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FORMULATION OF SORGHUM-PEANUT BLEND USING LINEAR PROGRAMMING FOR TREATMENT OF MODERATE ACUTE MALNUTRITION IN UGANDA

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A B S T R A C T

Infant and young child feeding practices in low-income countries are still inadequate leading to high rates of acute malnutrition. Formulas from local food materials are vital in formulations for management of child malnutrition in poor countries because they are affordable. Nutrient composition of sorghum-peanut blend (SPB) mixed with honey and ghee, and micronutrient-fortified corn-soy blend (CSB), a traditional food supplement, were analyzed. Proximate components and beta-carotene amounts were high in both products. Vitamin A level was higher in CSB than SPB. Proportions of essential fatty acids were low. Levels of iron, zinc, calcium, magnesium, phosphorus, potassium, manganese and sodium were adequate for recovery from moderate acute malnutrition (MAM). Energy content of CSB was 421kcal/100g while that of SPB was 430kcal/100g. Levels of condensed tannin, phytates, trypsin inhibitors and aflatoxins were below prescribed limits. In conclusion, levels of nutrients in SPB and CSB were adequate for treatment of MAM in children.

Keywords: Sorghum-peanut blend (SPB), corn-soy blend (CSB), nutrients and anti-nutrients.

INTRODUCTION

Moderate acute malnutrition (MAM) (Weight-for-Height < -2 to ≥ -3 Z scores]) is highly prevalent in low-income countries (Black *et al*., 2008; FAO, 2010). Sub-Saharan Africa is among the most hit regions with 239 million people malnourished and over 48 million of these being children (FAO, 2010). A child suffering from malnutrition has low immunity to diseases and is likely to die from common childhood ailments (Black *et al*., 2008). It is estimated that 3.5 million children under the age of five years die annually of malnutrition related illnesses (Black *et al*., 2008). Of the estimate, MAM accounts for 11% of the disease burden and mortality. In under-five mortality rates, Afghanistan, Democratic Republic of Congo, Nigeria, Ethiopia, Uganda, Tanzania, Madagascar, Kenya, Yemen, and Burma have the most immediate needs requiring interventions (Black *et al*., 2008). According to Uganda Demographic and Health Survey, 33% of children in Uganda are chronically undernourished (stunted) (UDHS, 2011). Five percent of children are acutely undernourished or wasted and 14% have low weight for their age (underweight).

Dietary management of children suffering from MAM results in recovery with reduced risk of morbidity. Fortified blended flour, largely corn-soy blend (CSB) and corn-soy blend plus milk and oil (CSB++), are the most common food supplements used for treating MAM (de Pee and Bloem, 2009). The supplementary product is fortified with vitamin A and iron. It is supplied to a targeted number of beneficiaries as a dry ration consumed in porridge form. Fortified blended flours, besides the high commodity cost, may be nutritionally deficient due to suboptimal micronutrient levels (de Pee and Bloem, 2008). A study has shown that children who recovered from MAM still remain at risk of malnutrition and death in the subsequent year after recovery (Chang *et al*., 2013).

Formulations using local foods are becoming popular for treating moderately malnourished children. At household level, optimal utilization of locally accessible nutrient-dense foods is demonstrated to be effective in dietary management of MAM (Ashworth and Ferguson, 2009). Local food materials are of low cost and yet

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provide essential nutrients required for successful recovery of children with MAM. A food product designed from local food materials would therefore be appropriate to address gaps arising from food aid. SPB was formulated based on linear programming for treating MAM in children of 6 to 59 months. Sorghum, groundnuts, honey and ghee were used in formulation. Nutrient and anti-nutrient characteristics of SPB and CSB were determined.

MATERIALS AND METHODS

Sample collection: Fresh raw materials used for formulation of SPB were locally procured from northeastern region of Uganda. Sorghum, groundnuts, ghee and honey were obtained from Nakapiripirit district, Karamoja region. Sorghum and groundnuts were sun dried for five days to moisture levels below 10%. Low-density material, particularly leaf, damaged kernels and stalk in sorghum were removed by winnowing. Dirt free sorghum was then milled into flour. Groundnuts were hand sorted to remove damaged kernels, foreign matter and the shriveled kernels. Groundnuts were roasted for 30 min using a charcoal stove before grinding to paste. Milk from Karamajong Zebu cows was traditionally processed by fermenting it for three days in pots. Fermented milk was churned in a jerrycan by hand until fat globules accumulated on top. Fat globules (ghee) were scooped off, washed to remove the whey, and then matured for one week to develop the flavor. The ghee was boiled using a charcoal stove for 30 min to remove impurities.

Formulation: Nutrisurvey computer software (2004), employing linear programming, was used for formulation of the local product. The quantity of each raw material depends on composition and the recommended daily allowances (Golden, 2009) for children between 6 to 59 months of age. Sorghum-peanut blend contained 55.2% sorghum, 18.6% peanut, 19.0% honey and 7.2% ghee. Corn-soy blend, a traditional supplementary formula, was obtained from World Food Programme and used as a control. Chemical analyses were done in triplicates to ascertain nutritional adequacy of SPB and CSB.

Proximate Analyses

Determination of protein: The amount of protein was determined by micro-Kjeldahl using the Tecator Digestion System and Kjeltec 2300 Autoanalyzer (Foss Tecator AB Hoganas, Sweden) according to AOAC (1999) method number 984.13. Samples were weighed (1g) and digested in concentrated sulphuric acid with one Kjeldahl tablet followed by distillation in 40% sodium hydroxide. The resulting solution was titrated with 0.1N hydrochloric acid using a mixed indicator (methyl red and bromocresol green).

Determination of moisture: Moisture was determined using the oven (Hotbox oven, Gallencamp, UK) drying method as described by AOAC (2000) method number 925.40. Samples were weighed (5 g) in dry petri dishes and heated in an electric oven at 105^{o}C for 5 hours. Dried samples were cooled in the desiccators, and the weight taken. The difference in weight was then obtained.

Determination of ash: The amount of ash was determined according to AOAC (1999) method number 972.15. Samples were weighed (5 g) in dry crucibles, carbonized on a hotplate, and heated in a muffle furnace at 550^{o}C for 6 hours. Ash content was determined by difference in weight after cooling samples in the desiccators to ambient temperature.

Determination of crude fiber: Crude fiber was determined using fiber analyzer (Lanbconco, Missouri, USA) according to the method outlined by Pearson (1976). Samples were weighed (1g) and transferred to a round bottom flask. Sulphuric acid (100 ml of 0.13M) was added and boiled under reflux for 45 min. The solutions were quickly filtered under suction and residues washed thoroughly with water until acid free. Residues were transferred back to flasks and 0.3M NaOH solution (100 ml) added. The mixture was boiled under reflux for 45 min and quickly filtered under suction. Residues were washed with water until base free and transferred to crucibles. They were dried to a constant weight in an oven (Hotbox oven, Gallencamp, UK) at 105^{o}C for 1 hour, cooled in a dessicator and weighed. Samples were incinerated at 550^{o}C for 8 hours and reweighed. Percentage crude fiber was then computed.

Determination of carbohydrate and energy: Carbohydrate was determined by difference in ash, moisture, fat, crude fiber and protein while energy was calculated according to Golden (2009).

Determination of beta-carotene: Beta-carotene was determined according to Harvest Plus method (Deila *et al.,* 2004) using UV-visible spectrophotometer (PerkinElmer, Lambda Bio 20, USA). Samples were weighed (0.2 g) and transferred into a mortar. Samples were mixed with acetone and then filtered into a 50 ml volumetric flask. The extract was transferred into a 500 ml separating funnel and petroleum ether (30 ml) added.

Distilled water (300 ml) was added slowly along the walls of the separating funnel. Samples were left to stand at room temperature allowing the two phases to separate and the lower aqueous phase discarded. The mixture was washed four times to remove residual acetone. In the last washing, the lower phase was discarded and the petroleum ether phase collected in a 50ml volumetric flask through anhydrous sodium sulphate. The volume was then made to the mark with hexane and absorbance taken at 450nm.

Mineral Analyses: Mineral content was analyzed using an atomic absorption spectrophotometer (Perkin Elmer, Norwalk, CT, USA) as described by AOAC (2005b) method number 975.03. Samples (2 g) were digested with concentrated nitric acid and hydrogen peroxide. Calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), zinc (Zn), sodium (Na), potassium (K) were determined at wavelengths 317.9 nm, 285.2 nm, 259.9 nm, 324.7 nm, 213.9 nm, 589.6 nm, and 766.5 nm, respectively, using an air-acetylene flame. Sodium chloride (NaCl) and potassium chloride (KCl) were used as standards for determination of Na and K. Standard solutions of magnesium oxide (MgO), calcium carbonate ($CaCO_3$) and ferrous ammonium sulphate ($Fe(NH_4)_2(SO_4)_2$) were used for determining concentrations of Mg, Ca and Fe. Phosphorus was determined calorimetrically using the spectronic 20 equipment (Gallenkamp, UK). Potassium dihydrogen phosphate (KH_2PO_4) was used as a standard for determination of phosphorus concentration.

Antinutrient Analyses

Determination of condensed tannins: Tannin content was determined using atomic absorption spectrophotometer (Perkin Elmer, Norwalk, CT, USA) according to Vanillin-HCL method (Broadhurst and Jones, 1978). A standard curve was prepared using catechin (Sigma-Aldrich Chemical, St. Louis, MO, USA). Samples (0.2 g) were mixed with 70% acetone (10 ml). The tubes containing dissolved sample in acetone were homogenized in a bath containing ice and water for 10 min and then centrifuged at 3800rpm at 4^{o}C for 30 min. The supernatant (original extract) was transferred into another tube without disturbing the residue, kept on ice and away from sunlight. The original extract (0.05 ml) was transferred into tubes and made up to 0.25 ml with 50% methanol. Vanillin (1.5 ml) and concentrated HCL (0.75 ml) were added. The tubes were homogenized and incubated at room temperature for 10 min after which absorbance was read at 500nm against a blank.

Determination of aflatoxins: Aflatest Fluorometer (VICAM V1 #4, Watertown, MA, USA) was used for determining aflatoxin in accordance with AOAC (2001) aflatest method number 991.31. A mixture of sample (50g) and salt (5g) were placed in a blender jar, to which was added methanol: water solution, 80:20 (100ml), and then blended for 1 minute. Extract was filtered through a fluted filter paper and 10ml of filtered extract transferred to a clean vessel, to which purified water (20 ml) was added and homogenized. Dilute extract was filtered through a glass microfiber filter and 1 ml (equivalent to 0.167 g sample weight) of it passed through aflatest-P-affinity column at a rate of 1 to 2 drops per second, followed by 2ml purified water, 1ml at a time. The column was eluated with 1 ml HPLC grade methanol and sample eluate collected in a glass cuvette. Aflatest developer solution (1 ml) was added to eluate, mixed and then placed in a fluorometer to measure aflatoxin content.

Determination of dietary fiber: Dietary fiber was determined using fiber analyzer (Lanbconco, Missouri, USA) according to AOAC (2000) method number 973.18. Samples (1 g) were mixed with acid detergent solution (100 ml) and dekalin (2 ml). The mixture was boiled and refluxed for 45 min. Conditioned crucibles were weighed and the reflux mixture filtered into crucibles by increasing vacuum progressively. The crucibles were then placed in an oven (Hotbox oven, Gallencamp, UK) at 100^{o}C for 1 hour, cooled in desiccators for 30 min and then weighed to determine weight of dietary fiber. Samples were weighed to ±0.0001g.

Determination of phytates: Phytates were determined by the Anion-Exchange method as described by AOAC (2000) method number 986.11. Phosphate was used as a standard. Samples were weighed (2 g) and transferred to Erlenmeyer flasks to which 2.4% HCl (40 ml) was added. The mixture was homogenized for 3 hours. Columns were prepared by adding resin (0.5 g) into the columns. After forming, resin beds were washed with 0.7M NaCl and distilled water. Homogenized samples were filtered and the filtrate (2 ml) transferred to 25 ml volumetric flasks. The Na_2EDTA-NaOH reagent (2 ml) was added and the solution diluted to volume with water. The solution was mixed and transferred to the column and the eluate then discarded. Water (15ml) and 0.1M NaCl (15 ml) were eluted through column and eluate discarded. A 0.7M NaCl (15ml) was eluted through the column and eluate collected in digestion

flasks. Concentrated H_2SO_4 acid (1ml) and HNO_3 acid (6 ml) were added to the flasks, and digested until active boiling ceased. After cooling, water (10 ml) was added; flasks swirled and heated at low temperature for 10 min to dissolve the salt. The cooled solution was transferred to a volumetric flask (50ml), molybdate solution (4 ml) and solfunic acid (2 ml) were added. The solution was diluted to volume with water and left to stand for 15 min. Absorbance was read at 880nm using atomic absorption spectrophotometer (Perkin Elmer, Norwalk, CT, USA).

Determination of trypsin inhibitor: The casein digestion method was used for determining trypsin inhibitor (Kakede *et al*., 1969). Samples (4 g) were weighed, and defatted using petroleum ether. Defatted samples were weighed (1 g) in Erlenmeyer flasks and the phosphate buffer added (20 ml). Contents were shaken on a shaker for 1 hour followed by centrifuging at 5000 rpm for 5 min. Supernatant (1 ml) was transferred to a 50 ml volumetric flask and diluted to volume with phosphate buffer. Sample aliquots (0.5 ml) were transferred to test tubes and distilled water added to make 1ml. Stock trypsin solution (1 ml) was added to each test tube and tubes placed in a water bath at 37^{o}C. Casein solution (2%, 1 ml) previously brought to 37^{o}C was added and then incubated at 37^{o}C for 20 min. The reaction was then stopped by adding 6ml of 5% trichloroacetic acid (TCA). Suspensions were thoroughly mixed on a vortex mixer and left to stand at ambient temperature for 1 hour. Suspensions were filtered, and the absorbance of filtrate and trypsin standards measured at 280 nm using atomic absorption spectrophotometer (PerkinElmer, Norwalk, CT, USA).

Determination of vitamin A: Vitamin A was determined according to AOAC (2001) method number 2001.13. Samples were weighed (10g) in 250 ml amber glass flat bottom round flasks. Ascorbic acid (0.5 g) and ethanol (50 ml) were added to the sample. Both 0.5M sodium sulphite solution (4 ml) and KOH solution (10 ml) were added to sample. Samples were saponified by boiling solution under reflux for 30 min. After hydrolysis, distilled water was added (20 ml). Solutions were cooled to ambient temperature under a stream of cold water. Samples were transferred to 250 ml separation funnels. Flasks were rinsed with distilled water (10 ml) and diethyl ether (50 ml). Funnels were swirled and left to stand to allow phases to separate. Bottom layer was collected in a flask and diethyl ether phase transferred to a separation funnel. This extraction step with diethyl ether was done three times. Diethyl ether extracts were washed with distilled water (50 ml) by inverting the funnel 5 times without shaking to avoid emulsions from forming. Diethyl ether extracts were drained in a clean flask by filtering over anhydrous sodium sulphate followed by rinsing of filter paper with diethyl ether (20 ml). Sample extracts were concentrated by drying in rotavapor at 40^{o}C and then dissolved in n-hexane (10 ml). Extracts were analyzed using TLC Silica Gel F_{254} plate. Retinol ester was used for preparing reference solution. The reference solution contained 0.01 mg retinol/µl ester (3.3 International Units (IU) from each ester/µl) in cyclohexane. A mobile phase was a mixture of ether and cyclohexane (20:80 V/V) stabilized with 1 g/l solution of butylhydroxytoluene. About 3 µl of each solution was spotted on the plate. Spots were examined in ultraviolet light at 254nm. A principal spot from test sample was confirmed by corresponding with that of retinol in the chromatogram of reference solution.

Determination of fatty acids: Fatty acids profile was determined using gas chromatography (GC) (PerkinElmer, Norwalk, USA) in accordance with AOCS (1998) method number Ce 1b-89. Samples (10 g) were mixed with chloroform (100ml) for 2 min with the Ultra-Turrax followed by centrifuging at 2000 rpm for 5 min. The mixture was filtered over a filter paper with anhydrous sodium sulphate and evaporated (20 ml) under a stream of nitrogen at 40^{o}C. Fat (0.5 g) was dissolved in diethyl ether (2 ml). A mixture of KOH in methanol (MeOH) solution (0.5 ml) was added to the dissolved fat solution. To the soap solution, water (2ml) and hexane (15 ml) were added. The mixture was shaken and left to stand to allow phases to separate after which the top layer was decanted. The mixture was washed four times with water (2 ml) to remove residual hexane. Samples were dried using anhydrous sodium sulphate. Dried samples were transferred to a GC-auto sampler vial. Samples and standards were run on the GC. Percentages of peak areas obtained were divided by the relative molecular weight of respective FAME to obtain moles percent of FA.

Statistical analysis: Data was analyzed using computer statistical software SPSS 17.0. Difference between means of proximate composition, fatty acid composition, minerals, vitamin A, beta-carotene and anti-nutrients were tested for significance using the least significance

difference (LSD) at 95% confidence level ($p<0.05$).

RESULTS AND DISCUSSION

Proximate composition

Moisture content: Levels of moisture in corn-soy blend (CSB) and sorghum-peanut blend (SPB) were 5.06% and 8.48%, respectively. Moisture content of both food products was within the range recommended (<10%) for proper storage of dehydrated foodstuff (CODEX, 2006). CSB and SPB had lower moisture contents than other formulated infant food products. Germinated popcorn-African locust bean blend and cerelac are reported to have high moisture contents of 10.2% and 11.3%, respectively (Ijarotimi and Keshinro, 2012). High moisture levels (above 10%) accelerate spoilage by promoting microbial activity and chemical reactions that reduces product shelf life. Levels of moisture in CSB and SPB were comparable to Ogi and other infant formulas (Ijarotimi and Keshinro, 2012). Sufficient drying of raw materials is critical for proper storage of supplementary foods.

Protein content: Corn-soy blend and SPB contained substantial proportions of protein (Table 1). The amount of protein in CSB was higher ($p<0.05$) than that in SPB. Protein contents of SPB (14.56%) and CSB (16.81%) were within the minimum recommended levels of 14% (N X 6.25) by CODEX (2006) for management of MAM. Accordingly, protein contents of the two supplementary food products provides for recommended daily intakes (RDI) (26g/1000kcal, 10.4% protein energy) for children of 6 to 59 months of age who are moderately malnourished (Golden, 2009). Protein recommendation by FAO/WHO and Institute of Medicine (IOM) for normal children is set at 21g/1000kcal. A diet containing 24g of protein per 1000kcal has also been recommended (Golden, 2009) for recovery of children suffering from moderate malnutrition. Peanuts contain high proportion of protein of high biological value. It has almost all essential amino acids particularly leucien and alanine. This provides SPB with adequate quantity (14.56%) of protein required for management of MAM among children.

Fat content: Fat was higher ($p<0.05$) in SPB (18.15%) than CSB (10.69%). The fat content of both products were above the prescribed minimum levels of 6% specified by CODEX (2006) for treating moderate malnutrition in children. Ghee and peanut contributes to the high amounts of fat in SPB. A child suffering from MAM has high-energy needs requiring a diet of sufficient fat content. Fat is also needed in the absorption of vitamins A and E (Michaelsen, 2009). Vitamins A and E are vital for immediate recovery from acute malnutrition and to reduce disease incidences in children. Milk-based products have been demonstrated to boost children's growth and immunity associated with fat-soluble vitamins (Diop el *et al*., 2003). It is desirable that supplementary diets contain high fat to provide the required energy to the malnourished child.

Carbohydrate content: Levels of carbohydrate in CSB and SPB were respectively, 63.60% and 51.88%. The CSB premix contained higher ($p<0.05$) proportion of carbohydrates than SPB (Table 1). Carbohydrates (sugars and starches) provide energy to cells in the body, particularly the brain. The Recommended Dietary Allowance (RDA) for carbohydrate is set at 130 g/d for children (IOM, 2005). Carbohydrates in SPB are mainly derived from honey and sorghum. About 95% of dry matter in honey is composed of carbohydrates, mainly fructose and glucose (Bogdanov *et al*., 2008). A high percentage of carbohydrates in honey comprises of simple sugars that are easily digested (Bogdanov *et al*., 2008). Levels of carbohydrates in CSB and SPB were adequate to provide sufficient energy for a child to recover from moderate malnutrition.

Total energy: Sorghum-peanut blend had higher energy content (430.38 kcal/100g) than that (421.23 kcal/100g) of CSB (Table 1). This is due to the high fat content of SPB associated with ghee and peanut. Energy density is an important quality of diets formulated for moderately wasted children given their increased energy need (Michaelsen, 2009). The energy contents of SPB and CSB were above the specified minimum value of 380kcal for fortified blended foods (FBF) by technical specifications of FAO (2004).

Dietary fiber: Corn-soy blend and SPB contained low dietary fiber (4.36 and 7.86%, respectively). The SPB had higher dietary fiber than CSB. Dietary fiber plays vital physiological and biochemical roles in digestion. Particularly, soluble fiber imparts prebiotic properties while insoluble fiber prevents constipation. According to Michaelsen (2009), constipation is not a major issue in malnourished children. This dictates low amount of insoluble fiber in the diets while that of the soluble should be high. Unfortunately, because of limited evidence on problems caused by insoluble fiber in children, no limits have been set. Based on extrapolation, a total dietary intake of 11g/1000kcal is recommended

in formulations of supplementary foods (Golden, 2009). A lower value of 0.5 g/kg body weight has been proposed (AAP, 1993). A further reference intake suggested for children 3 years and above for dietary fiber intake is 5 g plus 1 g for each year of age (Dwyer, 1995).

A study for dietary fiber intake recommends that children older than 2 years of age consume a minimal amount of dietary fiber equivalent to age plus 5 g/d (Williams *et al.,* 1995). According to Williams *et al.* (1995), a safe range of dietary fiber intake for children is between age plus 5 and age plus 10 g/d. This range of dietary fiber intake is considered to be safe for normal laxation, and helps prevent future chronic illnesses. In general, the "age plus 5" rule may be useful when determining the appropriate amounts of dietary fiber in diets for children. Based on above recommendations, amounts of dietary fiber in CSB and SPB remain within healthy levels.

Table 1: Proximate Composition of corn-soy blend and sorghum-peanut blend.

Parameter	CSB	SPB	*P value*
Moisture (%)	5.06±0.53[b]	8.48±0.09[a]	0.033
Protein (%)	16.81±0.41[a]	14.57±0.31[b]	0.027
Fat (%)	10.69±0.08[b]	18.15±0.13[a]	0.014
Ash (%)	2.59±0.00[a]	1.95±0.02[b]	0.000
Crude fiber (%)	1.25±0.17[b]	1.98±0.12[a]	0.031
Carbohydrate (%)	63.60±0.25[a]	51.88±0.19[b]	0.000
Total energy (kcal/100g)	421.23±3.09[a]	430.37±0.99[a]	0.060
Dietary fiber (%)	4.36±1.61[a]	7.85±0.07[a]	0.113

Results are expressed on dry basis except those of dietary fiber. Values in rows with different superscript letters are significantly different ($p<0.05$). Values are means of three replicates ± standard deviation.

Mineral content: The amount of ash in SPB was lower (1.95%) than that in CSB (2.59%) (Table 1). CSB is fortified with minerals. CSB is therefore expected to contain higher mineral contents than SPB. Sorghum contains reasonable amounts of mineral content close to that found in SPB (Gassem and Osman, 2003).

Levels of iron in SPB and CSB were 12.08 mg/100g and 16.67 mg/100g, respectively (Table 2). The amounts of iron in both products were within recommendations (9mg/1000kcal) for local diets formulated for malnourished children (Golden, 2009). In most malnourished children, storage levels of iron increases and may not decrease even in cases of severe anaemia. Anaemia is linked to multi-micronutrient disorders rather than iron deficiency alone. For example, it is has been associated with malaria and intestinal parasites. Iron nutrient density should therefore not be high but rather modest in diets formulated for malnourished children. Diets high in iron have been found to increase mortality rates (Ramdath and Golden, 1989). Iron supplements may therefore be recommended for other functions other than that of anaemia. It is a vital part of hemoglobin required in sizeable amounts in children (Michaelsen, 2009). This enhances oxidation of food components to provide energy, which is highly required in children. Sodium was low in the two food products, 30.41mg/100g and 27.50mg/100g for SPB and CSB, respectively (Table 2). Levels of sodium in the two products were not statistically different. Sodium is the main electrolyte in extracellular fluids. Total sodium in the body, instead of decreasing, increases considerably during malnutrition. This increase stems from the reduction in potassium concentration resulting in an electrolyte imbalance. Accordingly, sodium pump slows down consequently increasing intracellular sodium (Patrick, 1978). Diets that contain high sodium concentrations would then be detrimental arising from toxicity. Accordingly, requirements for moderately malnourished children have been set at a far lower level than those for normal children. Levels of sodium in SPB and CSB do not exceed the maximum recommended amount of 550mg/1000kcal set by Golden (2009).

Corn-soy blend contained higher amounts of zinc (4.15mg/100g) than SPB (1.74 mg/100g) (Table 2). Zinc helps in preventing diarrhea in malnourished children. It is also essential for growth, synthesis and maintenance of lean body mass (Michaelsen, 2009). Zinc is often the limiting growth nutrient in diets of populations with high prevalence of malnutrition. During weight loss, large amount of zinc is liberated from the tissue as a result of catabolism (Fell *et al*., 1973). Consequently, in moderate malnutrition muscle zinc concentration falls

from 81 to 64mg/kg (Cheek *et al*., 1970). Zinc amount in CSB was close to the range of 4.25 to 5.75mg/100g recommended by WFP (2002). The level of zinc in SPB was lower than the prescribed value. According to Williams and Mills (1970), a diet with lower levels of zinc results in anorexia hence sufficient amounts have to be availed through complementary sources to support normal growth. Meanwhile, Golden (2009) has recommended a nutrient density for zinc in local food-based diets of 13 mg/1000 kcal for moderately malnourished children. However, according to Michaelsen (2009) formulations using local foods may not attain these recommendations except through fortification.

The concentration (371.67mg/100g) of potassium in SPB varied significantly from that (626.67mg/100g) of CSB. These levels were within recommended value (1400 mg/1000 kcal) by Golden (2009). Depletion of potassium takes place in all malnourished children. Supplementary diets should contain sufficient potassium to maintain a renal excretion of 27mg/kg/day and a fecal excretion of 39mg/kg/day. Based on these considerations, potassium amount in SPB could repair tissue deficit of potassium in about three days for children. The amount of magnesium in SPB was 86.83 mg/100g while that in CSB was 71.83 mg/100g. Statistical analysis showed no significant difference in the concentrations of magnesium in the two food products. Both products met the recommended levels of 200 mg/1000 kcal (Golden, 2009). Magnesium is a growth nutrient and deficiency has a negative influence on growth since its deficiency interferes with protein utilization. Magnesium is particularly important for stunted children who need to grow. The level of calcium in SBP was 737.5mg/100g while CSB contained 891.6mg/100g. It is recommended that, diets should contain adequate amounts of calcium to avoid osteoporosis. In developing countries, even for cases of normal children, calcium levels are very low in most diets (Prentice, 1990). It is necessary that diets have sufficient calcium for normal bone density to be restored and maintained. In addition, the calcium: phosphorous ratio should be maintained within the range of 0.7 to 1.3 for all children above 6 months of age. Golden (2009) has recommended levels of 840mg/1000kcal if the formulation is to be fortified and 600mg/1000kcal if it's based on only local foods. Levels of calcium in SPB and CSB were adequate for rehabilitating a malnourished child.

Corn-soy blend contained low amounts of manganese (Table 1). The amount (2.14 mg/100g) of manganese in SPB was higher than that (0.73mg/100g) in CSB. Manganese is required during iron metabolism and its deficiency is associated with anaemia and skin lesions. Epilepsy in humans is also linked to low levels of manganese in the body (Carl, 1986). Malnourished children are shown to have lower levels of manganese compared to their normal counterparts (Garcia-Aranda *et al*., 1990). Diets for malnourished children should be rich in manganese to make-up for the deficiency. Level of Mn in SPB is above 1.2mg/1000kcal recommended by IOM (2002) for management of malnutrition among children. Phosphorus amounts (380-485mg/100g) were high (Table 2). In ill health, phosphate plays a critical role as a major acid-base buffer of the body and is critical for renal excretion of the acid generated. In moderately malnourished children, rickets is associated with phosphorous deficiency.

Phosphorous is likely to be a limiting nutrient in treatment of MAM (Michaelsen, 2009).

Table 2. Mineral contents of corn-soy blend and sorghum-peanut blend.

Minerals (mg/100g)	**CSB**	**SPB**	***P value***	**Recommended levels for MAM (mg/1000kcal)***	
				Food based	**Complement based**
Iron	16.67±1.44[a]	12.08±1.90[a]	0.128	9	18
Calcium	891.6±4.39[a]	737.5±6.96[a]	0.118	600	840
Magnesium	71.83±1.23[a]	86.83±1.91[a]	0.324	200	300
Sodium	27.50±2.16[a]	30.41±4.73[a]	0.539	550	550
Manganese	0.73±0.06[a]	2.14±0.75[a]	0.091	1.2	1.2
Zinc	4.15±0.19[a]	1.74±0.27[b]	0.012	13	20
Phosphorous	485±21.21[a]	380±14.14[a]	0.149	600	900
Potassium	626.67±30.62[a]	371.67±19.38[b]	0.013	1400	1600

CSB: Corn-soy blend; SPB: Sorghum-peanut blend; *Golden 2009. Values in rows with different superscripts are significantly different ($p<0.05$). Values are averages of three replicates ± standard deviation.

The amounts of phosphorus present in SPB meet the minimum amounts of 600mg/1000kcal recommended by Golden (2009) for diets formulated from only local foods. Phosphorous is likely to be a limiting nutrient in treatment of MAM (Michaelsen, 2009). The amounts of phosphorus present in SPB meet the minimum amounts of 600mg/1000kcal recommended by Golden (2009) for diets formulated from only local foods.

Vitamin A and beta-carotene: Sorghum-peanut blend had lower vitamin A level (204 IU/100g) than CSB (2,244 IU/100g) (Table 2). The high amounts of vitamin A in CSB premix is a result of fortification while that in SPB is solely contributed by ghee. A retinol density of 1900µg/1000kcal is recommended for a fortified food meant for management of MAM in children less than five years of age. For a diet formulated from local food materials, a retinol density of 960µg/1000kcal is considered adequate (Golden, 2009). However, if Vitamin A capsule distribution is in place with a verified wide coverage, then FAO/WHO (2001) recommends a retinol density of 600µg/1000kcal for a local food formula. Beta-carotene, a pro-vitamin A, was at 3.47mg/100g and 3.13mg/100g in CSB and SPB, respectively. The high level of beta-carotene in SPB makes it vital for supplementary feeding. Vitamin A in SPB is far below amounts recommended for supplementary feeding. This could necessitate complementing SPB with local foods rich in vitamin A.

Fatty acid profile: Palmitic (16:0), oleic (18:1, n-9), cis-11-eicosenoic acid (20:1), erucic (22:1, n-9) and arachidic (20:0) acids (Table 3) were the predominant fatty acids (FA) in CSB and SPB. Myristic (14:0), stearic (18:0), linoleic (18:2, n-6), linolenic (18:3, n-6) and lignoceric (24:0) acids were also in detectable amounts. No significant difference ($p<0.05$) existed in the proportion of FA in the two food supplements.

The proportions of total polyunsaturated fatty acids (PUFA) in SPB were 0.79% and 0.43% in CSB (Table 3). The predominant PUFA were linoleic acid (0.35% and 0.15% for SPB and CSB, respectively) and gamma-linolenic acid (0.3 to 0.45%), respectively. No significant difference was found in PUFA levels between the products, even in the two individual predominant PUFA. Omega-6-FA was found in respective levels of 0.45% and 0.31% for SPB and CSB. Omega-3- FA was less than 0.5% for both supplementary foods. Malnourished children have low levels of essential fatty acids (EFA), particularly omega-3 FA (Hansen and Wiese, 1954). Essential FA is required for brain and neural tissue development.

Table 3: The amounts of vitamin A, beta-carotene and fatty acids (%) in corn-soy blend and sorghum-peanut blend.

Parameter	CSB	SPB	*P value*
Vitamin A (IU/100g)	2244.00±569.93	204±0.00	0.124
Beta-carotene (mg/100g)	3.47±0.53	3.13±0.41	0.142
Myristic acid	0.3±0.14	0.45±0.21	0.205
Palmitic acid	3.75±3.61	5.75±1.34	0.430
Stearic acid	0.65±0.49	1.05±0.21	0.295
Oleic acid	29.60±4.24	24.95±1.34	0.448
Linoleic acid	0.15±0.07	0.35±0.07	0.295
Gamma-linolenic acid	0.30±0.28	0.45±0.70	0.500
Arachidic acid	24.70±1.27	25.1±4.81	0.899
Cis-11-eicosenoic acid	33.60±3.39	31.85±3.04	0.776
Erucic acid	5.90±3.11	8.25±0.49	0.526
Lignoceric acid	0.30±0.28	0.50±0.00	0.500
Saturated fatty acids	30.50±4.33	34.14±4.02	0.649
Mono-unsaturated fatty acids	68.94±4.74	65.06±3.92	0.641
Poly-unsaturated fatty acids	0.43±0.23	0.79±0.11	0.364
Omega-6-fatty acids	0.31±0.26	0.45±0.03	0.541
Omega-3-fatty acids	< 0.5	< 0.5	NQ
Trans-fatty acids	< 0.5	< 0.5	NQ
Omega-9-fatty acids	35.45±1.14	33.24±0.87	0.364

CSB: Corn-soy blend; SPB: Sorghum-peanut blend; NQ: Not quantified. Values in rows were not significantly different ($p<0.05$).Values are averages of three replicates ± standard deviation.

Moderately malnourished children have a dry, flaky skin resulting from the deficiency of EFA. A diet comprising of 5g/1000kcal omega-6-FA and 0.85g/1000kcal omega-3 FA is recommended for rehabilitating malnourished children. The amounts present in both food supplements were substantial albeit lower than recommendations. Levels of mono-unsaturated fatty acids (MUFA) were in substantial amounts with values of 68.94% for CSB and 65.06% for SPB. Oleic (29.60% in CSB and 24.95% in SPB), cis-11-eicosenoic (33.60% in CSB and 31.85% in SPB) and erucic acids (8.25% in SPB and 5.9% in CSB) were the most abundant MUFA. Saturated fatty acids (SFA) were relatively high with values of 34.14% for SPB and 30.50% for CSB. Stearic, myristic, palmitic and arachidic acids were the most predominant SFA present in both foods.

LEVELS OF ANTI-NUTRIENTS

Condensed tannin content: Sorghum-peanut blend had higher content (25.69 mg/g) of condensed tannins compared to CSB (3.14 mg/g). Level of tannins in SPB was close to those reported by Waniska and Rooney (2000) for sorghum. Condensed tannins even at a low level possess an astringent taste which contributes to a decreased intake of foods. Condensed tannins inhibit enzymatic digestion of protein by forming complexes with large quantities of proteins but this only occurs when present in high amounts (Knuckles *et al.,* 1985). In addition, plant-source foods, in particular legumes or a blend of cereals and legumes, contain substantial amounts of tannins which limit the absorption of some minerals. Meanwhile, tolerable levels of tannins in foodstuffs are not prescribed. It is therefore important that the amount of tannins and other naturally occurring toxins in supplementary foods be reduced through appropriate food-processing methods, such as roasting, soaking, germination, malting and fermentation.

Phytates: Phytate (myo-inositol hexakisphosphate) content was low in both food supplements. Sorghum-peanut blend had a higher content (1.53 mg/g) compared to that (0.49 mg/g) of CSB. The high levels of phytates in SPB could be due to high levels of phytates in sorghum and peanut (Waniska and Rooney, 2000). A diet containing substantial amounts of phytates reduces bioavailability of minerals particularly iron, calcium, magnesium and zinc, which are important in treatment of MAM (Michaelsen, 2009).

At the moment, prescribed limits for phytates in supplementary foods are lacking. Levels of phytates in SPB and CSB may be reduced through proper processing of sorghum and groundnuts. Supplementary foods, being a main source of energy consumed for months by moderately malnourished children, should contain reduced anti-nutrient content to avoid adverse health effects.

Table 4: Anti-nutrient contents of corn-soy blend and sorghum-peanut blend.

Parameter	CSB	SPB	*P value*
Condensed tannins (mg CE/g)	3.14±0.14^{b}	25.69±1.41^{a}	0.001
Phytates (mg/g)	0.49±0.25^{b}	1.53±0.32^{a}	0.008
Trypsin inhibitors (mg/g)	29.58±2.19^{b}	37.54±0.58^{a}	0.023

CSB: Corn soy blend; SPB: Sorghum peanut blend; Values in rows with different superscript are significantly different ($p<0.05$). Values are averages of three replicates ± standard deviation. Condensed tannins expressed in mg Catechin Equivalent (CE)/g.

Trypsin inhibitor content: Levels of trypsin inhibitors for both products were relatively high. Sorghum-peanut blend had a higher content (37.54mg/g) of trypsin inhibitors than that (29.58mg/g) of CSB (Table 4). Sorghum and peanuts contain high levels of trypsin inhibitors (Gassem and Osman, 2003). This explains the high levels of trypsin inhibitors in SPB. The high trypsin inhibitor levels in CSB are contributed largely by soy being the most concentrated source of trypsin inhibitors among all foods. But soy forms a small percentage (about 21%) of the formulation. The extrusion process used in CSB reduces levels of trypsin inhibitors explaining its low content. High levels of trypsin inhibitors may result in increased size of the pancreas and inhibition of child growth (Golden, 2009). Trypsin inhibitors can have a negative effect on growth but there is lack of data for malnourished children (Michaelsen, 2009). Thermal processing reduces the activity of trypsin inhibitor. Traditional methods such as roasting also inactivate trypsin (Hotz and Gibson, 2007). The low levels of trypsin inhibitors in SPB could be a result of processing of the raw materials.

Aflatoxin content: Sorghum-peanut blend had aflatoxin levels of 15ppb while CSB had levels of 4.5ppb. These amounts were below limits (20ppb) stipulated by FDA and Codex Alimenterius Commission (CODEX, 2006).

Aflatoxin intake has been associated with growth retardation, immune suppressing abilities and synergistic effects with infectious diseases like malaria and HIV in children. According to Michaelsen (2009) and Golden (2009), it is not possible to completely avoid this toxin and the goal is to reduce it to levels below limits 20ppb.

CONCLUSION

Sorghum-peanut blend contain adequate proportion of nutrients desirable for treatment of a child suffering from MAM. Levels of both micro and macro nutrients in SPB were adequate for recovery of children from malnutrition. However, it is important that the raw materials used in formulation are subjected to appropriate food-processing methods to minimize the amounts of anti-nutrient components in the product. Sorghum-peanut blend may, therefore, be used for management of MAM in children in rural community.

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