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Biochemical and Haematological Parameters of Children Fed Optimized Cereal-legume Blend supplemented with Moringa leaf Powder

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Abstract: Childhood malnutrition is still a serious public health problem in Nigeria. This may be attributed to poor infant and young child feeding practices. In a bid to address this challenge, the current study was initiated to produce optimal complementary foods (CF). Six composite blends designated F1, F2, F3, F4, F5, and F6 were formulated from yellow maize *(Zea mays)*, wheat (*Triticum aestivum*), millet (*Pennisetum glaucum*), groundnut *(Arachis hypogea)*, soyabeans (*Glycine max*), and *Moringa oleifera.* Nutrisurvey was used to calculate the proportion of ingredients in the composite blends to meet nutritional specification in codex guideline. Nutritional composition, functional and consumer acceptance analyses were conducted, as well as feeding trials in moderately malnourished children for eight weeks. Anthropometric, biochemical and selected haematological parameters of the children were used to assess the performance of the CF formulations. Results of proximate analysis indicated that moisture content; crude protein, fat, ash, crude fibre, and carbohydrate were within the codex guidelines. The amino acid profile indicated that all essential amino acids were present in acceptable quantity. The functional properties revealed that bulk density ranged from 0.63-0.81, water absorption capacity 86-90%, swelling index 0.33-1.34, reconstitution index 2.20-3.20, and pH 6.52-6.69. The sensory evaluations suggest that the CF formulations were well accepted by the participants. The feeding trial indicated growth and recovery in the children at Endline. The current study therefore, revealed that with proper blending of local foodstuff, it is possible to prepare acceptable and nutritionally adequate CF.

Keywords: Biochemical parameters, Children, Haematological and Malnutrition.

RESEARCH PAPER

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INTRODUCTION

Malnutrition is a condition that results from eating diets in which nutrients are either not enough or are too much such that it causes health related problems (Young, 2012). Most often, malnutrition is used to refer to undernutrition when there is inadequate supply of calories, proteins, or micronutrients. The World Health Organization, defined malnutrition as the cellular imbalance between the supply of nutrients and energy and the body's demand for them to ensure growth, maintenance and specific functions (WHO, 2006). This implies a disparity between the amount of nutrients that the body needs and the amount that it is receiving. One such form of malnutrition is protein energy malnutrition (PEM).

PEM is a form of malnutrition that affects primarily children worldwide especially in developing countries (Olu, 2001). PEM takes different forms such as: Marasmus, Marasmic-Kwashiokor, Underweight, and Kwashiorkor. The causes of PEM can be direct or indirect. The direct causes which are commonly referred to as immediate factors are inadequate food intake and diseases. While the indirect causes include: war, natural disasters, poor sanitation, and inadequate health facilities (UNICEF, 2013).

It is paradoxical that despite concerted efforts from Governments and Non Governmental Organizations, PEM remains a major public health problem. The World Health Organization posited that malnutrition accounts for 54 percent of child mortality globally (WHO, 2004). According to United Nations Children Fund (UNICEF), at any time approximately 100 million children suffer from moderate or severe forms of PEM (UNICEF, 2013). Similarly, it is estimated that in every hour of the day, 300 children die because of malnutrition and one in four children are chronically malnourished (Save the Children, 2012).

The spate of malnutrition among children in Nigeria has remained a source of worry to stakeholders in the Health sector. The Nigeria Demographic and Health Survey conducted in 2013 revealed that 37%, 29% and 18% of children in Nigeria are stunted, underweight and wasted respectively (NPC and ICFI, 2014). In 2018, the National Nutrition and Health Survey reported that 32% are stunted and 19.9% are underweight (NNHS, 2018). This is an indication that no significant progress have been made in reversing the problem.

Literature report indicates that infants and young children begin to experience malnutrition shortly after the first six months of exclusive breast-feeding (Akinola *et al*., 2014). At this stage, breast milk is no longer sufficient to meet the nutritional needs of the infant who is undergoing rapid growth and development. Therefore, complementary foods must be introduced to the child to sustain their growth, and prevent malnutrition (Steve and Olufunke, 2013). Complementary foods are foods other than breast milk that are introduced to infants at six months to provide nutrients. They should complement breast milk in provision of essential nutrients that the child needs for proper growth and development.

Despite numerous food substances available to formulate complementary foods, it is sad to note that most of these indigenous food substances are poorly combined or blended during formulation of gruels used as complementary foods (Akinola *et al*., 2014). Apart from protein and energy that are often lacking, there is a need to harness the micronutrient potential of the variety of vegetables available in many parts of Nigeria and other developing countries (Onoja *et al*., 2014). Therefore, the current study formulated improved complementary foods by optimizing the cereal legume ratio and supplementing with moringa leaf powder.

MATERIALS AND METHOD

Chemicals and reagents

All the chemicals and reagents used in this study were of analytical grade.

Procurement and Authentication of Food Materials

Maize, Wheat, Millet, Groundnut, Soya beans, and *Moringa oleifera* leaves were purchased in bulk from Birnin Kebbi New Market and authenticated in Department of Biology, Federal University, Birnin Kebbi.

Processing of the Food Materials

Desired quantity of the cereals and legumes were manually sorted to remove stones and dirt. This was followed by roasting of the cereals for about 10 to 15minutes (mins). The groundnuts were dehulled after roasting. Soya beans were soaked for about six hours, then dehulled and blanched for about 15 minutes, dried and roasted. The leaves were washed to remove dirt and soaked in 1% saline solution (NaCl) for 5 minutes to get rid of microbes. The leaves were drained of water and shade dried indoors. The dried leaves were ground and sieved.

Optimization and Formulation of the Complementary Foods

Nutrisurvey software was used to optimize the composite blends by varying the amounts of the various ingredients so as to enhance nutritional quality. From the result of the optimization, six blends designated F1, F2, F3, F4, F5 and F6 were chosen for the formulation. The proportion of various ingredients is presented in the Table 1.

Table 1: Composition of the Formulations per 100g dry weight

Ingredients	F1	F2	F3	F4	F5	F6
Maize	67.00	55.00	-	-	-	-
Wheat	-	-	67.00	55.00	-	-
Millet	-	-	-	-	67.00	55.00
Soybean	8.00	10.00	10.00	8.00	8.00	10.00
Groundnut	22.50	32.50	22.50	32.50	22.50	32.50
Moringa	2.50	2.50	2.50	2.50	2.50	2.50

Study area

The current study was conducted at Outpatient Therapeutic Site for community management of acute malnutrition in Birnin Kebbi and Kalgo Local Government areas of Kebbi state.

Ethical Approval and Informed Consent

Ethical approval was obtained from Kebbi State Ministry of Health. Informed written consent was taken from all the caregivers.

Recruitment and Randomization of Participants

The study was a community-based randomized trial in which participants were assign to groups in the order in which they joined the study.

Inclusion Criteria

- Children from12 to 59 months with MUAC <12.5 cm and ≥11.5 cm.
- Mothers accepting to prepare and feed their children with the CF.
- Residency within the study communities and available for entire period of the study.
- Written consent of a parent or guardian.

Exclusion Criteria

- Children <12 months or >59 months
- MUAC >12.4 cm and MUAC <11.5 cm or presence of bilateral pitting oedema
- Other acute illnesses requiring inpatient treatment.
- Participation in any other clinical trial

Sensory Evaluation

The samples were evaluated for colour, taste, smell and over all acceptability on a 5-point Hedonic scale as reported by Amankwah *et al*., (2009). The Samples were also presented to the children aided by their mothers to evaluate overall acceptability (Amankwah *et al*., 2009).

Product labelling and blinding

The product identification codes were marked in small print on the backside of each sachet, allowing the researcher and staff responsible for the food distribution to ensure correct distribution of the products to each Caregiver.

Description of the intervention and Feeding protocol

Caregivers were given weekly rations of 1050g, based on WHO recommendations that complementary foods should supply 550kilocalories per day for children 12 to 36 months (WHO/PAHO, 2003). After which they are expected to return with empty pack. The children were fed three to four time daily one of the complementary foods in the form of pap for up to eight weeks. Each serving of the complementary foods was 250ml (WHO, 2003; Onoja *et al*., 2014).

Study Design

Seventy participants were randomly selected and divided into seven groups of 10 participants respectively. The first six groups received the test formulation, while seventh group received Plumpy nut. The participants were treated as follows:

Group 1 received (67%) maize based complementary food (**F1**).
Group 2 received (55%) maize based complementary food (**F2**).
Group 3 received (67%) wheat based complementary food (**F3**).
Group 4 received (55%) wheat based complementary food (**F3**).
Group 5 received (67%) wheat based complementary food (**F5**).
Group 6 received (55%) wheat based complementary food (**F6**).
Group 7 received RUTF (Plumpy nut) (**F7**).

Blood samples were collected for biochemical and haematological analysis at end line (8weeks). Urine samples were also collected to estimate Iodine and Creatinine levels of the participants.

Anthropometric Measurements

Data on anthropometric parameters were obtained at baseline, 4weeks, and 8weeks by measuring weights, heights; mid upper arm circumference and skin fold thickness according to acceptable standard (WHO, 2006).

Estimation of Total Protein

Total protein was estimated according to method of Lowry *et al.*, (1951).

Estimation of Serum Albumin

Serum albumin was estimated to method of Doumas *et al*., (1971).

Estimation of Serum Globulin

Globulin was determined by difference between total protein and albumin (Turnwald and Barta, 1989).

Estimation of Serum Total Cholesterol

Cholesterol was estimated by enzymatic method as reported by Roeschlau *et al*., (1974). Cholesterol is determined after enzymatic hydrolysis and oxidation, the indicator quinoneimine is formed from hydrogen peroxide and 4-amino antipyrine in presence of phenol and peroxide.

$$\text{Cholesterol ester} + H_2O \xrightarrow{\text{cholesterol esterase}} \text{Cholesterol} + \text{fatty acid}$$

$$\text{Cholesterol} + H_2O \xrightarrow{\text{cholesterol oxidase}} \text{Cholestene-3-one} + H_2O_2$$

$$2H_2O_2 + \text{phenol} + \text{4-aminoantipyrine} \xrightarrow{\text{peroxidase}} \text{quinoneimine} + 4H_2O$$

Estimation of Serum HDL-Cholesterol

Estimation of Serum HDL-Cholesterol was according to Method of Lopez-Virella *et al.*, (1977).

Estimation of Serum Triglyceride

Triglyceride was estimated by Method of Jacobs and Van-Dermark (1960).

$$\text{Triglyceride} + H_20 \xrightarrow{\text{lipoprotein lipase}} \text{glycerol} + \text{fatty acid}$$

$$\text{Glycerol} + \text{ATP} \xrightarrow{\text{glycerol kinase}} \text{glycerol-3-phosphate} + \text{ADP}$$

Estimation of VLDL (mg/dl)

The concentration of VLDL (mg/dl) was determined as follows:

$$\frac{\text{TRIG}}{5} \text{ or } \frac{1 \times \text{Triglyceride}}{5}$$

Estimation of Serum LDL-Cholesterol by Method of Friedwald *et al.*, 1972

The concentration of LDL-Cholesterol (mg/dl) was determined as follows:

$$\text{T-Cholesterol} - \frac{\text{Triglyceride}}{5} - \text{HDL-Cholesterol}$$

Estimation of Serum Mineral Elements

Serum levels of selected mineral elements (Calcium, Iron, Zinc, and Copper) were analyzed by atomic absorption spectrophotometer (Whiteside, 1979).

Estimation of Urinary Iodine and Creatinine Concentration

The urine samples were analyzed for iodine as reported by Ohashi *et al*., (2000). Urinary creatinine was estimated by Jaffe's alkaline picrate method. Creatinine in alkaline medium reacts with picric acid to produce colour which is directly proportional to the concentration of creatinine.

Serum Vitamin A Determination

Serum vitamin A was estimated according to method of Rutkowski *et al*., (2006).

Estimation of Hematological Parameters

Full blood count was carried out using automated haematology analyser according to the method of Cheesbrough (2005).

Statistical Analysis

Data were reported as means ± standard error of mean of triplicate determination. Analysis of variance (ANOVA) was used to establish significant difference (P<0.05). Values were analyzed statistically using GraphPad PRISM version 6.05 software (Statcon, Witzenhausen, Germany).

RESULTS

The haematological parameters of the participants after intervention with the test formulations and Plumpy nut are presented in Table 2. Group F7 had the highest values for Hb (13.00g/dL) and PCV (36.80%) respectively. Group F3 on the other hand had the lowest values for Hb (11.20g/dL) and PCV (34.50%) respectively. Overall, the values suggest that the test formulations equally supported improvement in haematological parameters.

Table 2: Haematological Parameters of the participants after intervention with the Complementary Food Formulations

Group	Hb (g/dL)	PCV (%)	RBC (x10^6/µL)	WBC(x10^3/µL)	MCV (fL)	MCH (pg)
F1	12.40^a±0.06	35.80 ^{a}±0.41	4.20 ^{a}±0.06	11.70^a±0.40	74.70^a± 0.57	20.0^a±0.60
F2	11.90^a±0.12	35.90^a±0.28	4.41^b±0.23	11.50 ^{a}±0.28	73.20^a±0.13	23.3^a±0.40
F3	11.20^a±0.29	34.20^a±0.29	4.58^b±0.03	12.82^c±0.01	72.10^a±0.52	24.5^a±0.23
F4	11.50^a±0.28	34.50^a±0.28	4.75^b±0.14	12.40^a±0.23	75.70^a±0.26	25.5^a±0.18
F5	11.40^a±0.23	34.90^a±0.52	4.26 ^{b}±0.15	12.93^c±0.04	73.30^a±0.12	25.1^a±0.25
F6	11.70^a±0.40	35.10^a±0.35	4.30^b±0.17	12.27^b±0.15	75.90^a±0.25	23.5^a±0.45
F7	13.00^b±0.29	36.80^b±0.46	5.30^c±0.06	10.90^a±0.06	85.80^a±0.10	23.4^a±0.15

Values are mean ± standard error of mean (SEM). Values in the same column with different superscripts are significantly different at (P < 0.05). Groups designated F1- F6 were fed the formulations; F7 were fed Plumpy nut for eight weeks. Each group comprise ten participants.

Table 3 shows the Protein profile of the participants after intervention with the Complementary Food Formulations and Plumpy nut. Total protein, albumin, globulin in children fed the test CF formulations and children fed Plumpy nut had comparable values.

Table 3: Protein profile of the participants after intervention with the Complementary Food Formulations and Plumpy nut

Groups	Total protein	Albumin	Globulin	A/G
F1	6.20^b±0.03	3.80^a±0.40	2.40^a±0.03	1.58 ^{a}±0.01
F2	6.50^b±0.56	4.10^a±0.60	1.40 ^{a}±0.01	2.90^a±0.03
F3	5.90^b±0.04	3.60^a±0.57	2.30 ^{a}±0.05	1.57^a±0.01
F4	6.10^a±0.01	4.20^a±0.35	1.90^a±0.03	2.20^a±0.12
F5	5.50^a±0.56	4.00^a±0.58	1.50^a±0.06	2.67^a±0.39
F6	5.90^a±0.29	4.10^a±0.01	1.80^a±0.01	2.23^a±0.02
F7	6.80^b±0.23	3.90^a±0.57	2.90^a±0.40	1.34^a ±0.01

Values are mean ± standard error of mean (SEM). Values in the same row with different superscripts are significantly different at (P < 0.05). Groups designated F1- F6 were fed the CF formulations; F7 were fed Plumpy nut for eight weeks. Each group comprise ten participants. A/G is albumin globulin ratio.

Table 4 shows the lipid profile of the participants after intervention with the test formulations and Plumpy nut. No significant difference P> 0.05 was observed in Total cholesterol among the study groups. HDL-cholesterol and Triglycerides differed significantly between children receiving Plumpy nut and those receiving the test formulations.

Table 4: Serum Lipid profile of the Participants after intervention with the Complementary Food Formulations and Plumpy nut

Group	TC (mg/dL)	HDL-C (mg/dL)	LDL-C (mg/dL)	VLDL-C (mg/dL)	TRIG (mg/dL)	Aix
F1	$120.4^{a}\pm0.13$	$46.91^{a}\pm0.15$	$50.29^{b}\pm0.03$	$23.20^{b}\pm0.05$	$116^{b}\pm0.11$	2.57±0.01
F2	$116.0^{a}\pm0.06$	$39.00^{a}\pm0.06$	$59.00^{c}\pm0.09$	$18.00^{a}\pm0.04$	$90.0^{a}\pm0.08$	2.97±0.01
F3	$124.0^{a}\pm0.08$	$40.00^{a}\pm0.18$	$58.80^{c}\pm0.18$	$25.20^{b}\pm0.04$	$126.0^{b}\pm0.11$	3.10±0.02
F4	$110.0^{a}\pm0.14$	$39.00^{a}\pm0.06$	$50.60^{b}\pm0.15$	$20.40^{a}\pm0.03$	$102.0^{b}\pm0.07$	2.82±0.03
F5	$108.6^{a}\pm0.03$	$42.00^{a}\pm0.09$	$42.60^{a}\pm0.09$	$24.00^{b}\pm0.05$	$120.0^{b}\pm0.10$	2.37±0.06
F6	$105.8^{a}\pm0.04$	$38.20^{a}\pm0.10$	$45.60^{a}\pm0.13$	$22.00^{b}\pm0.04$	$110.0^{b}\pm0.10$	2.77±0.01
F7	$131.0^{a}\pm0.13$	$49.00^{b}\pm0.13$	$52.0^{b}\pm0.57$	$30.80^{c}\pm0.13$	$154.0^{c}\pm0.13$	2.67±0.06

Values are mean ± standard error of mean (SEM). Values in the same column with same superscripts are not significantly different at ($P > 0.05$). TC= Total cholesterol, HDL-C= High-density lipoprotein cholesterol, LDL-C=Low-density lipoprotein cholesterol, VLDL-C=Very low-density lipoprotein cholesterol, TRIG= Triglyceride and Aix= Artherogenic index.

Table 5: Urine Iodine and Creatinine of the participants after intervention with the Complementary Food Formulations and Plumpy nut

Groups	Urine Iodine (µg/L)	Creatinine (mg/dL)
F1	$115^{b}\pm0.57$	$82.0^{a}\pm0.15$
F2	$123^{a}\pm0.28$	$85.0^{c}\pm0.20$
F3	$119^{b}\pm0.10$	$80.0^{a}\pm0.28$
F4	$121^{a}\pm0.58$	$84.0^{c}\pm0.17$
F5	$123^{a}\pm0.56$	$85.0^{c}\pm0.58$
F6	$125^{a}\pm0.29$	$87.0^{b}\pm0.10$
F7	$130^{c}\pm0.23$	$90.0^{b}\pm0.15$

Values are mean ± standard error of mean (SEM). Values in the same row with same superscripts are not significantly different at ($P > 0.05$). Groups designated F1- F6 were fed the formulations; F7 were fed Plumpy nut for eight weeks.

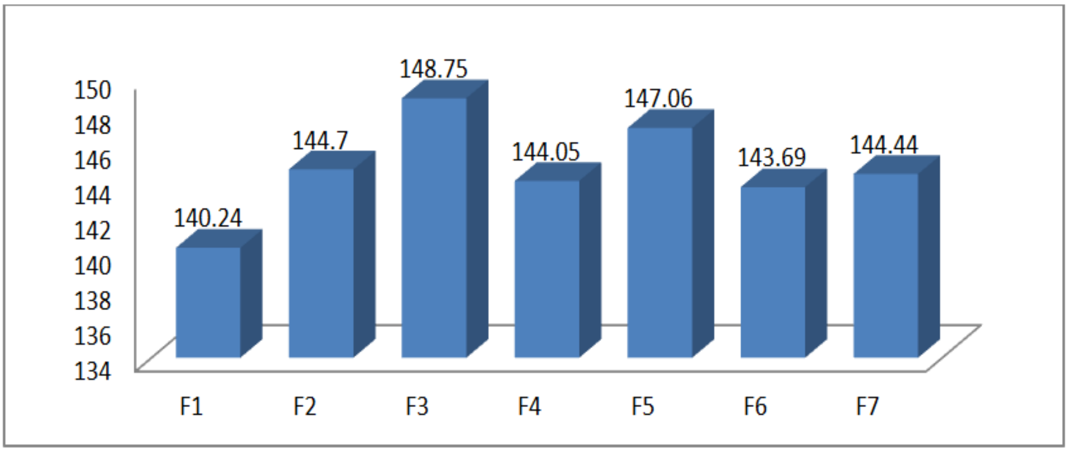

Figure 1: Urine Iodine/Creatinine (µg/g) after intervention with the Complementary Food Formulations
Values <20 µg/g severe Iodine deficiency, 50-99 µg/g moderate iodine deficiency; ≥100 µg/g (WHO, 2007)

The result of serum vitamin A is presented in Table 6. Groups F7 and F3 recorded the highest and lowest serum vitamin A respectively.

Table 6: Serum Vitamin A levels of the participants after intervention with the Complementary Foods

Group	Vitamin A (µg/dL)
F1	$45.00^{a}\pm0.28$
F2	$41.50^{a}\pm0.12$
F3	$40.00^{a}\pm0.18$

Group	Vitamin A (µg/dL)
F4	39.00[a]±0.06
F5	42.00[a]±0.09
F6	38.20[a]±0.10
F7	53.00[b]±0.57

Values are mean ± standard error of mean (SEM). Values with same superscripts are not significantly different at ($P > 0.05$). Groups designated F1- F6 were fed the CF formulations; F7 were fed Plumpy nut for eight weeks. Each group comprise ten participants.

Table 7: Selected Serum Mineral Levels of the participants after intervention with the Complementary Food Formulations and Plumpy nut

Sample	Zn (mg/dL)	Cu (mg/dL)	Fe (mg/dL)	Ca (mg/dL)
F1	0.085[a] ±0.001	0.065[a] ±0.005	0.100[a] ±0.007	9.00[b]±0.37
F2	0.078[a] ±0.002	0.063[b]±0.003	0.125[b] ±0.006	8.60[b] ±0.18
F3	0.073[a] ±0.003	0.054[c]±0.003	0.107[a] ±0.004	8.90[b]±0.32
F4	0.070[a]±0.005	0.060[b]±0.001	0.120[b]±0.007	8.50[b]±0.36
F5	0.075[a] ±0.003	0.060[b]±0.001	0.100[a] ±0.002	9.30[b] ±0.10
F6	0.080[a] ±0.010	0.056[b]±0.006	0.137[b]±0.028	9.50[b] ±0.18
F7	0.090[c]±0.002	0.075[b] ±0.005	0.145[b]±0.003	10.20[c]±0.21

Values are mean ± standard error of mean (SEM). Values in the same column with same superscripts are not significantly different at ($P < 0.05$). Groups designated F1- F6 were fed the formulations; F7 were fed Plumpy nut for eight weeks. Each group comprise ten participants.

DISCUSSION

The guiding principles in formulating CF are: High nutritional value to complement breastfeeding, Acceptability, Low price, and Use of local food materials (Dewey and Brown, 2003). The use of cereals and legumes to prepare CF for infants and young children has been suggested by previous studies (Temple *et al.*, 1996; Nnam, 2002). Literature report indicates that cereals have relatively low content of essential amino acid lysine and tryptophan (FAO, 1997; Okoh, 1998). Legumes on the other hand, are better sources of tryptophan and threonine. Therefore, a blend of cereal and legume would produce CF with superior amino acid profile. However, double mix of cereals and legumes may still be nutritionally inadequate in micronutrients (Osagie and Eka, 1998). Hence, the need for triple or quadrimix consisting of cereals, legumes, and vegetables like moringa.

Effect of the complementary food formulations on the haematological parameters of the children are presented in Table 14. The values of haematological parameters indicated availability of nutrients for synthesis of blood cells. In the current study, the blood components (Hb and PCV) of the children fed with the test formulations differ significantly ($P < 0.05$) with those of the children on RUTF (Plumpy nut). Even though, the values for haemoglobin and packed cell volume were within acceptable range.

Biochemical parameters of the study participants are summarised in Tables 15 and 16. Although the seven groups had mean serum albumin concentrations within the normal range, no significant differences were observed among the groups for albumin and globulin levels. However, Groups F4, F5, and F6 had lower levels of total protein which differed significantly p<0.05 with groups F1, F2, F3, and F7. While Group F7 had the highest levels of total protein, Group F5 had the lowest levels of total protein. The values of albumin-globulin ratio of the groups receiving the test CF did not differ significantly p<0.05 with the control group receiving RUTF.

The serum lipid profile of the participants after intervention with the CF formulations and Plumpy nut are presented in Table 16. The values of HDL-C for Groups F1-F6 differ significantly p>0.05 with Group 7 receiving RUTF. However, the values were within normal range. As for LDL-C, there was significant difference p<0.05 among the groups. While group F3 recorded the highest values, group F5 had the lowest values. Furthermore, there was no significant difference p<0.05 in the Artherogenic index as indicated in Table 16. Group 7 reported the highest level of triglyceride which differed significantly from the groups receiving the test formulation.

Figure 5 presents results for Urine Iodine/Creatinine (µg/g) after intervention with the complementary food formulations and Plumpy nut. The values obtained indicate no significant difference in the Urine Iodine/Creatinine ratio. According to WHO, values of Urine Iodine/Creatinine ratio <20 µg/g indicate severe Iodine deficiency, while 50-99 µg/g reveals moderate Iodine deficiency; and ≥100 µg/g indicate optimal Iodine status (WHO, 2007). The values obtained in current study indicate adequate Iodine status.

In an attempt to decide on the most optimal blends, a ranking system using nine nutritional, functional, and sensorial attributes was devised according to the modified method of Griffith *et al.*, (1998). The six blends were ranked from 1 (best) to 6 (worst) to objectively determine the best complementary blend. The blends yielding the lowest score were considered to possess the most suitable nutritional, functional, and sensorial attributes which are F4, F6, and F2 respectively.

CONCLUSION

The results obtained in this study demonstrate that the optimized cereal-legume blended supplemented with Moringa leaf powder improves the biochemical and hematological parameters of children. It was seen that supplemented diet increased the mean values of serum proteins, some minerals contents, erythrocyte indices, hemoglobin status, and decreased the mean value of serum creatinine and urea. The findings of this study show that the study optimized cereal-legume blend supplemented with Moringa leaf powder has the potential to improve the nutritional status and general health of children in developing countries. The nutritional value of the supplemented cereal-legume blend was found to be better as compared to the unsupplemented cereal-legume blend, due to the presence of essential micronutrients in Moringa leaf. Therefore, incorporating the optimized cereal-legume blend and Moringa leaf powder in the diets of children can help bridge the nutritional gap and improve the health and nutritional status of children.

Furthermore, biochemical and haematological parameters differed significantly between the control and treatment groups suggesting that the Optimized Cereal-legume Blend supplemented with Moringa leaf Powder had a positive effect on child health. The current findings provide valuable evidence to support the consumption of Optimized Cereal-legume Blend supplemented with Moringa leaf Powder in order to improve the health of children.

The findings of this study provide strong evidence that the optimized cereal-legume blend supplemented with Moringa leaf powder has a positive effect on the biochemical and haematological parameters of children. The results show that the optimized cereal-legume blend supplemented with Moringa leaf powder improved the haemoglobin, iron, zinc, and Vitamin A levels in the children's blood significantly. Furthermore, the improvement of biochemical parameters like fasting glucose, total bilirubin, and creatinine were significantly in favour of the optimized cereal-legume blend supplemented with Moringa leaf powder. All in all, the supplemented optimized cereal-legume blend with Moringa leaf powder has a beneficial effect on the nutritional status of children. This could be a potential strategy to improve the nutritional status of the children in low-income countries. Therefore, further research is recommended to fully understand the potential effect of such nutritional interventions.

The current study established the chemical compositions and nutritional qualities of six complementary food formulations. The findings from the proximate composition, amino acid profile and selected minerals indicate that the formulated CF meet nutritional specification in codex guideline on formulated complementary foods for infants and young children. The physicochemical and functional properties of the complementary food samples suggest that more of the samples could be prepared using a small amount of water yet giving the desirable energy density and semi-solid consistency which can easily be spoon-fed to infant and young children. The result of the sensory evaluation as revealed by the children and their caregivers point to acceptability of gruels prepared with the composite lends.

The feeding trials revealed that the CF formulations can support growth and recovery in children with moderate acute malnutrition. The results of the current study therefore provide a basis for the development of acceptable complementary foods that can provide the required protein and energy levels to support basal metabolism, physical activity and prevent PEM. Based on nutritional, functional, and sensorial attributes; blends F4, F6, and F2 with 55% cereals ranked best. Therefore, this study has established that with proper selection and combination of local foodstuff, it is possible to prepare complementary foods that would be acceptable, readily available, and nutritionally adequate.

Authors' Contribution

This study is a product of the collective efforts of the all authors. All authors participated in conceptualization, designing, supervising and coordinating the study. All authors conducted the experimental studies, analyzed, interpreted data and wrote the manuscript. All authors read and approved the final manuscript.

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