



Developing and Nutritional Quality Evaluation of Complementary Diets Produced from Selected Cereals and Legumes Cultivated in Gondar province, Ethiopia

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Abstract

Malnutrition is a great concern in developing countries which affects infants and young children in their early age. The objective of this study was to formulate low-cost complementary foods from selected cereals and legumes using household technologies and an attempt was made to evaluate nutritionally. Four complementary blends were formulated based on protein basis of the ingredients and their nutritional characteristics were compared with the commercial complementary food (Cerifam). Standard official procedures were used to determine the macronutrient composition of the developed diets and ingredients. High-performance liquid chromatography was used to quantify vitamins of the formulated diets, while minerals were analyzed using atomic absorption spectrophotometer. The crude protein values of cereal-legume based diets were ranged from 12.20-17.14% on dry matter basis. Mean separation using Least Significant Difference indicated that protein values to be significantly ($p < 0.05$) differed between the different composite flours. However, the crude protein content of all blended diets were statistically greater ($p < 0.05$) than the control value. Energy values of the blends were ranged from 394-560 kcal/100g and the values met the WHO recommendations of 0.8 -1.0 kcal/g from complementary foods. In general, the formulated diets were better than the reference diet and meet the recommended levels for protein, energy and problem nutrients like as zinc, iron and vitamin A based on an estimated daily intake of 65 g of weaning foods. Therefore, the formulated diets have a significant potential in poor rural and urban mothers for use in sub-Saharan Africa.



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Introduction

Malnutrition continues to be among the main public health problems affecting young children in many developing countries.^{1,2} According to UNICEF³, 26% and 43%, of children under the age of five years are stunted globally and in sub-Saharan Africa respectively. Forty-five percent of deaths in children below five years were due to being underweight for their age.⁴ Despite current improvements, childhood malnutrition is the common public health problem in Ethiopia also. According to recent report, 37% of children under 5 are stunted and 7% of children across the country are wasted⁵, the highest burden of this condition occurs in the early age of 6–23 months. Although reasons for malnutrition are various and interrelated, poor quality weaning diets as well as inappropriate weaning practices predispose children's to undernutrition, growth retardation, and high death.^{3,6} Over one-third of children mortality below five years is caused by malnutrition associated with inadequate complementary feeding practices.^{7,8}

Introducing safe and nutritious weaning diets that are affordable to low income families at 6 months is essential to achieve health, optimal growth, and development.⁷ The nutrient composition of weaning diets should be diverse and adequate to meet the infant's nutritional requirements. In general, diet and health in the early years have a major impact on the growth and development of children, in fact, growth is most flattering at this time.^{9,10} Nutrient requirements during this critical period are very high to support rapid growth rate while the nutrient supply is inadequate to meet the needs. Consequently, complementary diets needs to include all essential nutrients like carbohydrates, protein, fat, minerals and vitamins for their optimal growth and development.

Due to economic constraints, nutritious, commercially fortified foods are often too expensive and unattainable for most Ethiopian families. Thus, complementary diets are locally prepared cereal-based foods that are not complemented with legumes or tubers and thus deficient in the required levels of both macro- and micro-nutrients.³³ Furthermore, anti-nutritional factors and the viscosity (bulkiness) are high in an improperly processed plant-based diets, which compromise the bioavailability of essential minerals. Grains are a vital source of the essential amino acids like cysteine, methionine and also B-vitamins but

deficient in some essential amino acids, particularly lysine and tryptophan. In contrast, most legumes are rich in amino acid lysine but deficient in sulfur-containing amino acids.¹¹ Therefore, the processing and blending of grains with locally affordable protein-rich legumes and modification with some vegetables improves the protein composition and quality of the mixtures by mutual complementation of their individual amino acids.¹¹ Problems associated with the high dietary bulk and antinutritional factors are solved using a combined traditional technologies of soaking, steeping, germination, dehulling and roasting of the respective ingredients.^{12,13,14} These household approaches are inexpensive, sustainable and could be adapted to different dietary traditions and feasible strategies. In fact, the formulation of nutritious formula supplements using household level approaches has received much attention from local readily available materials in many low-income communities.^{3,6,15,16} In addition, many researchers suggest that supplementation of cereals with legumes such as soybean; beans, pea and chickpea is promising in complementary feeding.¹⁷ Thus, infant diets require appropriate processing and blending of locally affordable ingredients for improvement of their dietary quality and consistency. Therefore, our aim was to develop low cost complementary diets using affordable local ingredients to examine the feasibility of formulating complementary foods using household technology and their nutritional quality was evaluated.

Materials and Method

Collection of Raw Materials and Processing Approaches

The raw ingredients red teff (*Eragrostis tef* (Zucc.), maize (*Zea mays*), barley (*Hordeum vulgare*), wheat (*Triticum aestivum*), oat (*Avena sativa*), chickpea (*Cicer arietinum*), pea (*Pisum sativum*), beans (*Vicia faba*), soya beans (*Glycine max*), sesame (*Sesamum indicum*) and spinach (*Spinacia oleracea*) were recruited from local market in Gondar city, in enough quantities. The commercial weaning food (Cerifam) was purchased from Bahir Dar supermarket.

Processing of the Raw Materials

A combination of traditional methods of soaking, germination, dehulling and roasting of grains was employed prior to conducting the experiments to process into their respective flour as follows.

For the processing and production of bean, pea, chickpea, and soybean flours, unwanted particles and defective grains in the sample was cleaned and 1000 grams of each grain were soaked in water (1:10 w/v) for a period of 12 hours. The soaking water was removed, and samples were allowed to germinate in dark places up to 2 days by keeping it between thick layers cotton cloth. Distilled water was added daily to moisten the seeds. Then the seeds were simply dehulled since nearly all the seed coats had split open due to the germination. Finally, the dried materials were roasted at 350°C on stainless steel iron pan, with minor modification, reducing the roasting time to only 5 min. Then the grains were milled (Model No: GSB 1514) and passed through a 0.5 mm sieve, packed in to an airtight polythene bags for storage in a cool place (about 4°C) until used.¹³

Teff grains were cleaned for impurities by handpicking and all other undesirable components were removed by washing with tap water. This was followed by soaking the grains in distilled water for 12 hours. The water was then removed and the grains samples were placed between moistened cotton cloths and allowed to germinate at room temperature for 24 hours. After 24 hours of germination, the samples were sun dried for 8 hours and ground to fine powder using an electrical mill (Model No: GSB 1514).¹⁸ Maize grains were cleaned by hand picking and floatation to eliminate broken seeds and unwanted materials. Grain samples were cleaned with deionized water to remove dirt and dusts followed by steeping in clean water for 8 hours at normal temperature. The soaked samples were cleaned in water and spread evenly in a between thick layers of cotton cloth for germination in dark for 72 hours by adding fresh water daily to moistened the seeds. The malted samples were then sun dried for 20 hours and ground to fine flours to sieved (60 mesh), packaged in polyethylene bags.²

Wheat, barley and oat grains were cleaned for extraneous material, separately washed with distilled water and air-dried overnight. This was followed by controlled conditions of steeping and germination of the grains to prepare malt. The dried rootlets, husks and acrospires was removed by polishing the cured samples and milled to sieve (0.5 mm). The flour samples were then packed in airtight polythene bags to keep in a cool place until use.¹⁹

For the processing of sesame, the seeds were sorted, cleaned by distilled water to remove impurities and soaked in salt solution of 3% sodium chloride for 12 h. Thereafter, the grains were dehulled, washed and dried. The dried seeds were roasted at 70°C for 30min and were milled. The obtained flour was sieved and packaged in an airtight container for further use.²⁰ Spinach leaves was separately washed with distilled water, this was followed by drying of the leave samples at room temperature for 48 hours. Finally, the dried spinach (*Spinacia oleracea*) leaves were milled (Model No: GSB 1514) into powder to obtain smooth and consistent particle sizes. Soaking, sprouting (germination) and roasting was done to remove the anti-nutritive factors and to improve upon the flavor of the final product. Malting was practiced since it increases the digestibility, lowers the bulk viscosity and thereby increases the nutrient density.

Formulation of the Composite Diets

The blend proportion recommendation of 75% cereal and 25% legume for infant complementary food formulation was considered at the beginning.^{21, 22} The ingredient ratios was designed based on material balance method for the 0.5–1 year old infant²³, and the recommendations for supplementary foods targeted for nutrition intervention²⁴ and cost considerations. Furthermore, formulation was done by referring secondary sources of nutrient compositions of the raw ingredients to meet recommended levels of vital nutrients that are recommended in various guidelines of infants and children complementary foods.²⁵ A computer programme called NutriSurvey (ProNut-HIV, 2005) for Windows was adopted to estimate the nutrient proportions. The ten ingredients utilized for the formulations was processed separately into powdery flour forms and the multi mix composite was formulated by combining the flour obtained in different proportions (Table 1).

Analytical Method

Macronutrients Analysis

The standard official procedures were followed to determine the proximate composition of the developed diets and ingredients.²⁶ Moisture was estimated by oven drying method (Method #925.05). Ash values was determined by igniting five grams of samples using a muffle furnace at 550°C for

6 hours (Method # 941.12). Protein content in the samples were estimated by micro Kjeldahl (Method # 979.09). Protein values were found by multiplying the total nitrogen content by 6.25 factor. Crude fat was estimated by the Soxhlet extraction method through frequent extraction of 5 gram of samples preferably at 60-80°C) with petroleum ether (#930.09). The

Crude fiber content was evaluated according to the method 920.169. Total carbohydrate was calculated by differences.²⁷ Furthermore, energy content was calculated by multiplying the percentages of crude protein, total carbohydrates, and fat by the conversion factor of 4.0 kcal/g, 4.0 kcal/g and 9.0 kcal/g.²⁸

Table 1: Processed raw materials used in the formulations of the composite diets and their proportions

Formulation	Ingredients & processing methods	Proportion (% w/w)
Diet-1	Soaked, germinate-teff	40
	Soaked, germinated-maize	30
	Soaked, germinated, dehulled and roasted-pea	20
	Soaked, Dehulled and roasted-sesame	5
	Spinach	5
Diet-2	Soaked, germinate-teff	40
	Steeping, germination-wheat	30
	Soaked, germinated, dehulled and roasted-bean	20
	Soaked, Dehulled and roasted-sesame	5
	Spinach	5
Diet-3	Soaked, germinate-teff	40
	Steeping, germination-barley	30
	Soaked,germinated, dehulled and roasted-chickpea	20
	Soaked, Dehulled and roasted-sesame	5
	Spinach	5
Diet-4	Soaked, germinate-teff	40
	Steeping, germination-oat	30
	Soaked,germinated, dehulled and roasted-soyabean	20
	Soaked, Dehulled and roasted-sesame	5
	Spinach	5

Commercial formula (Cerifam) was used as a standard control

Analysis of Micronutrients

Beta-carotene content was analyzed using column chromatography and Shimadzu UV-Vis spectrophotometer (UV-1601PC, Japan). Extraction was done using acetone and petroleum ether as indicated by Rodriguez-Amaya and Kimura.²⁹ Various concentrations of β -carotene standards were prepared to draw a curve. Calculations were made from a standard curve ($R^2 = 0.999$). Ascorbic acid content of each sample was estimated by HPLC (Shimadzu, CTO-10A) method³⁰ with minor modifications. Series of concentrations of ascorbic acid standards were prepared to make a calibration curve. Calculations were made from a standard

curve ($R^2 = 0.999$).

Quantification of four water-soluble B-vitamins was done by HPLC with diode-array detection simultaneously. The issues of chromatographic interferences of cereal-legume flours were solved by solid phase extraction with Sep-Pak C₁₈ (500 mg) cartridges that allows the separation of B-vitamins and eliminate the interfering components.³¹ Various concentrations of the respective vitamin-B standards were used to draw the calibration curve. Standard solutions of B-vitamins were kept in dark glass flasks, to protect them from light and placed under refrigeration. A calibration curve was drawn for

the respective vitamins. Calculations were made from a standard curve with correlation coefficients ($R^2 > 0.999$).

A 20 μ L aliquot of samples and standards were injected in to the HPLC system and monitored by a photodiode-array detector at 234 nm for thiamine, 266 nm for riboflavin, 261 nm for niacin and 324 nm for pyridoxine. A 0.45 μ L membrane filter was used to filter the mobile phase followed by degassing by sonication before use. The flow rate was 0.7 ml/min and the column was operated at ambient temperature (25°C). Identification of the respective vitamins were achieved through comparison of their retention times. Minerals zinc (Zn), iron (Fe), copper (Cu), calcium (Ca), and magnesium (Mg) were analyzed by atomic absorption spectrometry (novAA-400P, Germany), following the methods of.³²

Statistical Analysis

All results of the formulated and control diets were subjected to One-way ANOVA using SPSS version 16.0 at 5% level of significance. The means were compared using Least Significance Difference (LSD) test and Duncan multiple range test at $P < 0.05$.

Results and Discussion

Proximate Composition of the Ingredients Used in the Formulation of the Diets

The proximate value of processed raw materials used for formulation of the blended diets are

summarized in Table 2. The protein content was in the range of 8.46-37.21%. Processed soybeans, beans, chickpea, and pea exhibited higher value of protein content with lowest value in wheat. Processed soybean in the present study had significantly ($p < 0.05$) higher protein value compared to literature value of the raw soybean.³³ This might be due to the processing methods such as roasting and germination which accounts for the greatest increase in protein content. However, this result is very close to soaked soybean value (37%) reported.³⁴ The moisture and ash values were ranged from 2.25-11.81% and 1.31-6.04%, respectively. Ash values indicates the total mineral content of a particular food sample.³⁵ All samples were significantly ($p < 0.05$) differed in ash content resulting from variation among individual raw materials and the soaking, roasting and dehulling process. Ash content of pea, chickpeas, soybean and beans were found to be low compared to literature values of unprocessed raw materials.^{34, 36} This could be due to the removal of the seed coat (hull) and partly due to the soaking and roasting processes. Ash content was significantly higher ($p < 0.05$) in Spinach and sesame than the rest of the samples. Fat content was found to be significantly higher ($p < 0.05$) in sesame and soybean (50.39% and 20.80%) respectively. The crude fiber content was ranged between 1.99-10.35%. Amount of crude fiber was statistically ($p < 0.05$) higher in spinach with the lowest value in maize.

Table 2: Proximate composition (g/100g) of the ingredients used in the formulation of the Blend

Ingredients	Moisture	Ash	Crude protein	Crude fat	Available CHO	Crude fiber
Teff	6.47 \pm 0.29 ^{bcd}	2.60 \pm 0.03 ^{cd}	9.33 \pm 0.39 ^a	3.45 \pm 1.45 ^{bc}	73.91 \pm 1.81 ^f	4.25 \pm 0.77 ^{ab}
Maize	7.58 \pm 0.41 ^d	1.51 \pm 0.06 ^{ab}	9.85 \pm 1.48 ^a	3.83 \pm 0.11 ^{bc}	75.23 \pm 1.51 ^f	1.99 \pm 0.11 ^a
Wheat	5.36 \pm 0.78 ^{bc}	1.31 \pm 0.18 ^a	8.46 \pm 1.01 ^a	2.03 \pm 0.15 ^a	81.03 \pm 1.14 ^g	2.16 \pm 0.08 ^a
Barley	5.49 \pm 0.25 ^{bcd}	1.71 \pm 0.04 ^{ab}	9.41 \pm 0.95 ^a	1.91 \pm 0.37 ^a	77.95 \pm 1.21 ^{fg}	3.52 \pm 1.21 ^{ab}
Oat	7.39 \pm 1.92 ^{cd}	2.17 \pm 0.09 ^{bc}	9.80 \pm 1.64 ^a	2.77 \pm 1.00 ^{ab}	74.92 \pm 4.35 ^f	2.95 \pm 0.36 ^a
Beans	6.42 \pm 0.94 ^{bcd}	3.03 \pm 0.16 ^d	31.30 \pm 0.98 ^e	1.73 \pm 0.02 ^a	53.22 \pm 6.13 ^d	6.12 \pm 0.51 ^{bc}
Chickpea	4.93 \pm 0.52 ^b	2.27 \pm 0.15 ^{bc}	29.24 \pm 0.85 ^d	4.56 \pm 0.74 ^c	63.45 \pm 2.80 ^e	2.98 \pm 0.50 ^a
Peas	7.34 \pm 2.77 ^{cd}	2.73 \pm 0.13 ^{cd}	27.18 \pm 0.80 ^c	1.53 \pm 0.62 ^a	73.36 \pm 1.82 ^f	4.03 \pm 0.64 ^{ab}
Soybeans	4.72 \pm 0.30 ^b	2.70 \pm 0.02 ^{cd}	37.21 \pm 0.74 ^f	20.80 \pm 1.57 ^d	29.48 \pm 1.27 ^b	7.76 \pm 0.94 ^c
Sesame	2.25 \pm 0.01 ^a	5.96 \pm 0.87 ^g	20.73 \pm 0.06 ^b	50.39 \pm 0.17 ^e	16.97 \pm 0.88 ^a	3.71 \pm 0.31 ^{ab}
Spinach	11.81 \pm 0.58 ^e	6.04 \pm 0.79 ^g	21.34 \pm 2.32 ^b	3.87 \pm 0.36 ^{bc}	46.53 \pm 5.68 ^c	10.35 \pm 4.44 ^d

Each value is mean \pm standard deviation of three replications on dry matter basis. The different superscript letters in the same column indicates significantly different ($P < 0.05$).

Macro Nutrient Composition of the Compounded Diets

The proximate nutrient composition of the four formulated diets and proprietary formula (Cerifam) are presented in Table 3. The crude protein values of cereal-legume based diets was in the range of 12.20-17.14%. Mean separation using LSD showed protein content was significantly ($p < 0.05$) differed among the different composite mixtures. Initial differences in protein composition among legumes might be contributed to the variations observed. Nevertheless, the crude protein values of all blended diets were statistically ($p < 0.05$) higher compared to the control value and meet the recommended dietary allowance.³⁷ The inclusion of legumes as well as teff allowed for increased protein composition of the developed products. The result was also an indication

that during ingredient processing protein was not denatured due to the moderate use of temperature (70°C).³⁸ The protein content of diet 4 was statistically ($p < 0.05$) higher than all other diets (17.14%). This might be due to the presence of soybean in diet 4, which provides a significant amount of protein as well as other vital nutrients.³⁹ Recent studies have indicated that the protein content of two or more plant-based foods (cereal- legume combination) is better compared to those produced from a single plant-based materials (cereal).⁴⁰ Calculated energy values provided by the blends were ranged from 394-560 kcal/100 g dry matter. Energy values in all the formulated mixtures were significantly ($p < 0.05$) higher than the control value (Cerifam) and exceeded the WHO recommendations of 0.8 -1.0 kcal/g from complementary foods.

Table 3: Proximate composition (g/100g) of the different formulated diets

Diets	Moisture	Ash	Crude protein	Crude fat	Crude fiber	Total CHO	Energy/ kcal
Diet 1	4.91±0.10 ^c	3.21±0.27 ^b	12.20±0.08 ^b	6.28±0.20 ^b	5.40±0.22 ^c	73.41±0.23 ^d	399 ^a
Diet 2	4.46±0.13 ^c	2.63±0.49 ^a	14.97±0.58 ^c	8.14±0.06 ^c	7.74±0.12 ^d	69.79±0.17 ^c	412 ^b
Diet 3	3.38±0.46 ^b	3.12±0.06 ^b	15.34±0.61 ^c	19.28±0.37 ^d	4.69±0.23 ^b	59.10±0.98 ^b	471 ^c
Diet 4	5.53±0.49 ^d	3.17±0.04 ^b	17.14±0.21 ^d	38.88±0.35 ^e	8.36±0.17 ^e	35.29±0.88 ^a	560 ^d
Control	2.29±0.18 ^a	2.33±0.36 ^a	11.15±0.26 ^a	2.44±0.15 ^a	3.47±0.05 ^a	81.78±0.65 ^e	394 ^a

Each value is mean ± standard deviation of three replications on dry matter basis. The different superscript letters in the same column indicates significantly different ($P < 0.05$).

The values of crude fat content were ranged from 2.44 -38.88%. A significant ($p < 0.05$) difference was observed in fat content among all-composite diets. Crude fat content was significantly ($p < 0.05$) higher in all the formulated diet than the control diet (Cerifam). However, the maximum fat content was detected in diet 4 (38.88%). This could be due to the inclusion of oil-dense soybean during diet formulation. This attribute tends to be in line with the recommendations⁴¹ that oil seeds and vegetable oils be included in food meant for infant and children, which will also increase the energy density. As indicated in this study, the content of fat was very low in other diets this might be attributed to the lower fat levels of cereals. Dietary fat is vital to facilitate absorption of fat-soluble vitamins, to supply energy in the body and to provide essential fatty acids that are required for normal brain development.⁴²

Among all the composite diets, diet 3 and diet 4 was able to meet the minimum requirement of 10–25% fat recommended by WHO for infant food. In this study, fat content of the formulated diet was higher than those reported for teff based complementary blends.³³ Total carbohydrate content was found to be statistically ($p < 0.05$) lower in the composite diets (35.29-73.41%), compared to the control diet (81.78%). The protein and fat content to the blend were mainly provided by chickpea, pea, beans, soybean and sesame while the main source of carbohydrate were cereals. The high protein and energy contents of these formulated diets revealed that they are suitable to support growth and development of infants.

The crude fiber values in the complementary food was ranged from 4.69 -8.36%. These values

are higher when compared to the control diets. A significant ($p < 0.05$) difference was observed in crude fiber composition among all the blended mixtures. The higher crude fiber values were observed in diet 4 (8.36%), while the least value was recorded in diet 3 (4.69%). In this study, fiber content was higher than the work reported by Fikiru, who reported fiber values of 3.1-4.1% in complementary food blended from maize, roasted pea, and malted barley.⁴³ In the present study, the crude fiber content is slightly higher compared to the recommended daily allowance of 5% fiber in complementary food.⁴⁴ A low levels of fiber in infant formulations has been recommended to encourage digestibility and absorption of foods by infants.⁴⁵ Moisture content is critical for predicting the shelf life of food products. In this study, the moisture content was ranged from 2.29- 5.53%. The highest moisture content was observed in diet 4 (5.53%), while the least value was observed in the control (2.29%). The moisture content of all the blended diets were statistically ($p < 0.05$) higher than the control sample. Nevertheless, all of the figures were within the acceptable range of 5% moisture.²⁵ The lower moisture values of the formulated diets are an important attribute, as it could improve the storage quality of the food due to the low water activity for microbial growth. The lower moisture content could be due to longer soaking and germination time which decreases moisture content significantly as a result of utilization of water for metabolic activities initiated by soaking.^{36,46} Our finding is similar with Mensa-Wilmot report (2.52–4.89%) who formulated cereal/legumes-based weaning food supplements.¹¹ It is also comparable to that of Tenagashaw report (2.51 to 7.36%) from Teff-based complementary foods fortified with soybean and orange-fleshed sweet potato.³³ However, our result is below Ijarotimi & Keshinro report (5.7-10.2%) for infant formulations from germinated popcorn, Bambara groundnut and African locust bean flour.⁴⁷ Ash content was ranged from of 2.33 to 3.21%. In general, among all the formulated diets diet 3 and diet 4 were found most acceptable terms of proximate composition when compared with the other formulations and better than the control (Cerifam) sold in Ethiopia for specific age range of 6 to 12 months. The results showed that most of the nutrient values were higher in diet 3 and diet 4 than in Cerifam product. Now a days

there is an interest in traditional household food technologies as a means of improving the quality and safety of complementary foods. However, the constraint of this technology is that, it is a little bit time-consuming and labor intensive.

The Mineral Profile of the Compounded Diets

The results of percentage of minerals in the compounded mixtures, as well as the daily estimated intakes from 65 g of the diet by infants compared with RDA, are presented in table 4. A significant ($p < 0.05$) differences in iron, calcium and magnesium content was observed between all sample diets. Moreover, iron content was significantly ($p < 0.05$) higher in diet 4 (21.57mg/100g) with the lowest value found in the control diet (6.570 mg/100g). Diet 3 (187.6 mg/100g) and diet 2 (185 mg/100g) showed the highest calcium content with the lowest value of 38.97 mg/100g in diet 1. The highest value of magnesium was observed in diet 2 (111.9 mg/100g) and the lowest value in the control (21.86 mg/100g). Magnesium plays a significant role in the structure and the function of the human body. No significant ($p > 0.05$) difference was observed in zinc content between diet 1 (4.970 mg/100g) and the control diet (4.980 mg/100g). The highest zinc value was found in the control (4.980 mg/100g) and the lowest value was observed in diet 3 (3.620 mg/100g). Diet 2 has the highest copper value (0.230 mg/100g) followed by diet 1 and control with same value of 0.210 mg/100g.

In the present study, the mineral composition of the developed diets were comparable to the commercial diet (control). Furthermore, the daily intakes of 65 g of developed diet was able to meet RDAs for the minerals zinc and iron between 5 to 12 months of age. Meanwhile, none of the formulated diets were able to meet the daily requirement of calcium, magnesium, and copper.³⁷ Zinc and iron are a critical trace mineral essential for young children and infants to facilitate their normal growth and development.⁴⁸ Relatively a high iron, copper and zinc content of the developed diets could be attributed to the supplementation of teff, spinach, and sesame during formulation and partly due to significant removal of iron and zinc inhibitors by the household processing approaches of ingredients.

Table 4: The mineral profiles (mg/100 g) and amounts that can be provided in 65g of the developed diets on dry mater basis

Mineral	Diet 1	Diet 2	Diet 3	Diet 4	Diet5 (control)
Calcium	38.97±0.15 ^a	185.0±0.46 ^d	187.6±0.01 ^e	49.78±0.21 ^b	97.64±0.03 ^c
Magnesium	73.41±0.02 ^c	111.9±0.02 ^e	85.49±0.03 ^d	38.60±0.14 ^b	21.86±1.59 ^a
Zinc	4.97±0.01 ^{cd}	3.68±0.01 ^b	3.62±0.01 ^a	4.96±0.01 ^c	4.98±0.01 ^d
Iron	18.55±0.06 ^d	12.65±0.01 ^c	10.95±0.01 ^b	21.57±0.07 ^e	6.57±0.07 ^a
Copper	0.21±0.01 ^b	0.23±0.01 ^c	0.19±0.00 ^a	0.20±0.00 ^a	0.21±0.01 ^b

Amount (mg) of minerals that could be provided in 65g of the blends

Mineral	Diet 1	Diet 2	Diet 3	Diet 4	control	RDA* (mg/day)
Cal	25.3	120.3	122	32.4	63.5	270
Mg	47.7	72.7	55.6	25.1	14.2	75
Zn	3.2	2.4	2.4	3.2	3.2	3
Fe	12.1	8.2	7.1	14	4.27	11
Cu	0.14	0.15	0.12	0.13	0.14	0.22

Each value is mean ± standard deviation of three replications on dry matter basis. The different superscript letters in the same horizontal row indicates significantly different ($P < 0.05$). Source: Recommended dietary allowance (RDA) from Gropper³⁷.

Table 5: Vitamin content (mg/100g) of the compounded diets in dry mater basis

Vitamins	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5 (control)
Vitamin A	2.25 ± 0.07 ^d	2.23 ± 0.17 ^d	1.11 ± 0.15 ^b	1.53 ± 0.13 ^c	0.31 ± 0.01 ^a
Ascorbic acid	0.00 ± 0.00 ^a	0.00 ± 0.00 ^a	0.86 ± 1.48 ^a	1.54 ± 0.42 ^a	20.21 ± 7.44 ^b
Thiamine (B1)	3.45 ± 0.36 ^c	3.93 ± 0.26 ^d	2.94 ± 0.11 ^b	2.41 ± 0.05 ^a	3.26 ± 0.02 ^{bc}
Riboflavin (B2)	2.95 ± 0.37 ^b	3.81 ± 0.29 ^c	3.20 ± 0.12 ^b	2.15 ± 0.41 ^a	1.84 ± 0.22 ^a
Niacin (B3)	7.75 ± 0.53 ^c	8.48 ± 0.55 ^d	7.46 ± 0.57 ^c	6.53 ± 0.03 ^b	4.25 ± 0.03 ^a
Pyridoxine (B6)	3.84 ± 0.49 ^a	3.09 ± 2.55 ^a	3.14 ± 0.13 ^a	2.43 ± 0.07 ^a	3.57 ± 0.02 ^a

Each value is mean ± standard deviation of three replications on dry matter basis. The different superscript letters in the same horizontal row indicates significantly different ($P < 0.05$).

Table 6: Estimated amount of vitamins in a daily intake of 65g of composite flours compared with RDAs

Vitamins	Diet 1	Diet 2	Diet 3	Diet 4	Diet5 (control)	RDA*0.5 to 1 year
Vitamin A	1.46	1.45	0.72	1.00	0.20	0.5 mg
Ascorbic acid	0.00	0.00	0.56	1.00	13.14	50 mg
Thiamine (B1)	2.24	2.56	1.91	1.57	2.12	0.3 mg
Riboflavin (B2)	1.92	2.48	2.08	1.41	1.21	0.4 mg
Niacin (B3)	5.04	5.51	4.85	4.24	2.76	4 mg
Pyridoxine (B6)	2.51	2.01	2.04	1.58	2.32	0.3 mg

Source: Recommended dietary allowance from Gropper³⁷

Vitamin Content of the Compounded Diets

The vitamin content, as well as the estimated amount in 65 gram of the formulated diets and the control compared with RDA, was presented Tables 5 and 6 respectively. A significant ($p \leq 0.05$) difference was observed in content of B-vitamins between the formulated and the control diets except pyridoxine (B6). Furthermore, thiamine (3.93%), riboflavin (3.81%) and nicotinic acid (8.48%) were significantly ($p \leq 0.05$) higher in diet 2 when compared to the other diets. In this study, no significant ($p > 0.05$) difference was observed in pyridoxine (B6) values among all the formulated and control diets. Furthermore, the values of all water-soluble vitamins in the formulated and control diets would meet the RDA value.³⁷ Beta carotene is the main provitamin A carotenoid in many green leafy vegetables. Higher levels of beta carotene have been reported in Spinach leaves. In this study, β -carotene content was ranged from 0.31 to 2.25 mg/100g. Among all the formulated diets evaluated, diet 1 and diet 2 was found to be statistically ($p < 0.05$) higher in β -carotene content compared to other diets. Whereas, the β -carotene value of the control diet (0.31 mg/100g) was statistically lower than the remaining diets. The β -carotene content in all the formulated diets would meet the RDA value of 0.5 mg/day for 5-12-month infant. Nevertheless, β -carotene was fell short of the recommendations in the control diet (0.31 mg/100g). The incorporation of spinach in the diets during formulation could be a reason for the high β -carotene content observed. Ascorbic acid content was ranged between 0.00 to 20.21 mg/100g. In this study, the content of ascorbic acid was very low in all diets, this may be due to that ascorbic acid is very sensitive to light and lost during sample processing or storage. None of the diets was able to meet the RDA value (50 mg/day) of vitamin C needs of this age group. Vitamin C is water-soluble vitamin required in high amount in our body. It protects us from scurvy disease and helps in the formation of folic acid in our body.

Conclusion

Despite current improvements, children chronic malnutrition continues to be the main public

health challenge in developing countries including Ethiopia. Poor quality weaning diets, as well as inappropriate feeding practices, predispose children to undernutrition. The study reveals that adequate processing and blending of locally available cereals and legumes and modification with some vegetables is suitable in the formulation of complementary food to combat protein-energy malnutrition in developing countries. Besides cereal-legume combination, the traditional technologies such as soaking, dehulling, germination, and roasting significantly improved the nutritional quality of the developed formulas. Furthermore, the formulated diets were better than the reference diet and meet the recommended levels for protein, energy and problem nutrients such as zinc, iron, vitamin A and water-soluble B- vitamins. Therefore, the formulated diets have a huge positive impact to use as complementary foods in poor rural and urban mothers. Further study is in progress to address the efficacy, effectiveness, and protein quality of such complementary formulations with rat model experiment.

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Conflict of interest

All the authors declare that they have no any potential conflicts of interest.

References

1. Ahmed T., Hossain M., Sanin K.I. Global burden of maternal and child undernutrition and micronutrient deficiencies. *Ann Nutr Metab.* 2012; 61: 8-17.

2. Abiose S.H., Ikujenlola A.V., Abioderin F.I. Nutritional quality assessment of complementary foods produced from fermented and malted quality protein maize fortified with soybean flour. *Pol. J. Food Nutr. Sci.* 2015; 65(1): 49-56.
3. United nations children's fund (. Improving child nutrition: the achievable imperative for global progress. New York: UNICEF (2013): 1-14.
4. Walton E., Allen S. "Malnutrition in Developing Countries." *Paediatrics and Child Health.* 2011; 21(9): 418-424.
5. Ethiopian Public Health Institute (EPHI) (Ethiopia) and ICF. Ethiopia Mini Demographic and Health Survey 2019: Key Indicators. 1-25.
6. Kehinde Alawode E., Idowu M.A., Adeola A.A., Oke E.K., Omoniyi S.A. Some quality attributes of complementary food produced from flour blends of orange flesh sweet potato, sorghum, and soybean. *Croatian journal of food science and technology.* 2017;9(2): 122-9.
7. Semahegn A., Tesfaye G., Bogale A. Complementary feeding practice of mothers and associated factors in Hiwot Fana Specialized Hospital, Eastern Ethiopia. *The Pan African Medical Journal.* 2014; 18:1-11.
8. Hlaing L.M., Fahmida U., Htet M.K., Utomo B., Firmansyah A., Ferguson E.L. Local food-based complementary feeding recommendations developed by the linear programming approach to improve the intake of problem nutrients among 12–23-month-old Myanmar children. *British Journal of Nutrition.* 2016; 116(S1): S16-S26.
9. Victora C.G., de Onis M., Hallal P.C., Blossner M., Shrimpton R. Worldwide Timing of Growth Faltering: Revisiting Implications for Interventions. *Pediatrics.* 2010; 125(3): e473–e480.
10. Dewey K.G., Vitta B.S. Strategies for ensuring adequate nutrient intake for infants and young children during the period of complementary feeding. Washington: 2013; Alive & Thrive, 7.
11. Mensa-Wilmot Y., Phillips R.D., Lee J., Eitenmiller R.R. Formulation and evaluation of cereal/legume-based weaning food supplements. *Plant Foods for Human Nutrition.* 2003; 58(3): 1-14.
12. Hotz C., Gibson R. S. Traditional food-processing and preparation practices to enhance the bioavailability of micronutrients in plant-based diets. *J Nutr.* 2007; 137(4): 1097-1100.
13. Nakitto A.M., Muyonga J.H., Nakimbugwe D. Effects of combined traditional processing methods on the nutritional quality of beans. *Food science & nutrition.* 2015; 3(3): 233-241.
14. Nkundabombi M. G, Nakimbugwe D., Muyonga J. H. Effect of processing methods on nutritional, sensory, and physicochemical characteristics of biofortified bean flour. *Food science & nutrition.* 2016; 4(3): 384-397.
15. Dewey K.G., Brown K.H. Update on technical issues concerning complementary feeding of young children in developing countries and implications for intervention programs. *Food and nutrition bulletin.* 2003; 24(1): 5-28.
16. Winichagoon P. Coexistence of micronutrient malnutrition: implication for nutrition policy and programs in Asia. *Asia Pac J Clin Nutr.* 2008; 17(S1): 346-348.
17. Ajanaku K. O., Ajani O., Siyanbola T. O., Akinsiku A.A., Ajanaku C. O., Oluwole O. Dietary fortification of sorghum-ogi using crayfish (*Paranephrops planifrons*) as supplements in infancy. *Food Science and Quality Management.* 2013; 15: 1-10.
18. Badau M.H., Jideanl I.A., Nkama I. Rheological behaviour of weaning food formulations as affected by addition of malt. *International journal of food science & technology.* 2016; 41(10): 1222-1228.
19. Fikiru O., Bultosa G., Fikreyesus Forsido S., Temesgen M. Nutritional quality and sensory acceptability of complementary food blended from maize (*Zea mays*), roasted pea (*Pisum sativum*), and malted barley (*Hordium vulgare*). *Food science & nutrition.* 2017; 5(2): 173-181.
20. Fasuan T. O., Fawale S. O., Enwerem D. E., Uche N., Ayodele E. A. Physicochemical, functional and economic analysis of complementary food from cereal, oilseed and animal polypeptide. *IFRJ.* 2017; 24(1): 275-283.
21. Gopaldas T., Mehta P., Patil A., Gandhi H. Studies on reduction in viscosity of thick rice gruels with small quantities of an amylase-rich

- cereal malt. *Food and Nutrition Bulletin*. 1986; 8(4): 1-7.
22. Plahar W.A., Okezie B.O., Gyato C.K. Development of a high protein weaning food by extrusion cooking using peanuts, maize and soybeans. *Plant Foods for Human Nutrition*. 2003; 58(3): 1-12.
23. FAO (1985) Energy and protein requirements: Report of a joint FAO/WHO/UNU Expert Consultation. In Technical Report Series (WHO) (No. 724). World Health Organization.
24. World Health Organisation Staff, World Health Organization, & UNICEF. Global strategy for infant and young child feeding. WHO, 2003; Geneva.
25. Codex Alimentarius Commission. Guidelines on formulated supplementary foods for older infants and young children CAC/GL08-1991. Rome: Italy.
26. AOAC International Official Methods of Analysis (18th ed.). 2000. Washington, DC: Association of Official Analytical Chemists.
27. Mahmoud A.H., Anany A.M. Nutritional and sensory evaluation of a complementary food formulated from rice, faba beans, sweet potato flour, and peanut oil. *Food and nutrition bulletin*. 2014; 35(4): 403-413.
28. WHO/FAO, 2011. Report of the Joint FAO/WHO Expert Consultation on the Risks and Benefits of Fish Consumption. Rome, Food and Agriculture Organization of the United Nations; Geneva, World Health Organization, 50 pp.
29. Rodriguez-Amaya D.B., Kimura M. HarvestPlus handbook for carotenoid analysis (Vol.2). Washington: International Food Policy Research Institute (IFPRI). 2004.
30. Vikram V. B., Ramesh M.N., Prapulla S.G. Thermal degradation kinetics of nutrients in orange juice heated by electromagnetic and conventional methods. *Journal of Food Engineering*. 2005; 69(1): 31-40.
31. Ekinci R., Kadakal C. Determination of seven water-soluble vitamins in tarhana, a traditional Turkish cereal food, by high-performance liquid chromatography. *ACTA chromatographica*. 2005; 15: 289.
32. AOAC (2003) Official methods of analysis of the association of official's analytical chemists, 17th ed. Association of official analytical chemists, Arlington, Virginia.
33. Tenagashaw M.W., Kenji G.M., Melaku E.T., Huyskens-Keil S., Kinyuru J.N. Teff-based complementary foods fortified with soybean and orange-fleshed sweet potato. *Journal of Food Research*. 2017; 6(1): 112-122.
34. Agume A.S., Njintang N.Y., Mbofung C.M. Effect of soaking and roasting on the physicochemical and pasting properties of soybean flour. *Foods*. 2017;6(2):1-10.
35. Kavitha S., & Parimalavalli R. Development and Evaluation of Extruded Weaning Foods. *European Academic Research*. 2014; II(4): 5197–5210.
36. Desalegn B. B. Effect of Soaking and Germination on Proximate Composition , Mineral Bioavailability and Functional Properties of Chickpea Flour. *Food and Public Health*. 2015; 5(4): 108–113.
37. Gropper S.S., Smith J.L., Groff J.L. Advanced nutrition and human metabolism. Fifth edition. 2009. Wadsworth, Cengage Learning
38. Mensa-Wilmot Y., Phillips R.D., Hargrove J.L. Protein quality evaluation of cowpea-based extrusion cooked cereal/legume weaning mixtures. *Nutrition Research*. 2001; 21(6):849-57.
39. Etiosa O.R., Chika N.B., Benedicta A. Mineral and Proximate Composition of Soya Bean. *AJOPACS*. 2017; 4(3): 1-6.
40. Wakil S.M., Onilude A. A. Microbiological and chemical changes during production of malted and fermented cereal-legume weaning foods. *Advances in Food Sciences*. 2009; 31(3): 2-8.
41. FAO/WHO. Food agriculture organization. Preparation and use of Food-Based Dietary Guidelines. Report of Joint FAO/WHO Consultation technical report series 880. 1998, Geneva.
42. Aranceta J., Pérez-Rodrigo C. Recommended dietary reference intakes, nutritional goals and dietary guidelines for fat and fatty acids: a systematic review. *Br J Nutr*. 2012; 107(S2): S8-S22.
43. Fikiru O., Bultosa G., Forsido S. F., & Temesgen M. Nutritional quality and sensory acceptability of complementary food blended from maize (*Zea mays*), roasted pea (*Pisum sativum*), and malted barley (*Hordium*

- vulgare*). *Food Science & Nutrition*. 2016; 5(2): 173–181.
44. Gibson R.S., Bailey K.B., Gibbs M., Ferguson E.L. A review of phytate, iron, zinc, and calcium concentrations in plant-based complementary foods used in low-income countries and implications for bioavailability. *s*. 2010; 31 (2_suppl2): S134-S146.
45. Adepeju A. B., Abiodun O. A., Dauda A. O., & Fatiregun A. A. Nutritional evaluation of weaning food prepared from fermented sorghum, germinated soybean and defatted sesame seed. *FUTA Journal of Research in Sciences*. 2016;12(2): 260–269.
46. Nwosu J. N. Evaluation of the Proximate Composition and Antinutritional Properties of African Yam Bean (*Sphenostylis sternocarpa*) Using Malting Treatment. *International Journal of Basic and Applied Sciences*. 2013; 2(4): 157–169.
47. Ijarotimi O. S., & Keshinro O. O. Formulation and Nutritional Quality of Infant Formula Produced from Germinated Popcorn, Bambara Groundnut and African Locust Bean Flour. *Journal of Microbiology, Biotechnology and Food Sciences*. 2012; 1(6): 1358–1388.
48. Makori N., Kassim N., Kinabo J., & Matemu A. Nutrient composition of cereals-based complementary flour and its nutritional adequacy in infants nutrition. *Journal of Food Research*. 2017; 6(6): 45-55.