processing

Figure 1 presents the effect of treatments on the phytate contents of the uncooked and the cooked ingredients. It was observed that the treatments used in this study had significant effects on phytate levels of the ingredients. The content of all treated ingredients were significantly lower ($p<0.05$) when compared to their corresponding uncooked ingredients. Figure 1 also revealed that treated maize ingredients recorded less than 50% reduction in phytate content. this result is similar to that revealed by Hotz and Gibson [14] who obtained almost 50% reduction in phytate content in maize.

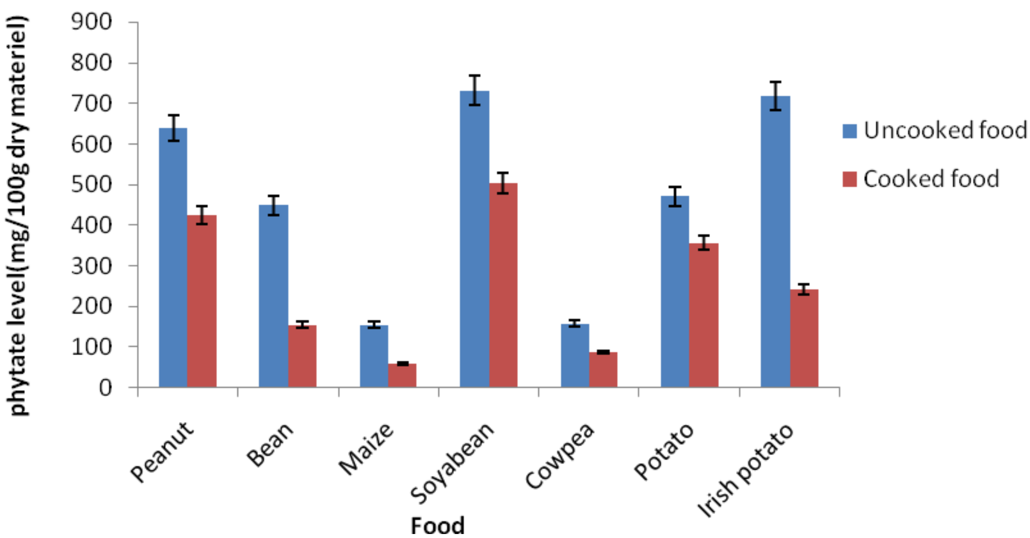

Figure 1: The effect of treatment on the phytate content

The most important anti-nutritional factors in the diet in low-income countries in terms of negative nutritional impact are phytates, which are the main constituents of cereals and pulses. The presence of phytates in foods harms the bioavailability of important minerals such as zinc, calcium [15,16] and iron [17]. Thus, through the various treatments carried out (peeling, soaking, and cooking), in this study we manage to reduce phytates and make the food edible without health risks.

Formulations of the products

The amounts of ingredients were calculated on a dry weight basis, for the formulation of RUSF. Blending trials of the different treated ingredients, based on their nutrient composition, resulted in the production of 09 ready to use supplementary foods that meet the WHO specification of RUSF and therefore could be used for the treatment of moderate acute malnutrition in children under 5 years of age.

Organoleptic quality of the products

The prepared nine RUSF formulae were subjected to sensory evaluation. Data were analyzed statistically and the best products were found out. The results of Acceptability tests of the 9 ready to eat food were presented in Table 2

Color

Potato/cowpea/Peanut (PCPe), Potato/Soybean/Peanut (PSPe), and Maize/Soybean/Peanut (MSPe) had higher color scores of 6.60, 6.47, and 6.40. The analysis of variance showed that in the case of color PCPe, PSPe, and MSPe were not significantly different ($p>0.05$) from each other but showed significant difference ($p<0.05$) when compared to the color scores of other samples.

Flavor

The highest sensory score for flavor was 5.80, 5.60, and 5,47 for Potato/Soybean/Peanut (PSPe), Irish Potato/Bean/Peanut (IBPe) and Maize/Soybean/Peanut (MSPe) respectively. In the case of flavor PSPe, IBPe and MSPe showed no not significantly different ($p>0.05$) but were different ($p<0.05$) when compared to the other samples.

Texture

Food samples with the best textures attributes were Potato/Cowpea/Peanut (PCPe) and Potato/Bean/Peanut (PBPe) with a sensory score of 5.93 and 5.73 respectively. There was no significant difference ($p>0.05$) between PCPe and PBPe.

Taste

Potato/Bean/Peanut (PBPe), Potato/Cowpea/Peanut (PCPe), Irish Potato/Soybean/Peanut (ISPe), Maize/soybean/peanut (MSPe) and scored highest in terms taste attribute with score 6.20, 5.87,6.0 and 5,87.
ANOVA showed that in case of taste, Pbp and ISp showed no significant difference ($p>0.05$), also MSPe and PCPe showed no significant difference ($p>0.05$), while PBPe, ISPe, MSPe, PCPe showed significant difference ($p<0.05$) when compared to taste scores of other samples.

Appearance

Potato/Cowpea/Peanut (PCPe) and Maize/Soybean/Peanut (MSPe) scored highest in terms of appearance with score values of 6.27 and 5,87 respectively.

Overall acceptability

The average sensory score for overall acceptance was 6.60, 6.27, and 5.87 for Maize/Soybean/Peanut (MSPe), Potato/bean/Peanut (PBPe), Irish Potato/Soybean/Peanut (ISPe). Product MSP, PBA, and PSP showed significant difference ($p<0.05$) in case of overall acceptability, while these Scores were significantly different ($p<0.05$) to the overall acceptability scores of the 6 other food samples. The overall acceptability mean showed the product MSPe is superior, which might be due to good color, taste flavor, and appearance than product PBPe and ISPe.

Table 2: Average sensory score for nine different formulas.

Sensory attributes	Samples								
	ICPe	MCPe	IBPe	PBPe	PCPe	ISPe	PSPe	MBPe	MSPe
Apparance	3.21±1.61[a]	3.87±1.25[a]	3.82±1.29[a]	4.38±0.67[ab]	6.27±1.39[b]	4.09±0.64[a]	3.68±1.02[a]	3.38±1.29[a]	5.87±0.91[b]
Coulour	3.27±1.02[a]	3.39±0.90[a]	3.27±0.99[a]	5.33±1.02[b]	6.60±1.13[b]	4.92±1.08[ab]	6.47±1.34[b]	2.96±0.92[a]	6.40±1.53[b]
Odour	5.08±1.41[a]	4,98±0.94[a]	4.23±1.91[a]	5.11±1.26[a]	4.38±0.97[a]	3.95±0.94[a]	5.22±1.17[a]	4.68±1.44[a]	4.78±0.98[a]
Taste	3.41±1,08[a]	3.24±1.09[a]	2.95±1.53[a]	6.20±1.58[b]	5.87±1.35[b]	6.0 ± 1.18[b]	2.92±1.49[a]	3.14±1.31[a]	5.87±1.09[b]
Texture	3.32±1.28[a]	3.56±0.98[a]	3.42±1.09[a]	5.73±1.06[b]	5.93±1.29[b]	4.60±1.03[ab]	4.86±0.96[ab]	2.88±1.13[a]	4.12±0.98[a]
Oilish	4.96±1.02[a]	4.86±1.21[a]	4.97±0.98[a]	3.98±1.09[a]	4.48±1.32[a]	5.01±1.37[a]	4.98±1.51[a]	5.36±1.74[a]	4.12±1.39[a]
Flavour	2.99±1.04[a]	3.41±0.99[a]	2.86±1.37[a]	5.60±1.07[b]	4.43±0.64[ab]	5.80±1.21[b]	3.97±1.38[a]	2.68±1.67[a]	5.47±1.04[b]
Overall acceptance	3.21±1.15[a]	3.27±0.94[a]	3.24±1.35[a]	6.27±1.28[b]	4.83±1.12[ab]	5.87±1.14[b]	3.29±0.98[a]	3.28±1.26[a]	6,60±1.27[b]

Means indicated with different letter are significantly different (P<0.05) depending on the student test.

Note : ICPe= Irish potato/Cowpea/ Peanuts, **MCPe=** Maize/Cowpea/Peanuts, **IBPe=** Irish potato/Beans/Peanuts, **PBPe=**Potato/Beans/Peanuts, **PCPe=**Potato/Cowpea/Peanut, **ISPe=**Irish potato/Soybean/Peanut, **PSPe=**Potato/Soybean/Peanut, **MBPe=**Maize/Bean/Peanut **MSPe=**Maize/Soybean/Peanut

Maize/Soybean/Peanut (MSPe), Potato/bean/Peanut (PBPe), and Irish potato/Soybean/Peanut (ISPe) blends with the highest score in terms of overall acceptability were subjected to another acceptability test. 10 children participated in the acceptability test and they ranged in age from 6 months to 48 months. The children's assessment was based on the proportion of the supplement food that the child consumed in 20 minutes. Figure 2 shows the percentage of children consumption after the general acceptance test.

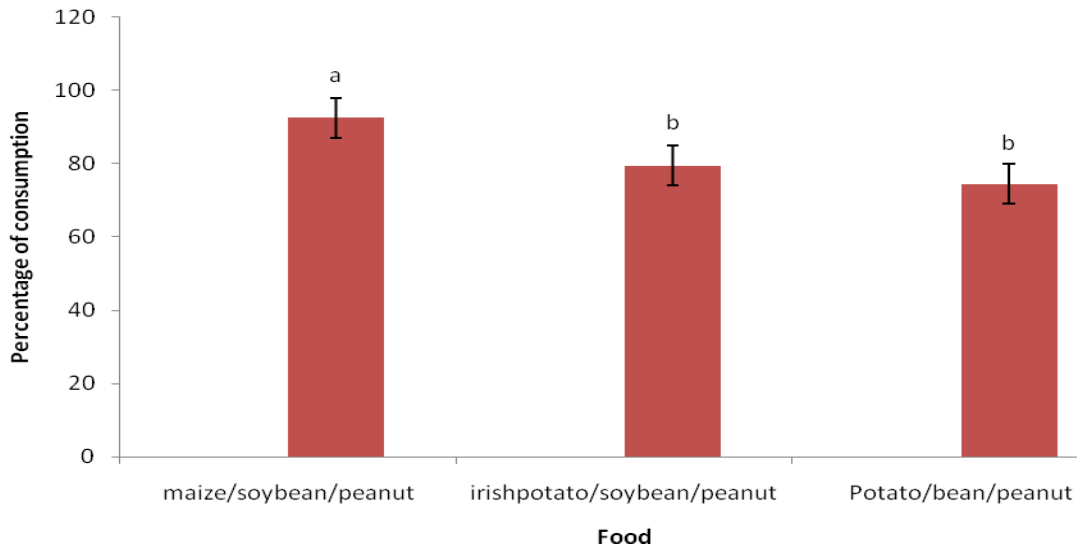

Figure 2: Percentage of food consumed by children in 20 minutes.

From the statistical analysis, the food product based on Maize/Soybean/Peanut (MSPe) was the most appreciated by the children during the acceptability test with a percentage consumption of 92.5% ± 6.74, when compared to the two other proposed foods, made respectively of Potato/Soybean/Peanut and Irish potato/bean/peanut with percentage consumptions of 79.5% ± 6.23 and 74.5% ± 7.86 respectively.

The supplementary ready-to-eat Maize/Soybean/Peanut selected contains: 20% peanuts, 21% soybeans, 19.4% corn, 19% sugar, 19% oil, and 1.6% CMV. The food products associated with the formulation of the supplement food are Maize, a high-carbohydrate source, associated with peanut rich in lipids and proteins, and soybean, rich in proteins.

The advantage of incorporating soybean into food is justified by the fact that soybean contains a balanced proportions proteins of good biological value containing all essential amino acids as well as vitamins and minerals. Its high lipid content gives it a high caloric value. Since animal proteins are often scarce and quite expensive in poor countries, the incorporation of plant proteins, especially soybean proteins, should be encouraged as they are inexpensive and available compared to other animal proteins.

Vegetable oils are important ingredients in the diets of malnourished children, they provide not only energy but also essential fatty acids, soybean oil was chosen here because it better covers the need for unsaturated fatty acids [18].

Analysis of ready to use supplementary Maize/Soybean/Peanut (MSPe) food

The Nutritional analysis of the supplementary food selected from the sensory analysis was carried out and the result is tabulated in Table 3.

The nutrient profile of this food is consistent with WHO recommendations for the treatment of acute malnutrition. ready to use supplementary Maize/Soybean/Peanut (MSPe) food possessed good quantities of protein 15.9g (11.68% energy), fat 33.7g (55.7% energy), carbohydrate 44.4g (32.62% energy) along with energy value 544.5 Kcal. These values are in line with the standards recommended by the WHO. Indeed, for the management of acute malnutrition in children, the food used must have an energy value between 520 and 550 Kcal, the energy from proteins must be between 10% and 12% and that from lipids between 45% and 60% [18]. The energy value of the formulated ready-to-use supplement food is close to that of other ready-to-use foods such as Plumpy Nut (543.4 Kcal) and RUFC India (520 Kcal) used for the treatment of moderate malnutrition [19].

The WHO recommendations for the management of moderate malnutrition in children include the use of specific foods, the elements particularly important for the feeding of children are: the content of essential fatty acids, quality of proteins, the bioavailability of micronutrients, low content of anti-nutritional factors mainly phytates and good microbiological quality. Besides, the food produced was fortified with a premix of minerals and vitamins to cover the high mineral and vitamin requirements of moderately malnourished children.

Table 3: Nutritional composition of 100 g of ready-to-use maize, peanut, and soybean-based supplemental food.

Nutrients	**Supplementary Maize/Soybean/Peanut (MSPe)**	**WHO recommendations for the treatment of acute malnutrition**
Macronutrients		
Water (g)	2.3	≤ 2.5
Energy (kcal)	544.5	520-550
Protein (g)	15.9 (11.68% enargy)	10-12% energy
Total fat(g)	33.7 (55.7% energy)	45-60% energy
Ashes (g)	2.2	-
carbohydrates (g)	44.4 (32.62% energy)	20-35% energy
Dietary fiber (g)	6.6	-
Minerals		
Calcium (mg)	66.7	300-600
Iron (mg)	14.1	10-14
Magnesium (mg)	111.0	80-140
Phosphorus (mg)	264.9	300-600 (excluding phytate)
Potassium (mg)	1118.2	1100-1400
Sodium (mg)	3.8	≤290
Zinc (µg)	12.4	11-14
Copper (mg)	1.8	1.4-1.8
Selenium (µg)	27.7	20-40
Iodine (µg)	75.0	70-140
Vitamins		
Vitamin C (mg)	54.6	50
Thiamine (mg)	0.8	0.5
Riboflavin (mg)	2.0	1.6
Niacin (mg)	9.0	5
Vitamin B6 (mg)	0.8	0.6
Folic acid (µg)	266.4	200
Vitamin B12 (µg)	1.7	1.6
Vitamin A (µg)	855.0	800-1100
Vitamin E (mg)	27.8	≥20

PDCASS = 0.95 . The values are the means of triplicate analysis

CONCLUSION

A ready-to-use supplementary food that can be used for the treatment of moderate acute malnutrition in children under 5 years of age has been formulated using pre-cooked soy flour, pre-cooked maize flour, peanut paste, sugar, soybean oil and a mineral-vitamin complex (MVC). This food complies with WHO recommendations for the management of moderate malnutrition.

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