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Quality attributes of maize-based supplementary diets in the *in vitro* for the management of moderately acute malnourished children

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Abstract
Background and Aims: Moderate Acute Malnutrition (MAM) is a major global health problem threatening the life of approximately 33 million children and affects 15% of under- five children in sub-Saharan Africa. The efforts to reduce the burden of severe acute malnutrition and drop child mortality rate require appropriate dietary management of MAM through promotion of an affordable, readily available and locally produced supplementary food. The aim of this study was therefore to formulate and evaluate the quality of locally produced maize-peanut and maize-soybean supplementary food.
Methods: Maize-peanut and maize-soybean composite flours were produced using standard procedure, packed in air tight polyethylene bags. Maize-Peanut {MPN} (182 g) and Maize-Soybean {MSB} (171.2 g) were re-constituted to slurry using 1,300 ml of water, 8 g of sugar and 8.4 g of vegetable oil. Proximate composition, minerals, vitamins, anti-nutritional and phytochemical composition, aflatoxin and microbiological assays and sensory properties were determined using standard analytical methods.
Result: Proximate composition was moisture (74.62%±0.02; 69.11%±0.01), crude protein (7.59%±0.02; 7.19%±0.02), crude fat (3.81%±0.02; 4.79%± 0.04), crude fiber (0.17%±0.02; 0.28%±0.03), ash (0.11%±0.02; 0.10%±0.02), carbohydrate (88.31%±0.02; 87.63%±0.06) and energy (417.96±0.08; 424.05±0.22) Kcal for MSB and MPN gruels, respectively. The mineral contents were calcium (14.15±0.00; 11.81±0.00) mg, iron (5.54±0.00; 4.84±0.00) mg, zinc (3.98±0.00; 3.13±0.00) mg, and iodine (297.33±1.16; 293.00±2.00) µg for MSB and MPN gruels, respectively. Vitamin contents of MSB and MPN gruels were B1 (2.30±0.02; 2.22±0.03) mg, B3(0.08 ±0.02; 0.06 ±0.03) mg, B9 (300.00±26.46; 150.00±17.32) mg, A (1.24±0.05; 1.13±0.04) RE, and K (0.86±0.02; 1.98±0.02) µg, respectively. Tannin (0.90±0.03; 0.93±0.02) %, saponin (0.30±0.04; 0.34±0.03) %, oxalate (0.24±0.02; 0.11±0.01) mg and alkaloid (0.12±0.02; 0.10±0.02) mg contents were not significantly different between MSB and MPN gruels.
Conclusion: The formulation diets are suitable as supplementary food for the management of moderate malnutrition in children6-59 months, they provided all the required macro and micronutrients as recommended for children under this condition.

Keywords: moderate acute malnutrition; maize-peanut; maize-soybean; supplementary foods; gruel; diet formulation; dietary management

Introduction

Moderate acute malnutrition (MAM) defined as a weight-for height z-score (WHZ) between -2 and -3, and studies have shown that around 33 million children suffers from MAM which has been revealed to be a major global health problem, resulting in increased diseased condition and death and delayed cognitive development (M.M Black *et al*. 2008; R.E Black *et al*. 2013) [8, 9]. To bridge the gap created by the non- availability of the conventional supplementary foods for the management of moderate acute malnutrition, formulation using available and affordable staple food commodities has been recommended as possible approach (Solomon & Owolawashe, 2007) and considerable attention has been given to the formulation and development of nutritious complementary foods from local and readily available raw materials by many economically developing nations (Alawode, Idowu, Adeola, Oke & Omoniyi, 2017) [4]. Consequently, the need to develop low-cost nutritious supplements through combinations of less expensive foods available in the localities or communities cannot be over emphasized (Omueti, 2009) [32]. The staples such as starchy tubers like cassava, cocoyam, and sweet potato, or on cereals like maize, rice, wheat, sorghum, and millet are the habitual family foods in economically developing countries (Kunyanga, Imungi, Okoth, Vadivel, & Biesalski, 2012) [23]. It has been reported that low cost of staples compared to non-staple foods has shown that diets can be adequate in energy but deficient in micronutrients (Hoppe, Andersen, Jacobsen, Molgaard, & Friis, 2008) [18]. However, quality of supplementary foods can be improved by diversifying the diet with locally available traditional whole grains, legumes, and vegetables through optimization of nutrients in the formulation (Kunyanga, Imungi, Okoth, Vadivel, & Biesalski, 2012) [23]. Seed and nuts proteins, especially from leguminous sources such as soybean and groundnut, have been reported to be potentially excellent sources of protein to upgrade the nutritional qualities of starchy roots and tubers, from which diets of children in developing countries are formulated (Okaka & Okaka, 1990) [27]. It has been reported that that when cereals and legumes are judiciously selected and combined, a desirable pattern of essential amino acids of high biological value is eventually obtained. Cereals are deficient in essential amino acids like lysine and tryptophan, while, legumes are deficient in sulphur containing amino acids, that is methionine and cystine, but rich in tryptophan and lysine (Weledesemayat, Tufa, Urga, & Mitiku, 2016) [42]. In view of the gap created by the high cost and non-availability of the conventional supplementary foods the present study, therefore, aims at formulating supplementary foods from the combination of both cereals and legumes.

Materials and Methods

Yellow maize, soya bean and peanuts were procured from Oba's market, Ado – Ekiti, Ado Local Government, Ekiti State while the packaging material (Nylon) was purchased from Agbeni/Ogunpa Market both in Ibadan, Oyo State, South-West, Nigeria.

Product preparation

Processing method for toasted soybean flour

The soybeans were thoroughly sorted to remove all extraneous materials. This was followed by washing the sorted soybean with water, thereafter soaked at room temperature for 12-hr, drained and blanched at 80^{O}C for 10min. It was allowed to cool and dehauled and dried in a hot air oven at 100^{O}C for 2 hr. The dried soybean was dry-milled, sieved and the flour was packaged in high density polyethylene (nylon) and stored at room temperature pending formulation of the diet.

Processing method for fermented maize flour

The maize grains were sorted by removing stones and other physical contaminants. This was followed by washing the sorted maize with water. It was then steeped in water for 48-hr for fermentation to occur. The fermented maize was washed and wet milled using attrition mill and then sieved to remove the husk. This was allowed to settle overnight and was decanted, the maize slurry was put in a clean jute bag and pressed to remove the water, this was oven dried in a hot air oven at 60^{O}C for 48-hr, milled and packaged**.**

Processing method for peanut grit

The peanuts were sorted by removing the extraneous materials. It was washed and air dried at room temperature for about 12hrs, roasted and winnowed. The peanuts were thereafter blended into grits, packaged in an airtight high density polyethylene (nylon) and stored in a refrigerator.

The calculated amounts of ingredients were weighed according to the formulation and mixed together homogenously using platinum mixer (HM990-SR7198111) (Platinum Machines, Sr. No. 34/1, Dagde Wasti, Pisoli, Hadapsar, Pune-411028, Maharashtra, India) after completion of proper mixing, the products were weighed using Camry electronic kitchen scale model: EK5055, packed in nylon and sealed using QASA nylon sealing machine (QNS-3200H) (Qlink Corp, Dongguan City, Guangdong Province, 523000, China). The package was kept at room temperature throughout the period of the research. The calculated amounts of ingredients for the two formulated diets were calculated on dry basis.

Diet Formulation

Maize Flour + Peanut grits (MPN)

According to World Food Program technical specifications for ready-to-use supplementary food (2016, 2018), 100g powder of complementary foods should contain 16g of protein from natural ingredients and premix. The proximate analysis of the peanut grits prior to the formulation of the diet revealed that the peanut grit and maize contained 35.15% and 3.8% protein respectively. The peanut supplied 65% of protein in the basal 16% protein content of the 100g composite flour while maize supplied the remaining 35% of the total protein. Hence to make up the expected 16% protein content of the formulated diet, peanut grits supplied 10.4% while maize flour supplied 5.8% as shown in the calculation below.

$$\text{Peanut grits} = \frac{16}{100} \times 65 = 10.4\%$$

(protein content contribution from peanut grits)

$$\text{Maize} = \frac{16}{100} \times 35 = 5.8\%$$

(protein content contribution from maize flour)

To calculate the weight of individual component of the composite flour (Maize-peanut MPN)

Peanut grits

100g = 35.15g protein (protein content of the peanut grits from the proximate analysis prior to formulation)

Xg = 10.4g of protein (protein contribution from the peanut grits to the composite flour)

$$Xg = \frac{100 \times 10.4}{35.15} = 29.6g$$

(grams of peanut grit in each sachet of the MPN composite flour)

Maize flour

100g = 3.8g protein (protein content of the maize flour from the proximate analysis prior to formulation)

Xg = 5.8g protein (protein contribution from the maize flour to the composite flour)

$$Xg = \frac{100 \times 5.8}{3.8} = 152.6g$$

(grams of maize flour in each sachet of the MPN composite flour)

A sachet of the supplementary diet was made of 152.6g maize flour

Total weight of MPN sachet = 182g (29.6g peanut grits + 152.6g maize flour)

Maize Flour + Soy-bean flour (MSB)

Maize – soybean composite four (MSB) was also formulated based on World Food Program technical specifications for ready-to-use supplementary food (2016, 2018), 100g powder of complementary foods should contain 16g of protein from natural ingredients and premix. The proximate analysis of the soybean flour prior to the formulation of the diet revealed that the soybean flour and maize flour contained 43.8% and 3.8% protein respectively. The soybean flour supplied 65% of protein in the basal 16% protein content of the 100g composite flour while maize supplied the remaining 35% of the total protein. Hence to meet the expected 16g protein content of the formulated diet, peanut grits supplied 10.4g while maize flour supplied 5.6g as shown in the calculation below:

Soybean Flour

$$\frac{65}{100} \times \frac{16}{1} = 10.4\%$$

(protein content contribution from soybean flour)

Maize flour

$$\frac{35 \times 16}{100} = 5.8\%$$

(protein content contribution from maize-flour)

To calculate the weight of individual component of the composite flour (Maize-soybean MSB)

Soy bean flour

100g = 43.8g protein

Xg = 10.4g of protein

$$Xg = \frac{100 \times 10.4}{43.8} = 23.7g$$

(grams of soybean flour in each sachet of the MSB composite flour)

A sachet of the supplementary diet was made of 23.7g of soybean flour.

Maize

100g = 3.8g protein

Xg = 5.6g

$$Xg = \frac{100 \times 5.6}{3.8} = 147.4g$$

(grams of maize flour in each sachet of the MSB composite flour)

A sachet of the supplementary diet was made of 23.8g of soybean flour

Total weight of MSB sachet = 171.2g (23.7g soybean flour + 147.4g maize flour)

Preparation procedure of the formulated diets

The gruel was prepared according to World Food Program (2018). A sachet or packed formulated supplementary food was reconstituted using 700ml of clean water at room temperature, the mixture was thoroughly mixed to ensure that there was no lump, thereafter additional 850ml of clean boiled water was added slowly, was continuously stirred with spoon and cooked for about 5 minutes until the gruel is set. Two tea spoons (8 g) of sugar and vegetable oil (8.4 g) were added respectively to increase the energy content, satiety and add some taste to the gruel.

Chemical Analysis

The supplementary foods were analyzed for moisture, crude protein, crude fat, ash and crude fiber by AOAC method (2010) [7], the carbohydrate content was determined by difference (that is: % Carbohydrate=100 – (% Crude fibre+% Fat+% Ash+% Moisture+% Crude protein), the energy was calculated by Atwater factor (FAO, 2003) [12]. Calcium and Magnesium content of the samples was determined using the standard method described in AOAC (2010) [7]. Potassium and Sodium content of the sample was determined using flame photometry method described by James (1995) [20]. Manganese (Mn), Selenium (Se), iron (Fe), zinc (Zn), Copper (Cu) by Atomic Absorption Spectrometry method described by James (1995) [20], Phosphorus was determined using molybdovanadate method while Iodine was determined titrimetrically using the method described by Kirk and Sawyer (1991) [21]. Thaimine, Riboflavin, Niacin and vitamin C were determined using the method described by Okwu and Josiah (2006) [30]. Vitamin B_6 and B_{12} was determined using the method described by Gaurav, Ashok, Amit & Gaurav (2011) [13]. The method described by Gill *et al* (2018) [14] was used to determine the Biotin content of the formulated diet. Vitamin B_9 and K was determined using the method described by Gaurav *et al* (2011) [13]. Vitamin A was determined the method described by Rodriguez-Amaya & Kimura (2004) [36] and vitamin D and E was determined using the method described by Kirk and Sawyer (1991) [21]. Saponin, tannin, alkaloid and oxalate content was determined using the method described by Onwuka (2005) [34].

Statistical analysis

All values are expressed as mean ± SD, t-test was performed using one-way ANOVA to obtain the significance between the supplementary foods (MSB and MPN).

Results

Energy and Proximate compositions of the formulated supplementary foods (gruel)

The moisture (74.62 %), crude protein (7.59%), ash (0.11%) and carbohydrate (88.31%) contents of MSB gruel were significantly ($p<0.05$) higher than that of MPN gruel (69.11%, 7.19%, 0.10% and 87.63% respectively). However, MPN is significantly higher in crude fat (4.79%), crude fiber (0.28%) and energy (422.39 Kcal) when compared to MSB (3.81%, 0.17% and 417.89 kcal respectively).

Minerals content of formulated supplementary foods (gruel)

The selenium and copper contents of MSB and MPN gruels were less than 0.05mg/100g. Besides, both gruels had the same potassium (2.7 mg/100 g) contents. The MSB gruel had 12.58, 14.15, 5.54, 3.98, 97.16 mg/100 g and 297.33 µg/100 g of sodium, calcium, iron, zinc, phosphorus and iodine when compared to MPN gruel (10.87, 11.81, 4.84, 3.13, 87.48 mg/100 g and 293.00 µg/100 g), respectively. However, the magnesium and manganese contents (14.30 and 10.87 mg/100 g) of MPN gruel were significantly ($p<0.05$) higher than those (11.10 and 9.99 mg/100 g) of MSB, respectively. Furthermore, gruel from MSB possesses higher Ca/K ratio (4.95 mg/100g) than MPN (4.13 mg/100g) gruel.

Vitamin composition of formulated supplementary food diets (gruel)

Vitamin B1 (2.30 mg), B7 (2.95 mg), B9 (300.00 µg) and K (0.04 µg) of MSB gruel are significantly ($p<0.05$) while vitamin B2 (0.05 mg), B3 (0.08 mg), are significantly ($p>0.05$) higher compared to those in MPN gruel (2.22mg, 2.16mg, 150.00µg, 0.03µg, 0.03 mg and 0.06 mg respectively). However, vitamin B12 (190.00 µg), C (45.37 mg) and E (1.98 µg) of MPN gruel are significantly ($p<0.05$) higher than B12, C and E (120.00 µg, 41.00 mg and 0.86 µg, respectively) in MSB gruel.

The anti-nutrient content of the formulated complementary food samples (gruel)

The tannin and saponin contents of MPN gruel (0.90% and 0.34%, respectively) were higher than the contents of MSB gruel (0.90% and 0.30%, respectively) though not significantly (p>0.05). In contrast, the oxalate and alkaloid contents of MSB gruel (0.24 and 0.12 mg, respectively) were higher than 0.11 and 0.10 mg, respectively in MPN gruel.

Discussions

Energy and Proximate compositions of the formulated supplementary foods (gruel)

The moisture contents (69.11 – 74.62 %) of the gruel (MPN and MSB) were lower than the value (82.10-86.85 %) reported by Ponka *et al*. (2015) [35] and by Ukegbu & Anyika (2012) [41] (74.50-77.29 %) in five varieties of pap commonly consumed in Maroua, Far-North Cameroun and in supplemented maize pap consumed in Ngor-Okpala Local Government Area of Imo State, respectively. Similar high moisture content was reported (Nwamarah & Amadi, 2009) [26] for complementary/supplementary foods and gruel. Result was contrary to the findings of Omenna *et al*. (2018) [31] who reported lower moisture content (between 63.26 and 64-52 %) for fermented maize, millet and sorghum/soybean pap. A probable reduction in the energy and nutrient densities of the complementary/supplementary foods at high moisture content has been previously reported (Ukegbu & Anyika, 2012; Ponka *et al*., 2015) [41, 35]. Studies have also shown that staple foods such as maize, millet and sorghum are high in starch and therefore absorb a lot of water during cooking which makes them bulky and results in eating larger volume of food to obtain enough energy and nutrients (FAO, 2004). The protein content of tMPN and MSB were significantly different (p<0.00) from each other and ranged from 7.19 to 7.59 %. This finding is consistent with the ranges (6.76-7.88 % and 4.3-8.44 %) reported for North-western Nigeria maize-millet pap (Anigo *et al*., 2010) [6] and co-fermented maize-millet- sorghum-soybean pap (Omenna *et al*., 2018) [31]. The current protein contents are higher than 2.22, 4.48 and 4.67-5.23 % reported for yellow pap, sorghum pap eaten in Nasarawa state (Makanju, 2012) [24] and complementary foods in North Western (Anigo *et al*., 2009) [5] of Nigeria, respectively. The crude fiber values (0.17-0.28 %) obtained for the gruels was similar to the findings (0.14-0.21 %, 0.33-2.57 %) of Ponka *et al*. (2015) [35] and Ukegbu & Anyika (2012) [41], respectively. Adepeju, Abiodun, Dauda, and Fatiregun (2016) recommended low levels of fiber in infant formulations to encourage digestion and absorption in infants. Foods used for complementary/supplementary feeding should contain low fiber so as to avoid high water absorption, displacement of nutrient and energy needed for the growth of children (Klim *et al*., 2001) [22]. Ash content of the gruels of the formulated diet (0.10-0.11 %) is lower than the ash contents (0.83–1.35 and 0.75–4.82 %) reported for pap commonly consumed in Maroua (Ponka *et al*., 2015) [35] and maize gruel (pap) consumed in Ngor-Okpala lga, Imo State, Nigeria (Ukegbu & Anyika, 2012) [41], respectively. The carbohydrate content of the gruels form of the formulated diets were significantly high (87.63-88.31 %). A similar pattern of result was reported by Ponka *et al*. (2015) [35] in Marou, Far-North Cameroun and by Ukegbu & Anyika (2012) [41] in Nigeria, though the values were slightly lower (79.49-85.29 %) and (77.29 %). The high carbohydrate content of the supplementary diets could be attributed to presence of maize, a cereal that formed the major constituent of the carbohydrate-based foods. The high carbohydrate levels could also be as a result of the microflora enzyme hydrolysis via fermentation which led to the synthesis of complex carbohydrates from other nutrients carbon skeletons (Onoja, Akubor, Gernar, & Chinmma, 2014) [33]. The present result falls within the range (55-75 %) recommended (WHO, 2003) [45] for all ages except children <2 years. However, the relatively high carbohydrate content of the formulated supplementary foods is an indication that the products would be effective in managing the MAM children (Ibironke *et al*., 2012). The total energy value calculated from the two formulated gruels fell within the codex recommendation for energy value (400-425 kcal/100g). The formulated foods (flour and gruel) are very good sources of energy, which could be attributed to the protein, carbohydrates and mostly fat contents. These energy-dense products could contribute in meeting the energy requirements of the MAM children.

Minerals content of formulated supplementary foods (gruel)

The mineral composition of the formulated supplementary diets showed that iodine and phosphorus were the most abundant. The finding also showed that the potassium, calcium, magnesium, iron and zinc,contents of the diets were low when compared with the WHO (2012) [46] standards proposed for the supplementary foods for the management of MAM children. This observation could be due to the sources of the formulated food samples, which are majorly plant based. However, the diets are nutritionally enough to cater for the needs of the children when complemented with their family diets.

The present values (10.87-12.58 mg/100 g) of sodium is lower than 32.7–42.00 mg/100 g reported for complementary foods from maize-carrot-pigeon pea flour blends (Bello *et al*., 2020) [8] but within the range (11.1 – 21.1 mg/100g) reported on three potential complementary foods from cereals and legumes (Solomon, 2005). However, current result is higher than 7.12 -8.56 mg/100 g reported for maize-millet-soybean complementary foods (Akinsola *et al*. 2017) [3]. Many studies have further reported different results (1.11-2.75, 0.78-3.39 and 73.78-150 mg/100 g) for sodium contents of complementary foods (Ukegbu & Anyika, 2012; Ponka *et al*., 2015 [41, 35]; Anigo, Ameh, Ibrahim & Danbauchi, 2010) [6]. High sodium intake has been linked with raised blood pressure (Gilbert & Heiser, 2005) and high blood pressure established during childhood can track into adulthood. The result obtained is in comformity with the recommendation of Scientific Advisory Committee on nutrition (SACN, 2003) [3] that sodium requirement of children should be low. Moreso, severely malnourished children usually have abnormally high levels of sodium (Golden, 2009) [15] and are deficient in potassium, therefore supplementary foods for their management should contain an adequate amount of potassium to maintain renal and fecal excretion of it. The low sodium content of the supplementary food is an indication that it is not harmful and will not have adverse effect on the kidney if consumed (Derbyshire & Davies, 2007) [11], hence can be a recommended diet in the management of moderately malnourished children.

The calcium content of the MSB and MPN gruel ranged (11.81 – 14.15 mg/100g). The result from this study showed that the calcium content of the gruels were considerably low when compared to the children's recommended dietary allowance. Several studies (Bolarinwa, Olajide, Oke, Olaniyan & Grace, 2016; Anigo, Ameh, Ibrahim & Danbauchi, 2010; Ponka *et al*., 2015 [6, 15]) have shown higher values of calcium in complementary/supplementary foods; 18.01-25.10 mg/100g, 27.68-47.95 mg/100g, and 30.2- 89.96 mg/100g, respectively. However, current finding was very low compared to the proposed WHO recommendation of 170-400 mg/100g of calcium in formulated supplementary foods. Considering the importance of calcium in formation and maintenance of teeth and bone health in infants and young children, this formulated product is not a good source of calcium. Thus, it should be further fortified or fed in combination with the family foods. This would help in reducing the incidence of substantial osteoporosis found among malnourished children (Reichman & Stein, 1968).

The present magnesium values (11.10 – 14. 30 mg/100g) of MSB and MPN gruels were lower than the WHO proposed recommendation (420 mg/100g) for the management of children with MAM (WHO, 2012) [46]. Contrary to this findingd Okoye & Ene (2018) reported lower magnesium values (0.64 - 1.26 mg/100g and 3.57-5.78 mg/100g) of fortified complementary foods in their respective studies. The magnesium values for all the formulated diets were low relative to the Codex Alimentarius Commission's recommendations which ranged from 40 mg to 76 mg/100g magnesium level in formulated complementary foods. In essence, the low magnesium content of the formulated diets could be attributed to maize that formed the significant part of it.

The potassium content of both gruels had the same value of 2.86 mg/100g. Potassium content is lower than 1500 – 2200 mg/100g proposed by WHO (2012) [46] for the management of children with MAM, hence the formulated complementary diets should not displace but rather be fed with family foods. This low value could be attributed to the food processing (fermentation) of the maize used in the formulated diets.

The values of phosphorus obtained (87.48 – 97.16 mg/100g) was significantly high. Results (1.42 – 2.47 mg/100g and 28.90 – 31.13 mg/100g) from different studies were not in agreement with the findings of this study (Bello, Akpaoko & Ntukidem, 2020; Akinsola, Idowu, Oke, Idowu & Laniran, 2017) [8, 3]. However, several studies reported higher values for phosphorus (105.35 -162 mg/100g, 92.03 - 171.32 mg/100g and 141.8 – 231 mg/100g) in fortified millet based ogi (Shalem, Ayasi & Onah, 2019), complementary food gruels from malted cereals, soybeans and groundnut (Anigo, Ameh, Ibrahim & Danbauchi, 2010) [6] and five varieties of pap commonly consumed in Maroua, Far-North, Cameroun (Ponka *et al*., 2015) [15] respectively. The high phosphorus content of the formulated diets could be attributed to their constituents and processing methods. The phosphorus content can be traced to the constituents (soyabeans and peanuts) of the formulated diet (Hother *et al*., 2016). On the other hand, fermentation is a processing method that could have contributed to the increase in the phosphorus content. Golden (2009) [15] reported that phosphorus requirement for the moderately malnourished child should equal or even exceed that of the severely malnourished child because of the additional requirement for bone formation.

Vitamin composition of formulated supplementary food diets (gruel)

Vitamin B_1 (2.30 mg), B_7 (2.95 mg), B_9 (300.00 µg) and K (0.04 µg) of MSB gruel are significantly ($p<0.05$) while vitamin B_2 (0.05 mg), B_3 (0.08 mg), are significantly ($p>0.05$) higher compared to those in MPN gruel (2.22mg, 2.16mg, 150.00µg, 0.03µg, 0.03 mg and 0.06 mg respectively). However, vitamin B_{12} (190.00 µg), C (45.37 mg) and E (1.98 µg) of MPN gruel are significantly ($p<0.05$) higher than $B_{12,}$ C and E (120.00 µg, 41.00 mg and 0.86 µg, respectively) in MSB gruel (Table. III). The thiamin content of the formulated supplementary diets (2.49-2.87 mg/100 g) is lower than 10.27-15.09 and 6.75-11.02 mg/100 g reported for millet-pigeon pea-crayfish (Okoye *et al*., 2019) and maize-black bean-crayfish (Okoye & Ene, 2018) complementary foods, respectively. It has been reported that daily requirement of thiamine depends on age, body weight, physiological conditions, and individual metabolism with respect to the overall energy content in the diet and that body requirements of thiamin is exclusively dependent on dietary supply as there is no endogenous synthesis (Hiffler, Rakotoambinina, Lafferty, & Garcia, 2016). The present thiamin content obtained in this study is within the range (>1 mg/100 g) proposed for the supplementary diet for the management of MAM children (WHO, 2012) [46]. Thiamin has an oustandingly clean safety profile with no upper dose limit (Hiffler, Adamolekun, Fischer, & Fattal-Vavleski, 2017), hence the formulated diet will provide the needed thiamin and there will be no side effect.

The vitamin A content of the gruel ranged from 1.13-1.24 mg/100g. This is within the vitamin A content (0.31-2.25 mg/100g) of cereal and legume based complementary food in Ethiopia (Yohannes *et al*., 2020) but lower than the value (3.01-14.66 mg/100g) found in maize-based complementary foods supplemented with black bean and crayfish flours (Okoye & Ene, 2018). Vitamin A plays a vital role in the maintenance of good sight and functioning of the immune system. Increase in vitamin A intake can reduce childhood deaths from measles, diarrhea, malaria and pneumonia by 25%. A high level of vitamin A in the diet has been suggested considering the widespread and severe effects of deficiency in malnourished children, their depleted hepatic stores, and the low fat content of the diet. A low-dose (5000 IU) vitamin A capsule has been advocated for moderately malnourished children when food based approach is adopted (Golden, 2009) [15].

The vitamin E content of the formulated gruel varied from 0.86 to 1.98 µg/100g. MPN gruel recorded a higher vitamin

E content than MSB. This could be as a result of peanut used in MPN formulation and this is in agreement with the report that peanut is a good source of vitamin E (Sanders, 2003). Vitamin E content found in this study is lower than the value (2840-12450 µg/100g) reported in maize-based complementary foods supplemented with black bean and crayfish flours (Okoye & Ene, 2018). Vitamin E is an important vitamin required for proper function of many organs in the body (Okoye & Ene, 2018). Malnourished children are prone to oxidative stress and have low levels of vitamin E, cholesterol, plasma selenium, albumin and zinc (Manary, Leeuwenburgh & Heinecke, 2000). Hence, supplementation and dietary diversification has been suggested as a possible solution to vitamin E deficiency most especially in malnourished children who may not get enough from their diets.

The anti-nutrient content of the formulated complementary food samples (gruel)

The tannin and saponin contents of MPN gruel (0.90% and 0.34%, respectively) were higher than the contents of MSB gruel (0.90% and 0.30%, respectively) though not significantly (p>0.05). In contrast, the oxalate and alkaloid contents of MSB gruel (0.24 and 0.12 mg, respectively) were higher than 0.11 and 0.10 mg, respectively in MPN gruel. The tannin content of the gruels (0.90 - 0.93 %) is lower than the value (15.57-37.42 %) seen in gruels formulated from malted cereals, soybeans and groundnut (Anigo, Ameh, Ibrahim & Danbauchi, 2010) [6] but similar to the value (0.12 - 0.22 %) in co-fermented maize-millet-sorghum-soybean pap (Omenna, Olanipekun & Ogunwale 2018) [31] respectively. The saponin content varied insignificantly from 0.30 - 0.34 % in MSB and MPN gruel respectively. Saponin content of present study is lower than the value (1.41 - 3.13 %) obtained in malted millet, plantain and soybean flours as reported by Bolarinwa, Olajide, Oke, Olaniyan & Grace (2016). Saponin is one of the anti-nutritional factors found in soybeans, however, the MSB saponin content was lower than that of MPN. This could be attributed to the processing method (soaking and blanching) of the soybean used in this study.

Oxalate content ranged from 0.11-0.24 %, though insignificantly (p > 0.05). The range obtained in this study is higher than the value (0.04-0.24 %) reported by Adepoju & Etukumoh (2014) [1] in nutrient composition of four commonly used local complementary foods in Akwa Ibom state, Nigeria.

The alkaloid content obtained from this study (MPN and MSB) varied insignificantly from 0.10 - 0.12 %. Finding of the present study is lower than the alkaloid content (9.26 - 14.16 %) of malted red sorghum-defatted soybean complementry food (Agbaje *et al.*, 2017) [2]. The tannin, saponin, oxalate and alkaloid contents of MSB and MPN gruels could be considered insignificantly low as a result of the processing methods, thus cannot constitute or hinder bioavailability of nutrients.

Table 1: Energy and proximate composition (%) of formulated supplementary foods (gruel as consumed) per 100g

Parameter	MSB Gruel	MPN Gruel		
	Mean ± SD	Mean ± SD	t-value	p-value
Moisture (%)	74.62 ± 0.02	69.11 ± 0.01	523.0	0.000***
Crude Protein (%)	7.59 ± 0.02	7.19 ± 0.02	22.3	0.000***
Crude Fat (%)	3.81 ± 0.02	4.79 ± 0.04	-38.3	0.000***
Crude Fibre (%)	0.17 ± 0.02	0.28 ± 0.03	-5.3	0.006**
Ash (%)	0.11 ± 0.02	0.10 ± 0.02	0.4	0.692
Carbohydrate (%)	88.31 ± 0.02	87.63 ± 0.06	-123.8	0.000***
Energy (Kcal)	417.89± 0.08	422.05 ± 0.22	-194.6	0.000***

Values are means ± standard deviation of triplicates. determination of samples p < 0.05 is significant.
MSB = Maize – Soybean, MPN = Maize-peanut. *P < 0.05 ** P < 0.01 *** P < 0.001

Table 2: Mineral contents (/100 g) of supplementary foods (gruel as consumed)

	MSB Gruel	MPN Gruel	*WFP		
Minerals	Mean ± SD	Mean ± SD		t-value	p-value
Sodium (mg)	12.58±0.00	10.87±0.00	270	1209.9	0.000***
Calcium (mg)	14.15±0.00	11.81±0.00	535	1403.8	0.000***
Magnesium (mg)	11.10±0.00	14.30±0.00	150	-2259.2	0.000***
Iron (mg)	5.54± 0.00	4.84-±0.00	10	479.5	0.000***
Potassium (mg)	2.86± 0.00	2.86±0.00	900	0.0	1.000
Zinc (mg)	3.98± 0.00	3.13±0.00	11	526.0	0.000***
Phosphorus (mg)	97.16± 0.00	87.48±0.02	450	828.7	0.000***
Iodine (µg)	297.33±1.16	293.00±2.00	100	3.2	0.031*
Copper (mg)	0.02±0.00	0.04±0.00	1.4	-14.5	0.000***
Manganese (mg)	9.99±0.00	10.87±0.00	1.2	-658.0	0.000***
Ca/K	4.95±0.02	4.13±0.02			

Values are means ± standard deviation of triplicates. Determination of samples P < 0.05 is significant. MSB = Maize – Soybean, MPN = Maize-peanut, *WFP, 2016. *P < 0.05 ** P < 0.01 *** P < 0.001

Table 3: Vitamin contents (/100g) of supplementary foods (gruel)

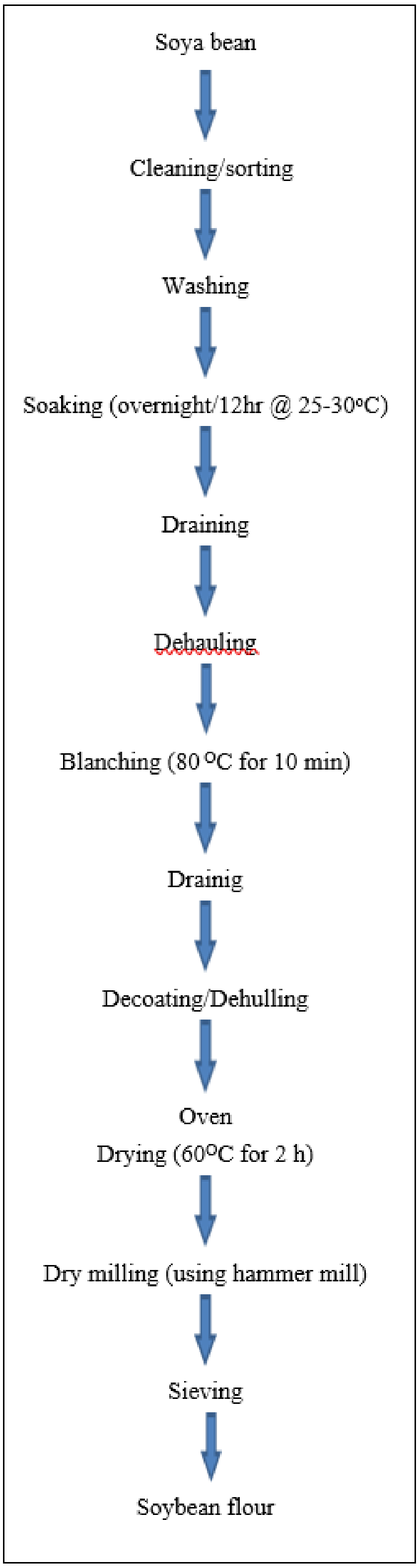
Vitamins	MSB Gruel	MPN Gruel	*WFP		
	Mean ± SD	Mean ± SD		t-value	p-value
Vitamin B_1(mg)	2.30 ± 0.02	2.22±0.03	1.0	5.1	0.007
Vitamin B_2(mg)	0.05±0.03	0.03 ±0.01	2.1	1.1	0.346
Vitamin B_3(mg)	0.08 ±0.02	0.06 ±0.03	13	1.0	0.368
Vitamin B_6(mg)	0.18 ±0.02	0.20±0.01	1.8	-1.6	0.184
Vitamin B_7(mg)	2.95 ±0.08	2.16±0.04	60	20.9	0.000
Vitamin B_9(µg)	300.00±26.46	150.00±17.32	330	8.2	0.001
Vitamin B_{12}(µg)	120.00±20.00	190.00±30.00	2.7	-3.4	0.028
Vitamin A (RE)	1.24 ±0.05	1.13 ± 0.04	550	3.4	0.031
Vitamin D(µg)	0.18±0.00	0.06 ±0,00	15	59.4	0.000
Vitamin E(µg)	0.86 ±0.02	1.98 ±0.02	16	-63.3	0.000
Vitamin K(µg)	0.04 ±2.52	0.03 ±2.31	900	9.5	0.001
Vitamin C(Mg)	41.17 ±0.28	45.37±0.12	60	-34.0	0.000

Values are means ± standard deviation of triplicates determination of samples P < 0.05 is significant. MSB = Maize – Soybean, MPN = Maize-peanut, WFP, 2016

Table 4: Anti-nutrient and phytochemical (/100g) content of the formulated supplementary foods (gruel)

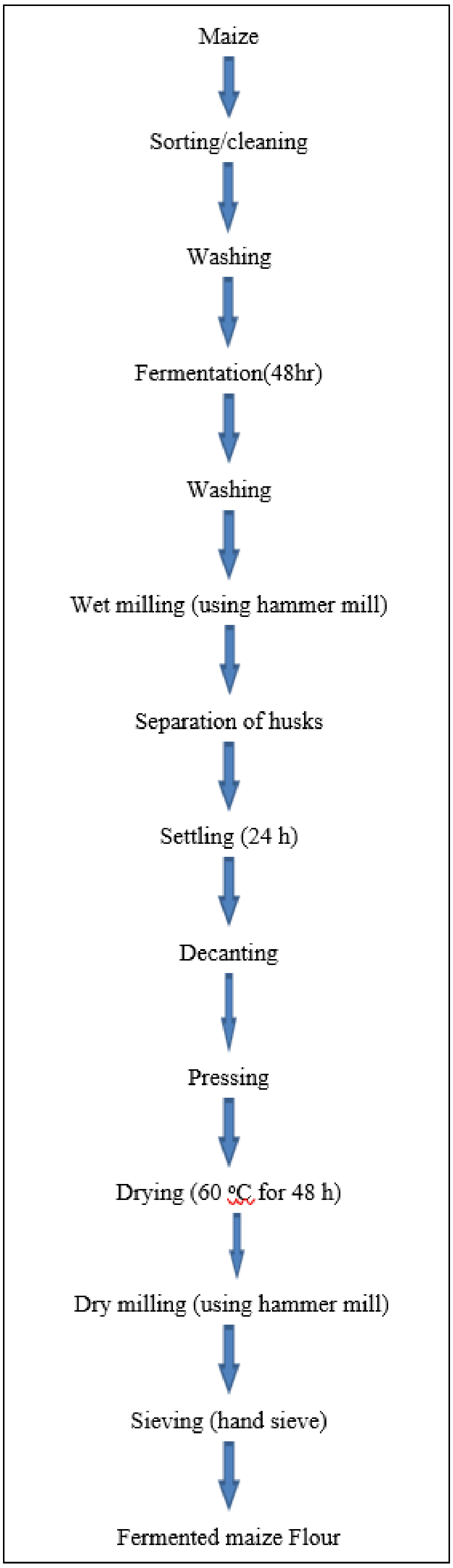
Anti-nutrients/ phytochemical	MSB Gruel	MPN Gruel		
	Mean ± SD	Mean ± SD	t- value	p-value
Tannin (%)	0.90±0.03	0.93±0.02	-1.4	0.238
Saponin (%)	0.30±0.04	0.34±0.03	-1.4	0.241
Oxalate (mg)	0.24±0.02	0.11±0.01	10.5	0.000
Alkaloid (mg)	0.12±0.02	0.10±0.02	1.6	0.184

Values are means ± standard deviation of triplicates determination of samples P < 0.05 is significant.
MSB = Maize – Soybean, MPN = Maize-peanut.



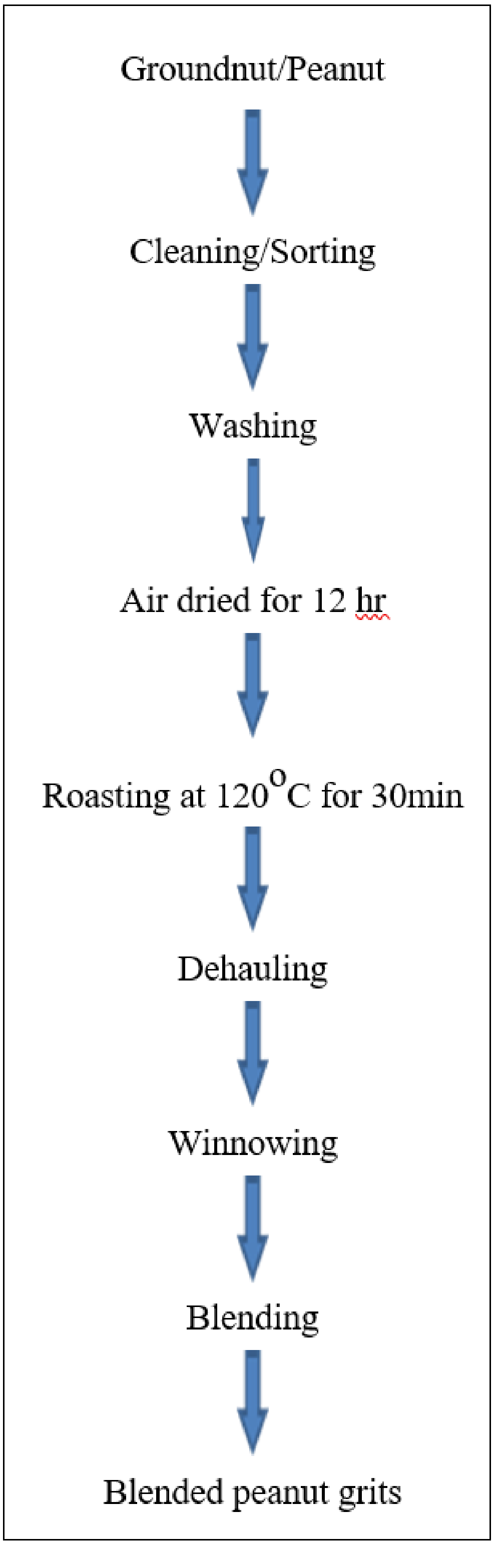
Ihekoronye & Ngoddy (1985)

Fig 1: Flow chart for the production of soybean flour



Awoyale, Maziya-Dixon & Menkir, 2016

Fig 2: Flow chart for the production of fermented maize (ogi) flour



Modified method of Ikeze *et al*, 2016

Fig 3.3: Flow chart for the production of groundnut grit

Conclusion

Conclusively, the optimum nutrient quality of the supplementary food formulated from maize-peanut and maize-soybean was found to conform with FAO/WHO requirement for children with moderate acute malnutrition. The food formulation prepared are suitable as supplementary food for the management of moderate malnutrition in children6-59 months, they provided all the required macro and micronutrients as recommended for children under this condition.

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Contributor's statement

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Declaration of competing interest

None of the authors has any conflict of interest to declare in relation to this quality improvement project.

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