NUTRITIONAL VALUE AND PHYTOCHEMICAL PARAMETERS OF READY-TO-USE THERAPEUTIC FOODS PREPARED FROM INDEGENOUS INGREDIENTS FOR THE MANAGEMENT OF SEVERE ACUTE MALNUTRITION

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Abstract

An adequate diet is essential for children's survival and well-being during their first two years of life. This study aims to formulate and assess the nutritional qualities of ready-to-use- therapeutic food made with pearl millet, *Moringa oleifera* seed and Bambara groundnut for management of Severe Acute Malnutrition. The food products were locally obtained and coded as follows: PMF: (100% Pearl Millet Flour); PBM1: (60% Pearl millet + 20% Bambara groundnut + 5% Moringa leave + 5% Vegetable oil + 10% Sucrose); PMB2: (50% Pearl millet + 30% Bambara groundnut + 5% Moringa leave + 5% Vegetable oil + 10% Sucrose); PMB3: (40% Pearl millet + 40% Bambara groundnut + 5% Moringa leave + 5% Vegetable oil + 10% Sucrose); CTL: Control (UNICEF product). Proximate, minerals, amino acid, free fatty acid profile of pearl millet ready-to-use- therapeutic food were determined based on standard analytical methods. The data was analyzed using one-way analysis of variance (ANOVA) at $p<0.05$. The crude protein contents of the formulated pearl millet ready-to-use-therapeutic food samples varied from 17.26 g/100 g in PBM1 – 21.51 g/100 g in PBM3. The mineral composition of pearl millet ready-to-use-therapeutic food showed that phosphorous (903.11 - 1061.33 mg/100g). The total amino acids ranged between 90.68 g/100 g in PBM1 – 98.94 g/100 g in PBM3. The proportion (%) of Total Amino Acids (TAA) to Essential Amino Acids (EAA) ranged from 58.40 – 60.52%. Prepared formulated samples may be an excellent way to manage severe acute malnutrition.

Keywords: Ready to use, Therapeutic foods, Severe acute malnutrition, Management

Introduction

Proper early childhood nutrition habits can help ensure that children receive adequate diet, which is essential for their survival and health especially throughout the first two years of life (Adebayo et al., 2013; Eyitayo, 2019; Oyeleke et al., 2019)). For a child to develop to the fullest extent possible, proper nutrition during infancy and childhood is essential (Talabi *et al.*, 2022). The primary causes of delay in growth and cognitive development, as well as a rise in the likelihood of morbidity and death in children, have been linked to inadequate and poor-quality supplementary diets (Black et al., 2008, Rogol et al., 2023, Yamashiro et al., 2022). Additionally, Given that it can be less expensive to produce Ready-to-Use Therapeutic Foods (RUTF) with less or no milk powder, or because using locally or indigenous ingredients could render RUTF more acceptable, WHO and UNICEF recommended that children with SAM could be managed at home using RUTF (WHO, 2011). Pearl millet exhibited higher levels of fat (5.7%), protein (14.0%), ash (2.1%) and fibre (2.0%) than other key cereal crops (wheat, rice, and sorghum). Groundnut Bambara (*Vigna subterranean*) high protein quality and amino acid content are the primary reasons for its use ((Alabi et al., 2023, Ramatsetse et al., 2023). Protein, vitamins, beta-carotene, amino acids, and other phenolics can all be found in good amounts in *Moringa oleifera* seeds (Anwar et al., 2007).

Due to recent problems such as insecurity, particularly in the northern region of the country, the need for RUTF has multiplied significantly in Nigeria throughout a span of years. Formulations utilizing inexpensive, regionally accessible food ingredients that are also suitable in terms of culture and organoleptic properties are required to satisfy the RUTF demand. In light of the necessity to create a therapeutic food that is high in nutrients and ready for usage. A breakthrough in RUTF production to lower costs could be the replacement of milk powder in the RUTF mix, as suggested by (UNICEF, 2016). This investigation is focused on the production and evaluation of nutritional elements and phytochemical parameters of ready-to-use-therapeutic food, implementing locally accessible food items in the management for severe acute malnutrition in children between 6-59 months from Pearl millet, Bambara groundnut and *Moringa oleifera* seed.

Materials and Methods

Food Materials Sources, Chemicals and Reagents

Pearl millet (*Penniselum glaucum*) and Bambara groundnut (*Vigna subterranea*) were bought from Gusau Central Market, Zamfara State, Nigeria; while *Moringa oleifera* was collected from the Afe Babalola University Ado-Ekiti farm, Nigeria. The analytical-grade chemicals used in the analysis were purchased from Sigma-Aldrich in London, UK.

Identification process of Food Materials

The raw food products were subjected to authentication, which was done at the Afe Babalola University, Ethical Approval – Health Research Ethical Committee (HREC), Afe Babalola University Ado – Ekiti (ABUAD/21/05/2024/434)

Methods

***Pearl millet flour preparation**:* With minor adjustments, the pearl millet was ground into flour using the (Akinyede et al., 2020) method.

Bambara groundnut flour preparation: Bambara groundnut flour was processed utilizing the technique proposed by (Talabi et al., 2019).

The methodology for the preparation of Moringa oliefera seeds flour: This was conducted utilizing the methodology established by (Ijarotimi et al., 2022,)

Pearl Millet Ready-to-use-therapeutic Food Formulation

The Pearl millet, Bambara groundnut, and *Moringa oliefera* seeds flour samples were blended together utilizing (UNICEF, 2016) criteria, the following food combinations were created: PMF (100% pearl millet flour), PMB1 (Pearl millet 60%, Bambara groundnut 20%, moringa leave 5%, vegetable oil 5%, and sucrose 10%). PMB2 (Pearl millet 50%, Bambara groundnut 30%, moringa leave 5%, vegetable oil 5%, and sucrose 10%) PMB3 (Pearl millet 40%, Bambara groundnut 40%, moringa leave 5%, vegetable oil 5%, and sucrose 10%) and UNICEF (Full fat milk 30%, peanut flour 25%, vegetable oil 15%, sucrose 28% and mineral mix 2). An Umthric mixer was used to mix the final mixture for 15 min for each formulation.

Evaluation of the Proximate, crude fat, protein, ash, crude fibre and Energy Content in Pearl Millet- Ready-to-Use Therapeutic Food

The proximate composition, assessment of the crude fat, protein, ash and crude fibre content of Pear millet ready-to-use- therapeutic foods were determined using (AOAC., 2012) method.

Energy value Evaluation

The determination of the energy in the samples was conducted using an indirect calculation approach proposed by (Iombor et al., 2009)

Assessment of Pearl Millet's Amino Acid Profile for Therapeutic Use

The (Spackman et al., 1978) method was employed towards the determination of amino acid profiles of the Pearl millet ready-to-use-therapeutic food blend samples.

Statistical Analysis

Three replicates of each data collection were conducted. Statistical analyses were carried out utilizing GraphPad Prism version 5.01 and the Statistical Package for the Social Sciences (SPSS) version 21.0 for Windows. The differences between the means were evaluated through one-way analysis of variance (ANOVA), with significance determined at $p<0.05$ using the New Duncan Multiple Range Test (NDMRT). Results were reported as mean (±SEM).

Results

The results tables 1-6 presented proximate composition, minerals composition, amino acids profile, fatty acids, phytochemicals composition and functional properties of pearl millet ready to use therapeutics foods.

Table 1: Proximate composition (g/100 g) of pearl millet ready-to-use- therapeutic food

Parameters	PMF	PBM1	PBM2	PBM3	CTL	RDA
Moisture	8.55 ± 1.03^{a}	7.86 ± 1.00^{ab}	7.54 ± 1.05^{ab}	7.31 ± 0.42^{b}	5.46 ± 0.88^{c}	<10
Total Ash	2.20 ± 0.08^{d}	2.52 ± 0.04^{c}	2.84 ± 0.03^{b}	3.00 ± 0.05^{a}	2.09 ± 0.02^{d}	>3
Crude Fat	2.73 ± 0.51^{e}	12.02 ± 1.13^{d}	15.85 ± 1.49^{c}	19.54 ± 1.05^{b}	30.87 ± 3.51^{a}	<25
Crude Fiber	3.22 ± 0.33^{d}	3.77 ± 0.11^{c}	3.93 ± 0.02^{b}	4.71 ± 0.04^{a}	1.59 ± 0.02^{e}	>5
Crude Protein	13.68 ± 1.49^{d}	17.26 ± 0.37^{bc}	19.92 ± 0.51^{b}	21.51 ± 0.32^{a}	18.05 ± 1.33^{b}	>14
Carbohydrate	69.62 ± 1.81^{a}	56.57 ± 1.36^{b}	49.92 ± 1.07^{c}	43.93 ± 1.05^{d}	41.94 ± 1.00^{e}	64
Energy kcal/100 g	357.77 ± 5.29^{e}	403.50 ± 4.37^{d}	422.01 ± 2.77^{c}	447.62 ± 3.81^{b}	517.79 ± 3.90^{a}	344

Mean ± SD. Values with the same superscript are not significantly different at p>0.05.
Key: PMF: (100% Pearl millet flour); CTL: Control (UNICEF product).
PBM1: (60% Pearl millet + 20% Bambara groundnut + 5% Moringa leave + 5% Vegetable oil + 10% Sucrose).
PMB2: (50% Pearl millet + 30% Bambara groundnut + 5% Moringa leave + 5% Vegetable oil + 10% Sucrose).
PMB3: (40% Pearl millet + 40% Bambara groundnut + 5% Moringa leave + 5% Vegetable oil + 10% Sucrose).
*RDA: (FAO/WHO, 1991) Recommended Daily Allowance.

Table 2: Mineral composition (mg/100 g) of pearl millet ready-to-use- therapeutic food

Parameters	PMF	PBM1	PBM2	PBM3	CTL	*RDA
Sodium (Na)	13.21 ±0.52[e]	172.72 ±1.43[d]	191.63 ±1.74[c]	264.96 ±1.66[b]	281.90 ±1.00[a]	296
Potassium (P)	183.65 ±1.33[e]	239.77±1.25[d]	274.81±1.70[c]	306.42±1.68[b]	336.01±1.06[a]	456
Phosphorous (K)	897.88±1.65[d]	903.11±1.35[c]	979.46±1.63[b]	1061.33±1.25[a]	861.42±0.80[e]	516
Calcium (Ca)	66.85±0.94[e]	171.66±1.02[d]	284.87±1.05[c]	319.66±1.45[b]	323.48±1.03[a]	500
Manganese (Mn)	1.22 ±0.01[e]	3.88 ±0.89[d]	5.67 ±0.61[c]	8.11 ±0.05[b]	10.20 ±0.05[a]	1.50
Iron (Fe)	11.85 ±1.00[e]	45.61 ±0.031[c]	66.38 ±0.48[b]	75.14 ±0.77[a]	15.09 ±0.03[d]	16
Zinc (Zn)	2.07±0.02[d]	35.38±0.80[c]	48.33±1.07[b]	63.89±1.42[a]	64.85±0.08[a]	3.20
Lead (Pb)	0.00 ±0.00[a]	0.00 ±0.00[a]	0.00 ±0.00[a]	0.00 ±0.00[a]	0.00 ±0.00[a]	0.01
Na/K ratio	0.01±0.00[d]	0.19±0.02[c]	0.19±0.02[c]	0.25±0.02[b]	0.33±0.01[a]	<1.0
Ca/P ratio	0.36±0.02[d]	0.72±0.01[c]	1.04±0.02[b]	1.04±0.01[b]	2.75±0.01[a]	>1.0

Mean ± SD. Values with the same superscript are not significantly different at $p>0.05$.
Key: PMF: (100% Pearl millet flour); CTL: Control (UNICEF product).
PBM1: (60% Pearl millet + 20% Bambara groundnut + 5% Moringa leave + 5% Vegetable oil + 10% Sucrose).
PMB2: (50% Pearl millet + 30% Bambara groundnut + 5% Moringa leave + 5% Vegetable oil + 10% Sucrose).
PMB3: (40% Pearl millet + 40% Bambara groundnut + 5% Moringa leave + 5% Vegetable oil + 10% Sucrose).
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Table 3: Amino acids (g/ 100 g of protein) profile of ready-to-use- therapeutic food

Parameters	PMF	PBM1	PBM2	PBM3	CTL	*RDA
Non-essential amino acids (NEAAs)						
Glycine	3.11^{e}	6.53^{c}	6.91^{b}	7.05^{a}	6.38^{d}	-
Alanine	5.03^{c}	4.69^{e}	5.38^{b}	5.67^{a}	4.92^{d}	-
Serine	4.07^{d}	4.33^{c}	5.83^{b}	6.03^{a}	6.02^{a}	-
Proline	1.89^{e}	2.93^{a}	2.14^{c}	2.36^{b}	2.01^{d}	-
Aspartic	4.45^{e}	4.67^{d}	4.78^{b}	4.90^{a}	4.73^{c}	-
Cysteine	2.27^{e}	2.99^{d}	3.36^{c}	3.54^{a}	3.47^{b}	-
Glutamic	12.07^{e}	16.75^{d}	17.42^{c}	18.73^{a}	17.51^{b}	-
Threonine	1.33^{e}	2.69^{d}	2.95^{a}	2.08^{c}	2.92^{b}	-
Tyrosine	3.25^{d}	4.08^{c}	4.13^{b}	4.66^{a}	4.09^{c}	-
Arginine	5.83^{e}	6.83^{d}	6.99^{b}	7.15^{a}	6.94^{c}	-
ΣNEAAs	43.30^{e}	56.49^{d}	59.89^{b}	62.17^{a}	58.99^{c}	-
Essential amino acids (EAAs)						
Phenylalanine	1.56^{e}	2.08^{c}	2.31^{b}	2.94^{a}	2.05^{d}	6.90
Histidine	3.14^{e}	3.57^{d}	3.98^{b}	4.33^{a}	3.87^{c}	1.00
Methionine	2.99^{d}	3.05^{c}	3.56^{b}	3.80^{a}	3.56^{b}	2.70
Threonine	4.03^{e}	4.33^{d}	4.69^{c}	5.08^{a}	4.81^{b}	3.70
Valine	4.97^{e}	5.91^{d}	5.99^{c}	6.21^{a}	6.04^{b}	3.80
Tryptophan	5.74^{a}	2.25^{b}	0.93^{c}	0.94^{c}	2.25^{b}	1.25
Isoleucine	3.51^{e}	3.88^{d}	3.95^{c}	4.11^{a}	4.05^{b}	3.10
Leucine	5.83^{e}	6.61^{d}	6.76^{c}	6.95^{a}	6.86^{b}	7.30
Lysine	1.07^{e}	2.51^{d}	2.78^{a}	2.41^{b}	2.28^{c}	6.40
ΣEAAs	**32.84^{e}**	**34.19^{d}**	**34.95^{c}**	**36.77^{a}**	**35.77^{b}**	
Predicted nutritional qualities						
TAA	76.14^{e}	90.68^{d}	94.84^{b}	98.94^{a}	94.76^{c}	-
TSAA(Meth+Cys)	5.26^{e}	6.04^{d}	6.92^{c}	7.34^{a}	7.03^{b}	-
ArEAA (Phe+Tyr)	4.81^{e}	6.16^{c}	6.44^{b}	7.60^{a}	6.14^{d}	-
%(TEAA/TNEAA)	75.84^{a}	60.52^{b}	58.40^{c}	59.14^{c}	60.63^{c}	36
PER (g/100g)	2.11^{d}	2.33^{c}	2.89^{a}	2.43^{b}	2.42^{b}	-
EAAI (%)	55.45^{e}	64.14^{c}	62.45^{d}	72.93^{a}	66.15^{b}	-
P-BV (%)	48.74^{e}	58.21^{c}	56.37^{d}	67.79^{a}	60.40^{b}	-
Nutritional index (%)	7.58^{e}	11.07^{d}	12.44^{b}	15.69^{a}	11.94^{c}	-
Arginine /Lysine	5.45^{a}	2.72^{d}	2.51^{e}	2.97^{c}	3.04^{b}	-
BCAAs	11.87^{e}	15.03^{d}	15.53^{b}	15.57^{a}	15.18^{c}	-

Mean values with the same superscript are not significantly different at p>0.05.
Key: PMF: (100% Pearl millet flour); PBM1: (60% Pearl millet + 20% Bambara groundnut + 5% Moringa leave + 5% Vegetable oil + 10% Sucrose); PMB2: (50% Pearl millet + 30% Bambara groundnut + 5% Moringa leave + 5% Vegetable oil + 10% Sucrose); PMB3: (40% Pearl millet + 40% Bambara groundnut + 5% Moringa leave + 5% Vegetable oil + 10% Sucrose).

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Table 4: Fatty acid profile of the formulated pearl millet ready-to-use-therapeutic food

Parameters	PMF	PBM1	PBM2	PBM3	CTL	*RDA
Saturated fatty acids (SFA)						
Caprylic acid	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]	-
Capric acid	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]	-
Lauric acid	0.00[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]	-
Myristic acid	0.28[e]	0.45[d]	0.52[c]	0.58[a]	0.55[b]	-
Palmitic acid	12.37[e]	16.82[c]	16.99[b]	17.51[a]	16.37[d]	-
Margaric acid	0.09[c]	0.09[c]	0.13[b]	0.17[a]	0.16[a]	-
Stearic acids	1.38[e]	5.11[c]	5.37[b]	5.93[a]	4.17[d]	-
Behenic acid	0.38[d]	0.68[c]	0.74[b]	0.81[a]	0.74[b]	-
Lignoceric acid	0.08[d]	0.91[b]	0.99[a]	0.24[c]	0.91[b]	-
Arachidic acid	0.14[c]	0.19[b]	0.14[c]	0.19[b]	0.22[a]	-
ΣSFA	14.72[e]	24.25[c]	24.88[b]	25.43[a]	23.12[d]	45.2 – 53.5
Monounsaturated fatty acids (MUFA)						
Palmitoleic acid	2.09[a]	0.98[b]	0.18[e]	0.36[c]	0.28[d]	-
Oleic acid	18.96[e]	49.61[d]	52.85[b]	57.32[a]	50.48[c]	-
Erucic acid	0.51[e]	0.55[d]	0.63[c]	0.79[a]	0.73[b]	-
ΣMUFA	21.56[e]	51.14[d]	53.88[b]	57.02[a]	51.49[c]	-
Polyunsaturated fatty acids (PUFA)						
Linoleic acid	28.61[e]	31.99[d]	33.76[c]	38.11[a]	35.11[b]	11 – 12
Linolenic acid	4.38[e]	10.89[d]	11.48[c]	12.93[a]	11.74[b]	0.8 – 0.9
Arachidonic acid	0.16[c]	0.11[d]	0.18[b]	0.21[a]	0.20[a]	0.5 – 0.6
ΣPUFA	33.15[e]	42.99[d]	44.83[c]	51.25[a]	47.05[b]	-
MUFA/PUFA	0.65[e]	1.19[b]	1.20[a]	1.11[c]	1.09[d]	-
PUFA/SFA	2.25[a]	1.77[e]	1.80[d]	2.01[c]	2.04[b]	>1.0
(PUFA+MUFA)/SFA	3.72[d]	3.88[c]	3.97[b]	4.26[a]	4.26[a]	>1.0

Mean values with the same superscript are not significantly different at p>0.05.
Key: PMF: (100% Pearl millet flour); PBM1: (60% Pearl millet + 20% Bambara groundnut + 5% Moringa leave + 5% Vegetable oil + 10% Sucrose); PMB2: (50% Pearl millet + 30% Bambara groundnut + 5% Moringa leave + 5% Vegetable oil + 10% Sucrose); PMB3: (40% Pearl millet + 40% Bambara groundnut + 5% Moringa leave + 5% Vegetable oil + 10% Sucrose); CTL: Control (UNICEF product).

Table 5: Phytochemical composition of ready-to-use- therapeutic food

Parameters	PMF	PBM1	PBM2	PBM3	CTL	*CV
Phenol (mg/g)	19.03±0.51[e]	31.05±0.43[d]	51.38±1.04[c]	63.26±0.22[a]	56.39±1.08[b]	-
Tannin (mg/g)	23.01±0.05[a]	17.63±0.11[b]	10.85±0.06[c]	8.13±0.08[e]	9.22±0.31[d]	3.0 g/ 100 g
Saponin (%)	18.68±0.09[a]	10.76±0.03[b]	7.66±0.05[c]	5.39±0.04[d]	4.13±0.07[e]	-
Oxalate (%)	19.24±0.04[a]	16.27±0.08[b]	15.36±0.05[c]	10.04±0.08[d]	9.42±0.07[e]	2.5 g/ 100 g
Trypsin Inhibitor (mg/g)	10.48±0.05[e]	14.00±0.01[d]	16.53±0.08[c]	20.62±0.05[a]	18.66±0.06[b]	0.25 g/100 g
Phytic (mg/g)	41.58±1.05[e]	51.88±2.04[d]	59.63±1.20[c]	65.09±0.35[a]	60.84±1.27[b]	5 – 6 g/100 g
Phytate/Ca (mmol)	0.377[a]	0.183[b]	0.127[c]	0.123[d]	0.114[e]	240
Phytate/Zn	9.780[a]	1.440[b]	1.220[c]	1.000[d]	0.920[e]	15,000
Phytate/iron	2.977[a]	0.965[b]	0.765[c]	0.765[c]	0.621[d]	>1,000
Phytate*Ca/Zn	33.062[a]	6.198[d]	8.690[b]	8.690[b]	7.472[c]	>200,000

Mean ± SD. Values with the same superscript are not significantly different at p>0.05.
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Table 6: Functional properties of Pearl Millet Ready-to-use-therapeutic Food

Sample	PMF	PBM1	PBM2	PBM3	CTL
Bulk Density (g/ml)	0.51 ±0.04^{e}	0.76±0.02^{d}	0.79±0.03^{c}	0.82±0.03^{b}	0.89±0.02^{a}
OAC (mg/g)	89.10±0.96^{e}	106.11±0.37^{d}	121.33±0.63^{c}	129.45±0.28^{b}	143.27±0.21^{a}
WAC (mg/g)	47.23±0.03^{c}	67.88 ±1.00^{b}	68.04±0.05^{b}	72.80±0.09^{a}	73.22 ±0.11^{a}
Least Gelation (%)	6.00±0.00^{a}	5.00±0.00^{b}	5.00±0.00^{b}	4.00±0.00^{c}	3.00±0.00^{d}
Swelling (%)	110.90±2.05^{e}	141.08±0.05^{d}	162.04±0.07^{c}	199.56±0.48^{b}	213.44±0.06^{a}

Mean ± SD. Values with the same superscript are not significantly different at p>0.05.
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PMB2: (50% Pearl millet + 30% Bambara groundnut + 5% Moringa leave + 5% Vegetable oil + 10% Sucrose).
PMB3: (40% Pearl millet + 40% Bambara groundnut + 5% Moringa leave + 5% Vegetable oil + 10% Sucrose).
*RDA: (FAO/WHO, 1991) Recommended Daily Allowance; OAC: Oil absorption capacity; WAC: Water absorption capacity.

Discussion of Findings

According to the results of the present study, the total ash concentration obtained falls within the range of values (2.00 - 78 g/100 g) as reported by Ijarotimi et al., (2022) for sorghum ready-to-use therapeutic meal enhanced with soybeans and *moringa oleifera*. The total ash content of food items provided a general estimation of the mineral concentration in the product. Hence, compared to the control samples (PMF - 100% pearl millet and CTL - UNICEF product), the pearl millet ready-to-use therapeutic food showed a higher mineral content needed for infant and toddler growth and also the development of the child. These values were significantly ($p<0.05$) higher compared with the control samples (3.22 g/100 g obtained in PMF – 100% pearl millet and 1.59 g/100 g obtained in CTL – UNICEF product). These results showed that pearl millet ready-to-use-therapeutic food had the highest crude fiber content than the control samples. Comparatively, these findings are within the range of values (2.0 – 2.82 g/100 g) reported by

(Ijarotimi et al., 2022) for sorghum ready-to-use-therapeutic food enriched with soybeans and *moringa oleifera* but lower than the recommended value (>5.00 g/100 g) for infant and young children's complementary foods by (FAO/WHO, 1991).

The amount of crude protein of the developed pearl millet ready-to-use-therapeutic food samples varied between 17.26 g/100 g in PBM1 – 21.51 g/100 g in PBM3. These values were higher ($p<0.05$) compared with the control sample 13.68 g/100 g obtained in PMF – 100% pearl millet but comparable with 18.05 g/100 g in CTL – UNICEF product. These results showed that formulated pearl millet ready-to-use-therapeutic food contained appreciable amount of protein content than the control sample (PMF – 100% pearl millet). This finding is within the range of values (7.72 – 16.93 g/100 g) reported by (Ijarotimi et al., 2022) for sorghum ready-to-use-therapeutic food enriched with soybeans and *moringa oleifera* as well as higher than the suggested value (14.00 g/100 g) for infant, and young children's complementary foods by (FAO/WHO, 1991).

The minerals composition of the present study showed that phosphorus (903.11 - 1061.33 mg/100g) was the most abundant in the formulated pearl millet ready-to-use-therapeutic food samples. These values comparatively were higher than the values obtained in 100% pearl millet (897.88mg/100 g) and CTL – UNICEF product (861.42 mg/100g) respectively. These values are lower compared with the mineral composition (phosphorus) values (3855.6 – 4581.0 mg/100 g) reported by (Ijarotimi *et al.*, 2022). for sorghum ready-to-use- therapeutic food enriched with soybeans and *moringa oleifera*. However, the values obtained in the present study are higher than the recommended (FAO/WHO, 1991) standard levels for infants' complementary foods. The Ca/P ratio of PBM2, PBM3 and CTL in present study were within the recommended (>1.0) value of (FAO/WHO, 1991) standard levels for infant's complementary foods. The Ca/P ratios result in this study for the ready-to-use-therapeutic food (PBM2, PBM3 and CTL) can be said to be not only good but also suggest that it might support children's bone and teeth development and improved intestine absorption of calcium (Ijarotimi et al., 2022).

The percentage ratio of Essential Amino Acid (EAA) to Total Amino Acid (TAA) ranged from 58.40 – 60.52% for the formulated pearl millet ready-to-use- therapeutic foods. A significant reduction ($p<0.05$) was noted in these values when contrasted with the 75.84% obtained in PMF – 100% pearl millet control sample but comparable with 60.63% in CTL – UNICEF product. The pearl millet ready-to-use therapeutic foods formulated TEAA to TAA ratio ranged from 38 to 55%, which was higher than the 36% deemed sufficient for infants' ideal protein intake ((Esan et al., 2018, FAO/WHO/UNU, 2007); These levels were significantly higher ($p<0.05$) than those found in the control sample, which recorded 12.07 g/100 g in PMF, a product composed entirely of pearl millet yet were comparable to the 17.51 g/100g found in CTL, a product from UNICEF. The human body needs glutamic acid, an alpha-amino acid, in the biosynthesis of proteins. It supports brain, cardiac, and metabolic processes. The total saturated fatty acid (SFA) composition of the formulated pearl millet ready-to-use-therapeutic food samples ranged between 24.25% in PBM1 and 25.43% in PBM3, while that of the control sample is 14.72% in PMF – 100% pearl millet and 23.12% in CTL – UNICEF product respectively.

Fatty acid profile of ready-to-use- therapeutic food formulated pearl millet ready-to-use-therapeutic food samples ranged between 51.14% in PBM1 and 57.02% in PBM3, while that of the control sample is 21.56% in PMF – 100% pearl millet and 51.49% in CTL – UNICEF product respectively. The values for the total polyunsaturated fatty acid (PUFA) in the formulated pearl millet ready-to-use-therapeutic food samples ranged between 42.99% in PBM1 and 51.25% in PBM3, while that of the control sample is 33.15% in PMF – 100% pearl millet and 47.05% in CTL – UNICEF product respectively.

The total phenol content in the formulated pearl millet ready-to-use-therapeutic food samples varied between 31.05 mg/g in PBM1 and 63.26 mg/g in PBM3, while that of the control sample is 19.03 mg/g in PMF – 100% pearl millet and 56.39 mg/g in CTL – UNICEF product respectively. The phytic content in the formulated pearl millet ready-to-use-therapeutic food samples ranged between 51.88 mg/g in PBM1 and 65.09 mg/g in PBM3, while that of the control sample is 41.58 mg/g in PMF – 100% pearl millet and 60.84 mg/g in CTL – UNICEF product respectively. In general, the anti-nutrients concentrations such as tannin, saponin and oxalate in the formulated pearl millet ready-to-use-therapeutic food samples were ($p<0.05$) lower when compared with the PMF – 100% pearl millet but comparable to CTL – UNICEF product but all are lower compared with the critical values limit presented in table 5 correspondingly.

The bulk density of the developed pearl millet ready-to-use-therapeutic food samples is significantly higher than that of the PMF but lower compared with the CTL. Nevertheless, the bulk density of formulated pearl millet ready-to-use-therapeutic food and CTL are within the recommended value (<0.7) of NIS for infant food. In the context of packaging, the significance of bulk density cannot be overstated (Adebayo et al., 2013, Sharma et al., 2012).

Water Absorption Capacity (WAC) of the formulated pearl millet ready-to-use-therapeutic samples varied from 67.88 mg/g in PBM1 to 72.80 mg/g in PBM3, whereas the control varied from 47.23 mg/g in PMF to 73.22 mg/g in CTL sample. The present study's pearl millet ready-to-use therapeutic food samples had lower WACs than PMF, which is advantageous for creating thinner gruels that will increase nutrient intake (Kulkarni et al., 1991). In addition, the food products' microbial activities were reduced, extending their shelf life (Giami & Bekebain, 1992).

Conclusion

The results of this study revealed lowered moisture composition of the formulated pearl millet ready-to-use-therapeutic food when compared with 100% pearl millet but higher compared with UNICEF product. The reduced moisture level may help with microbiological prevention and shelf life. The findings indicated that the pearl millet ready-to-use therapeutic food had the greatest amount of total ash, indicating a higher mineral content which could support child growth. Additionally, the pearl samples had a higher fibre content than the control samples. Also, formulated pearl millet ready-to-use-therapeutic food samples crude protein contents were higher than PMF – 100% pearl millet but comparable CTL – UNICEF product. This suggested that the diet would be advantageous for infants' growth and development. Although the energy value of the developed pearl millet ready-to-use-therapeutic food samples showed higher values than PMF – 100% pearl millet. Also, the study's Ca/P ratio results for the ready-to-use therapeutic foods (PBM2, PBM3, and CTL) were found to be favourable and may help children's teeth and bone growth as well as better intestinal calcium absorption. The amino acid profile of the developed pearl millet ready-to-use-therapeutic foods samples showed higher values in glutamic, histidine and arginine levels than the PMF – 100% pearl millet but comparable with CTL – UNICEF product. In addition, the overall amino acid profile was higher, indicating that the samples could be beneficial for growth and development of children.

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References

Adebayo, O. R., Olayiwola, O. A., & Shittu, S. A. (2013). Functional properties and anti-nutritional factors of some selected Nigerian cereals. *Comprehensive Research Journal of Agricultural Science (CRJAS)*, *1*(1), 1–5.

Akinyede, A. I., Oluwajuyitan, T. D., & Dada, J. B. (2020). Influence of substitution on amino-acid profile, physicochemical and sensory attributes of breakfast cereal from millet, soy cake, rice bran and carrot pomace blends. *MOJ Food Processing and Technology*, *8*(1), 19–27.

Alabi, O. O., Annor, G. A., & Amonsou, E. O. (2023). Effect of cold plasma-activated water on the physicochemical and functional properties of Bambara groundnut globulin. *Food Structure*, *36*, 100321.

Anwar, F. S., Latif, M. A., & Gilani, A. H. (2007). Moringa oleifera: A food plant with multiple bio-chemical and medicinal uses – A review. *Phytotherapy Research*, *21*, 17–25.

AOAC. (2012). *Association of Official Analytical Chemists*. Gathersburg, MD, USA.

Black, R. E., et al. (2008). Maternal and child nutrition: Global and regional exposures and health consequences. *The Lancet*, *371*, 243–260.

Davies, N. T., Carswell, A. J. P., & MC, F. (1985). The effect of variation in dietary calcium intake on the phytate-zinc interaction in rats. In *The International Conference on Trace Elements in Man and Animals (TEMA)* (pp. 456–457). Wallingford, U.K.

Esan, Y. O., Omoba, O. S., & Enujiugha, V. N. (2018). Biochemical and nutritional composition of two accessions of *Amaranthus cruentus* seed flour. *American Journal of Food Science and Technology*, *6*(4), 145–150.

Eyitayo, A. O. (2019). The evaluation of nutritional composition and functional and pasting properties of wheat flour-coconut flour blends. *Croatian Journal of Food Science and Technology*, *11*(1), 21–29.

FAO/WHO. (1991). *Guidelines on formulated supplementary foods for older infants and young children* (CAC/GL 08). FAO/WHO Joint Publications.

FAO/WHO/UNU. (2007). *Protein and amino acid requirements in human nutrition*.

Giami, S. Y., & Bekebain, D. A. (1992). Proximate composition and functional properties of raw and processed full fat fluted pumpkin seed flour. *Journal of Food Science and Agriculture*, *59*(32).

Hallberg, L., Brune, M., & Rossander, L. (1989). Iron absorption in man: Ascorbic acid and dose-dependent inhibition by phytate. *American Journal of Clinical Nutrition*, *49*(1), 140–144.

Hemalatha, S., Platel, K., & Srinivasan, K. (2007). Influence of germination and fermentation on bio-accessibility of zinc and iron from food grains. *European Journal of Clinical Nutrition*, *61*(3), 342–348.

Ijarotimi, O. S., Fatiregun, M. R., & Oluwajuyitan, T. D. (2022). Nutritional, antioxidant and organoleptic properties of therapeutic-complementary-food formulated from locally available food materials for severe acute malnutrition management. *Bulletin of the National Research Centre*, *46*(39), 1–15.

Iombor, T. T., Umoh, E. J., & Olakumi, E. (2009). Proximate composition and organoleptic properties of complementary food formulated from millet (*Pennisetum psychostachynum*), soybeans (*Glycine max*) and crayfish (*Euastacus spp*). *Pakistan Journal of Nutrition*, *8*(10), 1676–1679.

Kulkarni, K. D., Kulkarni, D. N., & Ingle, U. M. (1991). Sorghum malt-based weaning food formulations: Preparation, functional properties, and nutritive value. *Food and Nutrition Bulletin*, *13*(4), 1–7.

Morris, E. R., & Ellis, R. (1985). Usefulness of the dietary phytic acid/zinc molar ratio as an index of zinc bioavailability to rats and humans. *Biological Trace Element Research*, *19*(1), 107–117.

Oyeleke, G. O., Akinyele, O. A., & Daramola, I. A. (2019). Some quality characteristics and carbohydrate fractions of Bambara groundnut (*Vigna subterranea* L.) seed flour. *IOSR Journal of Applied Chemistry*, *2*(4), 16–19.

Ramatsetse, K. E., Ramashia, S. E., & Mashau, M. E. (2023). A review on health benefits, antimicrobial and antioxidant properties of Bambara groundnut (*Vigna subterranea*). *International Journal of Food Properties*, *26*(1), 91–107.

Rogol, A. D., Laffel, L. M., Bode, B., & Sperling, M. A. (2023). Celebration of a century of insulin therapy in children with type 1 diabetes. *Archives of Disease in Childhood*, *108*(1), 3–10.

Sharma, A., Jana, A. H., & Chavan, R. S. (2012). Functionality of milk powders and milk-based powders for end use applications—A review. *Comprehensive Reviews in Food Science and Food Safety*, *11*(5), 518–528.

Sofie, S. A.. (1987). Degradation products of bran phytate formed during digestion in the human small intestine: Effects of extrusion cooking on digestibility. *Journal of Nutrition*, *117*(12), 2061–2065.

Spackman, D. H., Stein, W. H., & Moore, S. (1978). Chromatography of amino acids on sulphonated polystyrene resins: An improved system. *Analytical Chemistry*, *30*, 1190–1205.

Talabi, J. Y., Makanjuola, S. A., & Egbagbara, E. V. (2022). A mixture design approach to developing a cereal-based complementary meal for better nutritional quality. *African Journal of Food, Agriculture, Nutrition and Development*, *21*(9), 18748–18766.

Talabi, J. Y., Origbemisoye, B. A., Ifesan, B. O., & Enujiugha, V. N. (2019). Quality characterization of biscuits from blends of Bambara groundnut (*Vigna subterranea*), ground bean seed (*Macrotyloma*) and moringa seed (*Moringa oleifera*) flour. *Asian Food Science Journal*, *12*(4), 1–12.

Turnlund, J. R., King, J. C., & Keyes, W. R., (1984). A stable isotope study of zinc absorption in young men: Effects of phytate and α-cellulose. *American Journal of Clinical Nutrition*, *40*(5), 1071–1077.

UNICEF. (2016). *Ready-to-use therapeutic food: Current outlook*. https://www.unicef.org/supply/files/RUTF_Supply_Update

WHO. (2011). *World health statistics report: Joint child malnutrition estimates—levels and trends*. World Health Organization.

Yamashiro, K., et al. (2022). Prevalence of abnormal blood pressure and the association between blood pressure and anthropometric measures or body indices in Japanese university students—a cross-sectional study. *BPB Report*, 140–146.