



International Journal of Food and Nutrition Research (ISSN:2572-8784)



Formulation of a Complementary Flour with High Nutrient Density and Micronutrient Content

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ABSTRACT

Child malnutrition is one of the biggest problems affecting about 195 million under five children in low income countries, such as Malawi. The most common forms of malnutrition are protein-energy malnutrition, vitamin A deficiency, zinc deficiency and Iron deficiency anemia. Complementary foods are generally cereal based and do not meet the nutrient requirement as recommended by the World Health Organization. The aim of this study was to improve iron and zinc contents of the usual traditional maize-based complementary porridge by blending it with high energy and micronutrient rich locally available foods.

Raw materials used in the formulation of the complementary flour underwent simple household level food processing technologies such soaking, roasting and germination. The control complementary flour was prepared from 100% raw maize flour. Individual complementary flours were analyzed for proximate composition using standard methods while iron and zinc were determined using atomic absorption spectrophotometer. Pumpkins had significantly high amount of iron (68 mg/100g) and energy (460.03 Kcal) compared to all the ingredients. Zinc was significantly high in pigeon peas roasted at 160 °C for 40 minutes. The protein content in pigeon peas fluctuated with raw pigeon peas having 14.69 g/100g which was significantly (P=0.05) lower than the protein content of pigeon peas roasted at 40 and 15 minutes (21.25 g and 20.2 g/100g respectively). Significant (P=0.05) increase in the mean iron and zinc contents of germinated finger millet from 11.57 to 13.57 mg/100g were observed at the 48 and 72-hour germination time respectively as

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How to cite this article:

Chikondi Memory Liomba, Catherine Nkirote Kunyanga, Angela Adhiambo. Development Of Multimix Composite Flour As Complementary Food For Infants In Malawi. International Journal of Food and Nutrition Research, 2018; 2:11.

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compared to 7.6 mg/100g observed in raw finger millet. After proximate composition four complementary porridge flours were developed by blending each of the analyzed flour in varied proportions. Linear programming was used to optimize nutrients of the formulated products to meet micronutrient and macronutrients requirements of the target group. The formulated flour combinations and the control were evaluated based on the macronutrient and micronutrients targets for a recommended nutrient intake daily ration of complementary food for the age group 6 to 24 months old children. The complementary flours in which millet, pumpkins and pigeon peas were incorporated provided significantly ($p < 0.05$) higher amounts of iron, zinc, energy, protein than the control. All four formulations were able to meet iron, zinc, protein, carbohydrate and energy recommended nutrient requirements for infants. However formulation CPV1 and CPV2 had higher nutritional value and nutrition density than the rest of the formulations. Therefore based on these results it can be concluded that complementary flour made from maize alone can be improved by incorporating millet, pigeon peas and pumpkins since they have shown to improve the amount of zinc, iron and protein which may in turn help reduce protein energy malnutrition and iron and zinc deficiencies

Key Words: Iron deficiency; zinc deficiency; complementary flour; optimization; legumes; pumpkins, Finger millet; optimization

Introduction

In developing countries such as Malawi, chronic malnutrition is prevalent and begins during infancy [1]. Lack of food, improper infant and child feeding practices critically affects child growth, development and survival when coupled with high rates of infections during the first two years of life [2]. In Malawi, the most common forms of malnutrition are protein-energy malnutrition (PEM), vitamin A deficiency, zinc deficiency (64% for under five children) disorders, and Iron deficiency anemia (22% for under five children)[3]. Meals are prepared mainly from indigenous cereals and legumes [4]. The use of legumes and cereals make composite foods suitable for infant and young child feeding is well founded [5].

Maize, millet and pigeon peas are indigenous African cereal grains and pulses of considerable

nutritional and cultural importance in Africa [6]. Pumpkin (*Cucurbita moschata*) is an important traditional plant food of indigenous communities. Pumpkins produce high yield, have high amount of minerals and long storage life [7]. Pumpkins are available in Malawi almost throughout the year. Pumpkin flour could be used to supplement cereal flours in complementary porridge and bakery products to improve nutritional and sensory qualities of such products [8, 9]. However, to the knowledge of the authors, no report has been given on the effect of blending dried whole pumpkin fresh and seeds flour to cereal-legume complementary foods.

These African plant foods are often characterized by high levels of anti-nutrients such as phytates and oxalates which are potent inhibitors of bioavailability of zinc, iron and calcium [10]. Consumption of foods that contain

antinutrients by infants and young children can predispose them to malnutrition [11,4]. This in turn affects the children's immune systems leading to diseases such as pneumonia, diarrhoea, malaria and acute malnutrition [12].

Soaking, germination and roasting are important household food processing methods. Germination has been an indigenous technique practiced in most rural areas of Malawi. Though the locals attribute this practice to improved beverage taste from germinated grain, the practice also improves their nutritional value of the foods. Soaking has also been an indigenous technique practiced in rural communities of Malawi especially for cereal grains and legumes before cooking. It said to soften the grain and therefore cooks faster. These processing treatments are also effective in eliminating the antinutritional factors in foods [13]. The effects of some processing methods on the nutritional values of some legumes have been reported [14, 15].

Several types of commercial weaning foods are marketed in Malawi, even though these foods are available and nutritious, most of them are expensive and only available for the rich. Rural mothers therefore depend on available low-cost food mixtures to wean their infants and these consist mainly of un-supplemented cereal porridge made from raw maize.

Thus, this study investigated the potential of roasting, soaking and germination in developing complementary Cereal-pulse-vegetable based complementary porridge flour for infant feeding (6-24 months) and the effect of these indigenous processing technologies on proximate composition of the ingredients. Secondly the study aimed at utilizing linear programming to optimize the macronutrient ratio of these foods using locally available, traditionally accepted and used Malawian ingredients. Linear programming is a tool that has been used successfully to evaluate and formulate complementary foods and children's diets [15], using locally available foods to create optimal diets that meet nutritional requirements.

2. Materials and Methods

2.1. Study Setting

The study took place in Agriculture Research Trust laboratories in Lilongwe district. This is where processing of ingredients, proximate composition and formulation of the products was done. Kasungu district was where the raw ingredients were sourced. The major crops produced in this district include maize, sorghum, millet, groundnut, cowpea, soybean, gram beans, common beans, pigeon peas, pumpkins and sweet potatoes. Some of the produce mentioned was used in the formulation of the porridge flour that was developed.

2.2. Ingredients used for processing of complimentary foods

Maize (*Zea mais*), finger millet (*Eleusine coracana*), pigeon peas (*Cajanus Cajun*) and pumpkins

(*Cucurbita maxima*) were purchased from the local market in Kasungu district in Malawi.

2.3. Study Design

The experimental design of this study is shown in Table 1. There was a total of 5 treatments.

2.4. Product formulation

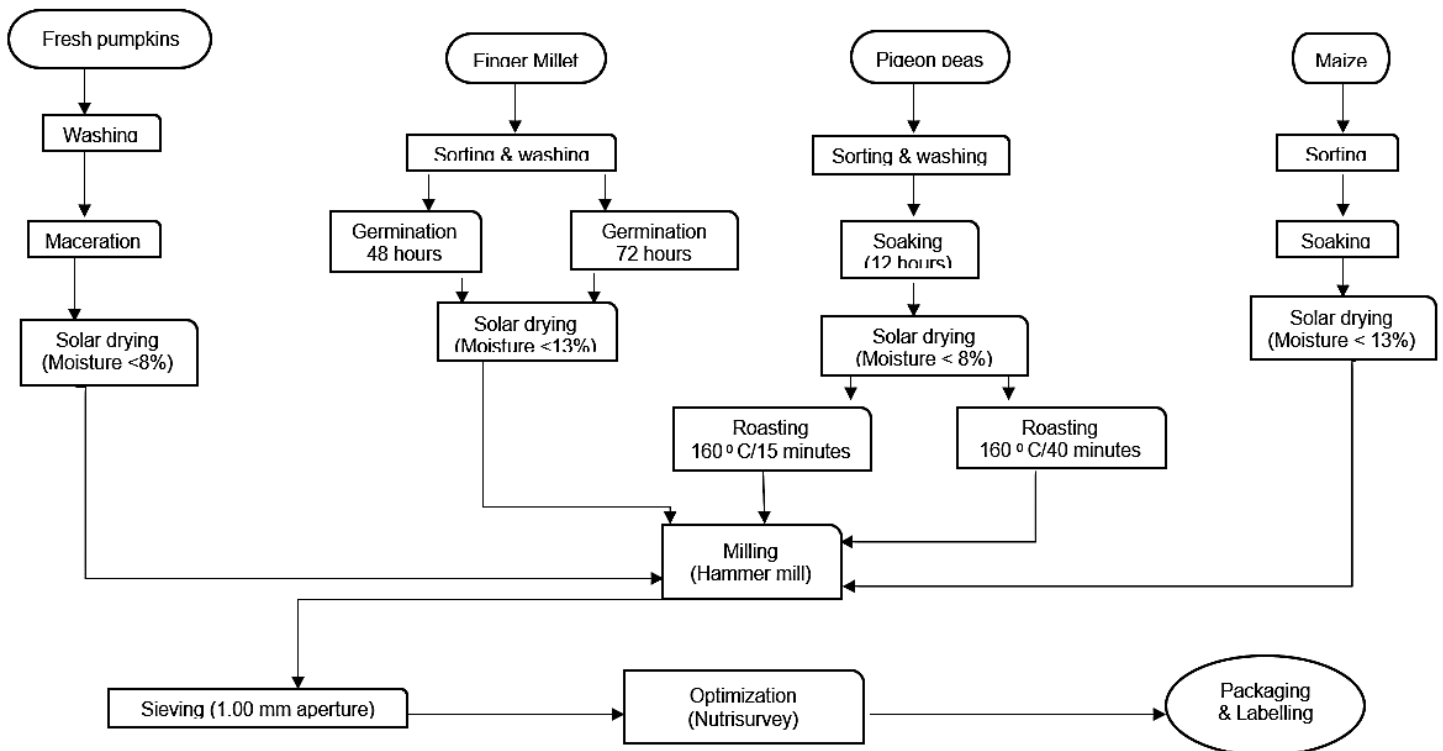
The ingredients were divided into two portions. The first portions of maize grains, finger millet and pigeon peas were not subjected to any form of treatment apart from milling and were used as control. The second portions underwent various processing methods such as roasting, germination and soaking (figure 1).

2.3. Nutrient Analysis

Pumpkin flour, unprocessed finger millet flour (control), germinated finger millet flour, unprocessed pigeon peas (control), roasted pigeon peas flour, soaked maize and unprocessed maize flour (control) were analyzed for proximate composition, zinc and iron contents in triplicates using the standard methods as described by AOAC [16]. Iron and zinc were estimated using the atomic absorption spectrophotometer (Varian AA 20 Leicestershire, England).

Table 1: Study Design

Roasting	Germination (Room Temperature)	Soaking (Room Temperature)	Drying (<8% moisture)
1. Pigeon peas 40 min/160 °C	Millet 48 hours	Maize 24 hours	Pumpkins
2. Pigeon peas 15 min/160 °C	Millet 72 hours	Maize 24 hours	Pumpkins
3. Pigeon peas 40 min/160 °C	Millet 72 hours	Maize 24 hours	Pumpkins

**Figure 1: Flowchart diagram for preparation of multimix complementary flour**

2.4. Description of food optimization methodology

Maize, millet, pigeon peas and pumpkins blends in optimized proportions formed the basis of the formulations of complementary foods. Nutrient content of each ingredient obtained from proximate assessment results was entered in Nutrisurvey (2010 version) to modify the food data base to suit the composition of Malawian foods. To optimize iron, zinc, protein and energy contents of the flour to be formulated linear programming of Nutrisurvey (2010 version) was used. The proportions of maize flour, millet flour, pigeon peas flour and pumpkin flour were determined on the basis of the recommended nutrient intakes (RNI) for iron, zinc, energy and

protein for infants 6-23 months old [17]. Five foods, Control (traditional maize porridge), CPV1, CPV2, CPV3 and CPV4 were formulated.

3. Data Analysis

Data were analyzed using statistical package for social sciences (IBM SPSS 22 statistic). The mean scores were analyzed using analysis of variance (ANOVA) method and difference separated using Dunnet test. A p-value of < 0.05 was regarded as being statistically significant.

Results and Discussion

4.1. Nutrient composition of the raw materials used in the formulation

4.1.2. Moisture content for all ingredients

Table 3 shows the nutritional composition of raw ingredients which did not undergo any food processing apart from milling. The moisture content of finger millet was significantly higher (10.84 %) than that of other ingredients ($P < 0.05$). Isingoma and others found similar results with moisture content of finger millet at 10.44 %. There was no significant difference in moisture content for maize, pigeon peas and pumpkin flour. The moisture content for maize (7.43%) agrees with that of Jemberu [18] who found that the moisture content of maize flour that was used during the formulation of maize based complementary food was 7.82%.

4.1.3. Finger millet

Proximate assessment for unprocessed millet flour (FMRw) showed that the carbohydrate content, iron and zinc contents were 76.2 %, 7.6 mg/100 g and 3.49 mg/100 g respectively (Table 4). Studies have reported carbohydrate content of 79.5%, iron content of 9.9 mg/100g flour and zinc content of 4.8% in finger millet which are very close to the present study findings (Bachar et al., 2013). The protein content in this study is within the reported of 5.6-12.7 mg by Paragya and Raghuvanshi [19]. Even if the fat content of finger millet in this study was significantly higher (3.87%) than that found by Bachar and others [20] finger millet cannot be used as a good source of fat in formulation of high energy complementary foods. The difference in the study findings on fat could be attributable to varietal and geographical differences.

4.1.4. Maize

Table 2 shows the nutritional composition of unprocessed maize flour. The amount of carbohydrate was 78.32%, iron 2.01 mg/100 g and zinc was 3.81 mg/100 g. Results on carbohydrate content for maize (78.32%) compare closely with findings by Govender [21]. The high amount of carbohydrate found in maize flour gives it an upper hand to improve the carbohydrate content of complementary foods for children. However the amount of zinc and iron were very low at 2.01 mg/100 and 3.81 mg/100 respectively. This provides an evidence

on why communities that depend on maize alone as a complementary food for children have high micronutrient deficiencies. Ogbe and Affiku [22] reported 6.0 mg of zinc and 1440 kcal energy against 2.1 mg zinc and 382.7 kcal energy observed in the present study. Muhimbula et al., [23] also reported protein content of 31.62-35.59 g and iron content of 20.34-33.68 mg which are quite higher than the present study findings.

4.1.5. Pigeon peas

The values of crude protein, crude fat and total carbohydrate for raw pigeon peas flour (PPRw) were recorded to be 20.62%, 2.67% and 65.23% respectively. The fat content for all samples is lower than that reported by Akande [24]. This variance may be due to varietal difference. The high amount of carbohydrate found in this study indicates that pigeon peas can also be a good source of energy in infants' foods. The nutrient content as regards to crude protein was 20.62% which is with the WHO/FAO recommended nutrient intake for infants. Nutritionally, pigeon peas protein is an excellent complement to lysine-limited cereal protein, hence the basis for the use of pigeon peas flour as an economical protein supplement in cereal based complementary foods [25]. Pigeon pea is a high protein legume and incorporation of pigeon peas flour in infant foods has a greater potential in overcoming protein-calorie malnutrition in the world [26]. Crude fibre content, which represents the amount of indigestible sugar in the pigeon peas fall within the acceptable range of 1.52 to 0.42% [27]. The importance of fibre in human diet cannot be over emphasized. Fibre helps to maintain the health of gastro intestinal tract, and also prevent colon cancer [28]. Reports have shown that diets that are low in fibre are undesirable as they could cause constipation and such diets have been associated with diseases of colon like piles, appendicitis, and cancer.

4.1.6. Pumpkin

Whole Pumpkin flour with rind removed (PKd) had a significantly high amount of fat, zinc, iron and energy ($p < 0.05$) than the rest of the

ingredients (Table 2). The high amount of fat, iron and zinc makes pumpkins a cheap and good source of these nutrients and justifies its ability to be used to formulate high energy and micronutrient rich infant foods [29]. Pumpkins also had a significantly high amounts of fibre

though the fibre was within the recommended range of <5% (FAO/WHO 2004). Fibre prevents constipation but high amounts of fibre in the seeds could be a challenge in infants' diet since it causes irritation of the gut mucosa [30].

Table 2 Nutrient composition of raw ingredients

Variables	Moisture	Cho	Protein	Fat	Ash	Fibre	Energy	Iron	Zinc
MRw	7.43±0.13 ^a	78.32±0.23 ^a	9.34±0.18 ^a	3.56±0.06 ^a	1.35±0.01 ^a	1.00±0.00 ^{ab}	382.70±1.07 ^a	2.01±0.07 ^a	3.81±0.10 ^a
PPRw	7.56±0.17 ^a	72.92±0.29 ^b	14.69±1.43 ^b	0.95±0.36 ^b	3.90±0.02 ^b	1.52±0.28 ^b	359.0±1.00 ^b	3.45±0.3 ^b	4.31±0.05 ^b
FMRw	10.84±2.23 ^b	76.20±1.65 ^a	8.13±0.18 ^a	3.87±0.02 ^a	0.96±0.56 ^a	0.54±0.10 ^a	372.15±7.02 ^a	7.60±0.73 ^c	3.49±0.05 ^a
PKd	7.14±0.05 ^a	38.59±0.45 ^c	17.40±0.38 ^c	26.23±0.052 ^c	10.64±0.05 ^c	3.50±0.21 ^c	460.03±0.17 ^c	68.32±0.45 ^d	6.11±0.18 ^c

Values are mean (n=3) ± standard error on dry weight basis, values with different superscript in the same row significantly different (Dunnett test, P= 0.05) MR_w= Raw maize, PPR_w= Raw pigeon peas, FMR_w= Raw finger millet, PK_d= Dried pumpkin flour, CHO= Carbohydrate

4.2. Nutrient composition of the processed raw materials used in the formulation

4.2.1. Germinated finger Millet

The total mineral content for finger millet germinated for 72 hours (FMGd48) was higher (2.52%) than the total mineral content for finger millet germinated for 48 hours (FMGd72) though the difference was not significant. No significant differences were observed in values of FMGd48 and FMGd72 for gross energy. The amount of iron in finger millet germinated for 72 hours was significantly higher (13.57mg/100g) than that of finger millet germinated for 48 hours (p <0.05). These results are in agreement with Inyang and Zakari [31] who reported that the amount of iron increased from 3.3 mg/100 g (ungerminated) to 4.5 mg/100 g (germinated). This indicates that germinating millet for a longer period than 48 hours increases iron content in the millet. Therefore, germination could be an appropriate food-based strategy to derive iron and other minerals maximally from food grains [32]. The high iron content observed in finger millet could help address the iron deficiencies that are common among infants and preschool children in Kasungu and the whole Malawi. On the contrary, the amount of crude fat decreased with germination time. The fat content in millet

germinated for 48 hours was significantly higher (P= 0.05) at 3.81 g/ 100 g as compared to 2.67 g/ 100 g for millet germinated for 72 hours. Chaudhary and Vyas [33] also noted similar results on crude fat concentration during a study on the effect of germination time on finger millet on nutrient composition. They found that finger millet germinated for 24 hours had a high amount of crude fat (2.03 g/100 g) while that germinated for 48 hours had a low amount (1.23 g/ 100 g) of crude fat and this difference was significant (P=0.05). Several researches have coded reason for reduction in fat content during germination which could be due to total solid loss during soaking prior to germination or use of fat as an energy source in germination process which was used as the major source of carbon for seed growth as fatty acids are oxidized to carbon dioxide and water to generate energy for germination.

4.2.2. Roasted Pigeon Peas

The moisture content of pigeon pea seed as affected by the processing treatments is presented in Table 3. Roasting for 40 minutes at 160 °C significantly (P<0.05) decreased the moisture content of the pigeon peas to 1.38%. This was expected as seeds were subjected to higher temperatures for a longer time. The

lowest moisture content registered by roasted pigeon peas flour sample indicates that the flour is better preserved by roasting the pigeon peas seeds compared to other treatments [33] and nutrients would be preserved. It has been reported that higher moisture content leads to food spoilage through microbial actions [34]. Reduced moisture content ensures the inhibition of microbial growth, hence is an important factor in food preservation [35]. The result indicates that roasting may favor keeping quality of pigeon peas.

The protein values of the flour from roasted pigeon peas flour were slightly different but the difference was not significant ($p < 0.05$). The slight increase in the protein value of the processed pigeon peas may be due to break down of crude protein to amino acids during processing, Oboh [36]. The high values obtained for protein in this research (20.62% and 21.25%) indicates that pigeon peas is a good source of protein and compares favorably with values obtained for other legumes like cowpea [37] and kidney beans [38]. It has been earlier reported that when food is subjected to roasting, the activity of proteolytic enzymes is increased [39]. The higher protein value obtained for the roasted sample is due to the increased activity of proteolytic enzymes, which hydrolyzed inherent proteins to their constituent amino acids and peptides.

The zinc contents of the roasted pigeon were also high at 7.5mg/100 g and can be used to

compliment low zinc cereal flours in production of complementary flour for weaning children. The amount of fat obtained in this study was very low for pigeon pea and therefore pigeon peas cannot be used as a good source of fat when formulating infant foods.

4.2.3. Soaked Maize

In the present study, maize flour that had been soaked for 24 hours (MSRs) (Table 3) had slightly lower crude protein (8.65) and fat content (3.56) compared to raw maize flour sample (MRw) (Table 3). These were higher than those found in the literature for the maize flour, which was 7.7g/100g [40]. The difference could be attributable to variety differences and geographical variation. The protein content of white maize is generally low (Johnson 2000, p38) [41]. White maize is known to have low levels of the essential amino acids lysine, methionine and tryptophan [42]. A study conducted by Scott, and others (2006) found that lower density maize plants contain limiting amounts of the essential amino acids lysine and tryptophan. These limiting amino acids are high in pulses and legumes such as pigeon peas therefore this gives a basis of complementing maize flour with pulses and legumes. Iron content significantly increased ($P < 0.05$) from 2.01mg/100 in MRw to 2.85mg/100 in MSRs. Though iron content increased it is still very low below the recommended amount (11-16 mg/100) as such maize flour is not a good source of iron.

Table 3: Nutrient composition of processed raw materials

Variable	Moisture	Cho	Protein	Fat	Ash	Fibre	Energy	Iron	Zinc
MSd	4.94±0.12 ^a	82.00±0.15 ^a	8.65±0.10 ^a	3.39±0.08 ^a	1.02±0.01 ^a	1.05±0.046 ^a	393.11±0.86 ^a	2.85±0.14 ^a	3.34±0.11 ^a
PPRs15	5.07±0.06 ^a	68.17±1.34 ^b	20.62±0.32 ^b	2.67±0.07 ^a	3.47±0.06 ^b	1.16±0.10 ^a	379.20±1.84 ^b	6.02±1.10 ^b	6.74±2.13 ^b
PPRs40	1.38±0.11 ^b	69.90±0.57 ^b	21.25±0.18 ^b	4.17±0.43 ^b	3.3±0.10 ^b	0.42±0.04 ^b	402.13±2.02 ^c	7.25±2.37 ^b	7.5±2.75 ^b
FMGd48	10.86±1.83 ^c	74.34±0.97 ^c	8.75±0.18 ^a	3.81±0.03 ^a	2.24±0.14 ^a	1.16±0.10 ^a	366.65±3.94 ^d	11.57±0.24 ^c	3.10±0.05 ^a
FMGd72	11.76±1.88 ^c	74.09±1.75 ^c	8.96±0.21 ^a	2.67±0.82 ^b	2.52±0.09 ^{ab}	1.59±0.03 ^a	356.23±8.17 ^e	13.57±0.49 ^d	4.11±0.17 ^c

Values are mean ($n=3$) ± standard error on dry weight basis, values with different superscript in the same row significantly different (Dunnett test, $P = 0.05$) MSd= Soaked maize, PPRs15= pigeon peas roasted for 15min/160 °C, PPRs= Pigeon peas roasted for 40 min/160 °C, FMGd48= finger millet germinated for 48 hours, FMGD72= Finger millet germinated for 72 hours, CHO= Carbohydrate

4.2.4. Optimization of cereal–legume blends using linear programming model

Table 4 shows nutrient contents of optimized cereal–pulse-vegetable composite flours. It was found that it is possible to achieve optimal complementary foods that meet energy, protein, iron and zinc requirements through blending different local ingredients to make one product. In this study, improvements in energy balance were achieved by the addition of pumpkin seed flour which had the highest amount of fat (26.23%) than the rest of ingredients, while improvements in protein quantity were achieved by the addition of pigeon peas which had the highest amount of protein of (14.69-21.25%).

Optimization of macronutrients (Fat, protein, carbohydrate, energy) and micronutrients (iron and zinc) ratios was achieved in all the cereal-pulse-vegetable combinations of the developed flours. Each flour blend met over 80% of the RDA for iron, zinc, protein, carbohydrate and energy. Protein intake in infancy stimulates growth, and there is a strong positive association between protein intake at 9 months of age and later height and weight [43]. Improvement of dietary protein quality by the introduction of

higher-quality protein varieties of maize has had positive effects on growth in children in studies conducted in Africa, Asia, and Latin America [44]. Another consideration for protein requirements is the need for increased protein during infection and recovery and in energy deficit [45]. Infants and young children in developing countries can suffer from multiple infections per year, each lasting for 1 to 2 weeks [46], which will increase protein and lysine requirements [47].

A diet that is moderately deficient in energy (5% below requirement) can increase protein needs by 10% [48]. Thus, a complementary food blend that helps a child meet his or her daily energy requirements and has additional lysine will improve utilizable protein to meet increased needs. In addition, the macronutrient balance achieved in the optimized blends may be important in the prevention of stunting: in a study of different types of fortified complementary food, including sprinkles, Nutritabs, and energy-dense, fat-based Nutributter, all had positive effects on motor development in children 6 to 12 months of age, but only Nutributter positively affected growth [49]

Table 4 Nutrient contents (g/100 g) of optimized cereal–pulse-vegetable composite flours

Formulation	Protein	CHO	Energy	Fat	DF	Zinc(mg/100g)	Iron(mg/100g)
CPV1	12.8	67.1	391.8	8.0	2.1	4.5	20.5
CPV2	11.9	70.2	392.6	7.1	1.8	4.3	17.3
CPV3	14.1	66	387.6	7.5	1.8	5.2	21.2
CPV4	12.4	69.5	398.6	7.9	1.5	4.7	19.3

Values are mean (n=3) ± standard error on dry weight basis, values with different superscript in the same row significantly different (Dunnet test, P= 0.05) CPV1= Germinated finger millet (48 hours), roasted pigeon peas (15 minutes), pumpkin flour and soaked maize (70:10:10:5) CPV2 = Germinated finger millet (48 hours), roasted pigeon peas (40 minutes), pumpkin flour and soaked maize (70:15:8:7) CPV3 = Germinated finger millet (72 hours), roasted pigeon peas (15 minutes), pumpkin flour and soaked maize (50:20:20:10) CPV4 = soaked maize, Germinated finger millet (72 hours), pumpkin flour and roasted pigeon peas (15 minutes), (60:15:15:10) DF= Dietary fibre, CHO= Carbohydrate

2.5.4. Expected nutrient intake from cereal-pulse-vegetable porridges compared to maize porridge (100%) and WHO guidelines

Table 5 shows the number of servings, amount per serving, amount of solids in the serving, cost of the porridges per day and the % RNI expected to be met by the porridges made from these flour

formulations. After adjusting on the expected number of porridge servings per day basing on WHO guidelines for infant feeding, traditional maize porridges (control) and all formulations (CPV1, CPV2, CPV3, CPV4) met the RNI for providing energy for children aged 7-24 months. Foods for infants should be energy dense because of the limited gastric capacity in young children coupled with the need for increased nutrient intake [50]. The formulated cereal-pulse-vegetable porridges if integrated in the feeding practices of local communities and combined with nutritional education could address children's energy needs.

However, for the maize porridge there was a very huge gap for iron for it only catered for less 30% of the RNI for all the age groups of infants. MDHS [51] reported that among children aged 6-24 months Kasungu district, central region of Malawi plain maize porridge and sometimes maize-soy porridges were the main complementary foods and only 5.3% of under five children were fed with minimum acceptable diet. Prolonged consumption of maize porridge by infants and young children as their primary food puts them at high risk for developing ID and IDA [52]. This could be the reason why iron deficiency anaemia prevalence rate is still high in Kasungu at 60% among under five children [53].

On the other hand the rest of the formulations (CPV1-CPV4) met the recommended RNI for iron and zinc. This is because high iron (millet and pumpkin) flours were blended with the low iron maize flour. Despite adding high fat food (pumpkin) the fat gaps still remained for all children for it was below 50%. Maize flour porridges fortified with pigeon peas, pumpkins and millet have the potential of meeting RNIs for energy, protein, iron and zinc. In this study, improvements in energy balance and iron were achieved by the addition of pumpkin flour which had the highest amount of fat (26.23%) and iron (68.32mg/100 g) than the rest of ingredients, while improvements in protein quantity were achieved by the addition of pigeon peas which

had the highest amount of protein (up to 21.25%). All the porridges costed less than \$ 1 per day.

2.6. CONCLUSION

Development of low cost nutritious foods can be done by blending the commonly consumed maize with other locally available foods using simple household level technologies. This could be a practical food based approach aimed at combating malnutrition among infants and children in Malawi and other developing countries. Weaning foods developed from local food materials complied with the infants food specification outlined by FAO/WHO. Nutrient analysis found that pigeon peas had the highest protein content (14.69% to 21.25%) among all ingredients. Iron content was high in millet than in maize but pumpkin had the highest amount of iron amongst all the ingredients (68.32 mg/100 g). Zinc was also highest in pumpkins and closely followed by pigeon peas. Traditional technologies, such as germination, soaking and roasting of cereals and legumes could be easily adopted to prepare weaning foods for they improve their nutrient content as seen in this study.

Competing Interests

Authors have declared that no competing interests exist.

Acknowledgement

The authors would like to extend their heartfelt gratitude to Professor John Kamanula and Steve Kaunda (Mzuzu University) who provided technical guidance during nutrient analysis of the food samples, Atupele Mwanyongo and Mr. Chinkhadze (Agriculture research Trust) for their assistance during determination of iron and zinc contents. Special thanks to the Mzuzu University, department of science and the Agriculture research trust (ARET) for providing technical assistance and laboratory facilities to conduct the study.

Source of Funding

This material is based upon work supported by the United States Agency for International

Development, as part of the Feed the Future initiative, under the CGIAR Fund, award number BFS-G-11-00002, and the predecessor fund the Food Security and Crisis Mitigation II grant, award number EEM-G-00-04-00013.

Abbreviations: PEM (protein energy malnutrition); CPV (cereal-pulse-vegetable), RNI (recommended nutrient intake); WHO (World health organization); RDA (Recommended daily intake)

Table 5: Nutrient intake from cereal-pulse-vegetable porridges compared to the control and WHO guidelines

Variable	7-8 months	9-11 months	12-23 months
Serving			
Number of servings	1	1	1
Amount of serving	150 ml	200 ml	300 ml
Amount of solids in porridge	75 g	100 g	150 g
Cost per day			
Maize porridge (control)	11.25	15.0	22.5
CPV1	35.8	47.7	71.55
CPV2	20.33	27.1	40.65
CPV3	22.77	30.3	45.45
CPV4	28.65	37.4	56.1
Energy (RNI)			
	200 Kcal	300 Kcal	500 Kcal
Maize porridge (control)	287.025 (144)	382.7 (128)	574.05 (115)
CPV1	264.15 (132)	353.2 (118)	528.3 (106)
CPV2	293.85 (147)	352.2 (117)	528.3 (106)
CPV3	294.45 (147)	392.6 (131)	588.9 (118)
CPV4	290.7 (145)	387.6 (129)	581.4 (116)
Protein (RNI)			
	9.1 g	9.6 g	10.9 g
Maize porridge (control)	7.01 (77)	9.34 (97)	14.1 (129)
CPV1	7.73 (85)	10.3 (93)	15.45 (142)
CPV2	9.6 (105)	12.8 (133)	19.2 (176)
CPV3	8.93 (98)	11.9 (124)	17.85 (164)
CPV4	10.58 (116)	14.1 (147)	21.15 (194)
Iron			
	11 mg	11 mg	11 mg
Maize porridge (control)	1.51 (14)	2.01 (18)	3.02 (27)
CPV1	13.13 (119)	17.5 (159)	26.25 (239)
CPV2	15.4 (140)	20.5 (186)	30.75 (280)
CPV3	12.8 (116)	17.3 (157)	25.95 (236)
CPV4	15.9 (145)	21.2 (193)	31.8 (289)
Zinc			
	2.8 mg	2.8 mg	2.8 mg
Maize porridge (control)	2.9 (104)	3.81 (136)	5.72 (204)
CPV1	2.8 (100)	3.8 (136)	5.7 (204)
CPV2	3.38 (121)	4.5 (161)	6.75 (241)
CPV3	3.23 (115)	4.3 (154)	6.45 (230)
CPV4	3.9 (139)	5.2 (186)	7.8 (279)

Iron* Assuming medium iron bioavailability (10%). Zinc** Assuming moderate bioavailability (30%) References: World Health Organizations Recommendations (Dewey and Brown 2002; Ruel, Loechl, and Pelto 2004). Numbers in brackets represent % RNI met.

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