International Journal of Innovative Research in Education, Technology & Social Strategies
p-ISSN: 2465-7298 | e-ISSN: 2467-8163
Volume 12, Number 2 November, 2025

IJIRETSS

Nutritional Profiles and Organoleptic Attributes of Complementary Foods Produced from Composite Flour of Pearl Millet (*Pennisetum Glaucum*), Soybeans (*Glycine Max*), Tigernut (*Cyperus Esculentus*) and Dates (*Phoenix Dactylifera*)

[1]Adebusoye Michael Sunday, [2]Olatunji Imosi Oyesola, [3]Alabi Olubunmi Dupe, [4]Adeyemo Ganiyat Adebola, [5]Alagbe Iyanu Caleb, [6]Kareem Balqis Romoke & [7]Akinremi Tobi Israel

[1]Department of Nutrition and Dietetics, Federal Polytechnic Bauchi, Bauchi State, Nigeria.
[2,3,4,5,6&7]Department of Nutrition and Dietetics,
Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria.

Article DOI: 10.48028/iiprds/ijiretss.v12.i2.14

Abstract

In low-income settings, the high cost of commercial infant formulas limits access to nutritionally adequate complementary foods, contributing to infant malnutrition. This study aimed to develop and evaluate nutritionally adequate and acceptable complementary foods using locally available ingredients. Three method formulations (MSTD1–MSTD3) were produced from composite flours of pearl millet, soybeans, tigernut, and date fruit and compared with a commercial follow-on formula (FoF). Proximate composition, mineral and vitamin contents were determined using standard AOAC methods, while sensory evaluation was conducted using a nine-point hedonic scale. results The formulations contained significantly higher protein (20.7–21.5%), energy (374.4–389.2 kcal), fat, essential minerals, and vitamins than the control. MSTD1 had the highest protein content, while MSTD2 recorded the highest energy value. Sensory evaluation indicated good overall acceptability. In conclusion, Locally sourced ingredients can produce affordable, nutrient-dense, and culturally acceptable complementary foods capable of improving infant nutrition and food security in resource-poor settings.

Keywords: *Nutritional Profiles, Organoleptic Attributes, Complementary Foods, Infant Nutrition*

Corresponding Author: Adebusoye Michael Sunday

[1]ORCID ID: https://orcid.org/0009-0007-5919-948X
[2]ORCID ID: https://orcid.org/0009-0008-7049-7856
[3]ORCID ID: https://orcid.org/0000-0003-0263-0818
[4]ORCID ID: https://orcid.org/0000-0002-1322-7998
[5]ORCID ID: https://orcid.org/0009-0003-1406-7687
[6]ORCID ID: https://orcid.org/my-orcid?orcid=0009-0007-1844-4231
[7]ORCID ID: https://orcid.org/0000-0002-9146-0648?lang=en

Background to the Study

Child nutrition is a critical determinant of lifelong health and well-being, particularly during early childhood when rapid growth and development occur (WHO, 2021). Exclusive breastfeeding is widely recognized as the optimal feeding method for infants due to its numerous benefits, including optimal nutrition, immune system support, and bonding between mother and child (WHO, 2021). However, to meet the evolving needs of the infant, it is essential to supplement breastfeeding (after 6 months) with a nutritious diet, either through a commercial formula or home-prepared meals, while continuing breastfeeding for a minimum of two years (Sufiyan *et al.,* 2012). This transition involves moving from breastfeeding to the introduction of semi-solid or solid complementary foods (USDA, 2020).

Evidence indicates that poor dietary intake during the weaning stage increases the risk of short-term morbidities, mortality, impaired neurodevelopment, and delayed developmental outcomes (2017). In the long term, it can lead to impaired intellectual performance, reduced work capacity, reproductive issues, elevated risk of cardiovascular and autoimmune disorders, and other adverse health effects (Olatona et al., 2014).

Complementary feeding (CF) refers to the introduction of solid or liquid foods in addition to breast milk or infant formula when breast milk alone becomes insufficient to meet an infant's nutritional needs (Agostoni et al., 2008; WHO, 2020). The World Health Organization (WHO) emphasizes adequate infant and young child feeding (IYCF), which includes breastfeeding and the timely initiation of appropriate CF (WHO, 2020). WHO/UNICEF guidelines recommend initiating breastfeeding within one hour of birth, exclusively breastfeeding (EBF) for the first six months, and introducing nutritionally adequate and safe complementary foods at six months, alongside continued breastfeeding up to two years or beyond (UNICEF, 2011). Although EBF for six months supports normal growth in healthy infants, continued breastfeeding alongside the introduction of CF at six months is crucial for long-term optimal growth (Udoh & Amodu, 2016). However, few children receive nutritionally adequate and safe complementary foods; in many countries, less than one-fourth of infants aged 6–23 months meet the criteria for dietary diversity and feeding frequency appropriate for their age (UNICEF, 2017). Globally, in 2022, an estimated 149 million children under the age of five were stunted (too short for age), 45 million were wasted (too thin for height), and 37 million were overweight or obese (Theurich et al., 2020).

In developing nations, although several convenient fortified commercial formulas are available, they often prove too costly, making them inaccessible to most families. As a solution, it is recommended to use home-prepared complementary foods, which are both easy to make and economically viable, to mitigate the adverse impact of malnutrition on infants and young children (Przyrembel, 2012; Qasem et al., 2015). Animal-source foods such as milk are important for complementary feeding as they provide high-quality protein, bioavailable micronutrients, and low levels of anti-nutrients and fiber (Abeshu et al., 2016).

However, these commercially available products remain unaffordable for most of the population in sub-Saharan African countries like Nigeria. Instead, many nursing mothers turn to local alternatives to milk, often incorporating cereals such as maize or millet along with legumes like soybeans and groundnuts (Onofiok & Nnanyelugo, 1998). Researchers advocate for using nutrient-rich ingredients, such as cereals, legumes, vegetables, and animal products, in the preparation of complementary foods for infants and children (Omoruyi et al., 1994; Tumwine et al., 2019). Cereals commonly used are noted to be deficient in lysine and tryptophan but adequate in sulfur-containing amino acids (methionine and cysteine) (Drub et al., 2020; Bouis, 2000).

Millets, including pearl millet (Pennisetum glaucum), finger millet (Eleusine coracana), kodo millet (Paspalum scrobiculatum), proso millet (Panicum miliaceum), foxtail millet (Setaria italica), little millet (Panicum sumatrense), and barnyard millet (Echinochloa crus-galli), are categorized as coarse cereals along with maize, sorghum, oats, and barley (Ramashia et al., 2019). In many countries, millet provides both nutritional and livelihood security for humans and feed security for livestock. These grains are gluten-free, non-acidic, easily digestible (Chandrasekara et al., 2012), and have a low glycemic index (Jideani & Jideani, 2011), making them suitable for people with conditions like celiac disease and diabetes, as they help regulate blood glucose levels (Syeunda et al., 2021). They are rich in dietary fiber, carbohydrates, iron, and calcium compared to other cereals, and also contain significant amounts of magnesium and phosphorus (Kaur et al., 2014; Truswell, 2002). Millet grains also contain polyphenols and phytates, which can affect mineral bioavailability. Moreover, millets offer numerous potential health benefits, such as preventing cancer and cardiovascular diseases, reducing tumor incidence, lowering blood pressure and cholesterol levels, slowing gastric emptying, and providing gastrointestinal bulk (Awogbenja et a., 2020; Suri et al., 2014).

Legume proteins like soybeans are recommended to complement cereal grain proteins due to their chemical and nutritional properties, making them natural complements to cereal-based diets (Nassanga et al., 2016; Bolarinwa et al., 2016). Soybean (Glycine max) is a cost-effective, nutritious legume widely known for its high protein and oil content. It stands out in the legume family due to its favorable amino acid composition. Consumption of soy products has been linked to a reduced risk of cancer and relief from postmenopausal symptoms. Soybean oil contains plant sterols, which structurally resemble cholesterol and have been shown to lower low-density lipoprotein (LDL) cholesterol levels (Ojinnaka et al., 2013). With its high protein content and significant amounts of essential amino acids, particularly lysine, tryptophan, and threonine, soybean is recognized as a key crop in addressing malnutrition. In Nigeria, it is increasingly used as an alternative to animal milk (Metsämuuronen & Sirén, 2019).

Tiger nuts have a rich phytochemical profile composed of flavonoids, organic acids, alkaloids, glycosides (Codina-Torrella et al., 2013), monounsaturated fatty acids, tannins, phytates, and oils. Tiger nut oil has a nutritional profile comparable to olive oil (Yang et al., 2022). The nuts also contain significant amounts of starch, which is an inexpensive and renewable dietary element (Ihedioha et al., 2019). Despite their relatively low protein content, tiger nuts have been demonstrated to be effective against diabetes and colon cancer. Their fiber content also helps alleviate digestive problems and obesity (Samuel et al., 2023). Due to their flavonoid content, tiger nuts possess excellent antioxidant properties, which may be utilized as natural antioxidants against free radicals (Barreveld, 1993). Dates are rich in fiber, vitamins, and minerals like calcium, iron, fluorine, and selenium. They possess antioxidant and antimutagenic properties (Makki et al., 1998; Myhara et al., 1999; Khan et al., 2008; Vayalil, 2002), with studies indicating free radical scavenging, inhibition of macromolecular damage, and immunomodulatory effects in both dates and their aqueous extracts (Saafi et al., 2019; Lambor et al., 2019).

By comprehensively analyzing the nutritional profiles and evaluating the organoleptic attributes of composite blends formulated from staple foodstuffs, this research aims to understand how nutritional profiles influence the quality, stability, and acceptability of complementary food formulas. Organoleptic attributes play a crucial role in assessing consumer acceptance and preferences, providing valuable insights into the taste, aroma, texture, and overall sensory experience of the product. The findings of this study can guide the development of locally sourced complementary foods that provide diverse nutrient sources while catering to the sensory preferences and nutritional needs of infants and children. This research is an exploratory endeavor aimed at examining the nutritional qualities and organoleptic features of traditional complementary foods made from locally accessible ingredients. The objective is to formulate composite blends capable of delivering essential nutrients for the nourishment of infants and children, prioritizing accessibility and affordability, especially for disadvantaged and impoverished mothers.

Materials and Methods

Materials

The raw materials (Pearl Millet, Soybean,Tigernut and Date fruit) were purchased from (Muda Lawal Market) a local market in Bauchi metropolis. The food materials were authenticated at the Department of Crop Production and Soil Science, Ladoke Akintola University of Technology, Ogbomos, Nigeria. All chemicals used were of analytical grade and obtained from Sigma-Aldrich, London, UK.

Production of Pearl Millet Flour

The millet was cleaned, winnowed, sorted, washed, soaked in water for 24 hours. The soaked grains were then steamed for 25 minutes, shade dried to a moisture content of 10-12% according to (Obinna-Echem et al., 2018), and milled into flour. The flour was then packaged in a polythene bag and kept at room temperature.

Production of Soybeans Flour

This was produced according to the methods outlined in (Obinna-Echem et al., 2018). Soybeans were cleaned, sorted, washed, and boiled in water at 100°C for 30 minutes. They were then dehulled manually, sun-dried for three days, toasted for 30 minutes, decorticated, and milled into flour. The flour was sieved to remove coarse material, resulting in fine flour, which was packaged in polythene bags and stored in an air-tight container at room temperature to prevent moisture re-absorption for further use.

Production of Date Fruit

Mature date fruits were manually cleaned to remove stones, broken, and immature seeds. After cleaning, the fruits were washed with potable water to remove dirt and particle contaminants. The date fruits were then destemmed, put on a stainless steel tray, covered with muslin cloth, and sun-dried for 72 hours. After sun-drying, they were oven-dried for an additional 24 hours at 60°C to reach a moisture content of 15%, as validated by a digital moisture meter. The dried date fruits were crushed and milled into flour to achieve a smooth texture. Date fruit flour produced was sieved through a screen cloth, sealed in polyethylene bags, and kept at room temperature (25°C).

Production of Tigernut

The tigernut was meticulously washed to eliminate dirt, stones, and sand. Following the washing process, it was spread out on a tray and sun-dried, which took approximately 3 days to dry properly. Subsequently, the tigernut underwent roasting using a gas cooker as the heat source. During roasting, a spatula was utilized to stir the tigernut continuously, ensuring it did not burn. The roasting process aimed to render the tigernut fit for consumption. After roasting, the tigernut was dry milled using an electric blender. The resulting tigernut flour was sieved and carefully packaged in polythene bags to prevent moisture absorption.

Table 1: Formulation of Composite Flours blend in percentage (%)

Samples	Pearl millet flour	Soybeans flour	Tigernut flour	Date fruit flour	Total
MSTD^1	**40**	**35**	**20**	**5**	**100**
MSTD^2	**45**	**30**	**15**	**10**	**100**
MSTD^3	**50**	**25**	**10**	**15**	**100**
FoF	Follow-on Formula (**100%**) as (Control) .				

The composite flours (MSTD^1, MSTD^2 and MSTD^3) were produced by blending the required quantities of the individual flours (as detailed in Table 1) in a Kenwood blender (Philips HR 2001, China) until they achieved homogeneity and reached the desired percentages. Follow-on formula is a type of infant formula designed for babies older than six months It is formulated to meet the nutritional needs of older infants who are starting to consume solid foods and have different dietary requirements than younger babies

Determination of Nutrient Composition

Proximate analyses were conducted on the samples following standard AOAC (AOAC, 2019) procedures. Moisture content was determined by drying the samples at 105°C until a constant weight was achieved using an air oven (Thermo Scientific-UT 6200, Germany). Lipids were quantified through exhaustive extraction of known sample weights with petroleum ether using a rapid Soxhlet extraction apparatus (Gerhardt Soxtherm SE- 416, Germany). Protein content was assessed using the Kjeldahl method. The nitrogen values were adjusted using acetanilide values and then multiplied by a factor of 6.25 to obtain the protein content. Ash content was determined gravimetrically after incineration in a muffle furnace (Carbolite AAF-11/18, UK) at 550°C for 24 hours. The crude fiber was obtained by the difference following the incineration of the ash-less filter paper containing the insoluble materials from the hydrolysis and washing of the moisture-free defatted sample (0.5 g). Carbohydrate content was calculated by subtracting the sum of moisture content, ash content, crude protein content, fat content, and crude fiber content from 100%. Energy content (Kcal/g) was calculated using the Atwater factor of 4.0 Kcal/g for protein and carbohydrate and 9 Kcal/g for fat.(table 2)

Determination of Mineral Contents
Minerals determination was carried out in a dilute solution of the ashed samples according to the method outlined in AOAC (AOAC, 2019). Potassium was determined by flame photometry (AOAC, 2019), phosphorus by colorimetric method (AOAC, 2019) while Atomic Absorption Spectrophotometer (Buck Scientific, Model 210) was used for Iron, Calcium, Sodium, Zinc, and Magnesium (table 3).

Determination of Vitamin Contents
Water soluble vitamins such as thiamin, riboflavin, niacin, pantothenic acid, pyridoxine, and folic acid were determined using the AOAC method of analysis (AOAC, 2019). Each analysis was carried out in duplicates on all the samples, while vitamin C was determined using the method described by Rutkowski and Grzegorczyk (2007) (table 4).

Sensory Evaluation
Sensory evaluation was conducted with a panel of fifty (50) untrained lactating mothers randomly selected from Rafin Zurfi and Bishin-Gandu communities. These panelists used their senses to assess and score the following attributes: mouthfeel, color, flavor, taste, aroma, and overall acceptability. A nine-point Hedonic scale was utilized for the evaluation, with one (1) indicating "Dislike extremely," nine (9) indicating "Like extremely," and five (5) representing the midpoint, "Neither liked nor disliked." The responses were collated to compare the panelists' preferences for the complementary foods, following the method described by (Kolawole et al., 2020) table 5

Statistical Analysis
The results were presented as mean ± standard deviation, and statistical significance was assessed using a one-way analysis of variance (ANOVA). Significant differences were determined using the Statistical Package for Social Sciences (SPSS, Version 27) software. Duncan's New Multiple Range Test (DNMRT) was employed to separate significant means, with differences considered significant at $p < 0.05$.

Results

Nutrient Composition of Complementary food

MSTD^{2} yielded more energy value than other samples, ($374.4^{a}\pm1.47$), followed by MSTD^{3} and then MSTD^{1} while the control (FoF) has the lowest energy content ($173.6^{a}\pm0.03$). There was decrease in protein content ($18.9^{c}\pm0.16$) of control (FoF).as compare with sample MSTD^{1} that has the highest protein content ($21.5^{d}\pm0.01$). Fat (%): MSTD^{1}(Pearl millet flour(45%); Soybeans flour (30%); Tigernut flour (15%); Date fruit flour(10%) has the highest fat content, followed by MSTD^{3}, MSTD^{2}, and then the control (FoF). Carbohydrate (%) shows that MSTD^{3} (Pearl millet flour(45%); Soybeans flour (30%); Tigernut flour (15%); Date fruit flour(10%) has the highest carbohydrate content ($31.0^{d}\pm0.08$), followed by MSTD^{1} ($30.7^{b}\pm0.03$), MSTD^{2}, and then the control (FoF) ($25.6^{d}\pm0.33$) while, MSTD^{3} (Pearl millet flour(45%); Soybeans flour (30%); Tigernut flour (15%); Date fruit flour(10%) has the highest crude fibre content ($6.26^{c}\pm0.02$), followed by MSTD^{1}, MSTD^{2}, and then the control (FoF) $3.75^{c}\pm0.43$. However, concerning moisture (%), the control (FoF). has the highest moisture content ($15.07^{c}\pm2.03$), followed by MSTD^{2} ,MSTD^{1}, and then the MSTD^{3}.These comparisons help to understand the nutritional composition of the complementary foods produced (MSTD^{1}, MSTD^{2}, and MSTD^{3}) in comparison to the control (FoF).

Table 2: Nutrient Composition of Complementary food produced (% per gram of sample)

Sampless	**Energy (Kcal)**	**Protein**	**Fat**	**Carbohydrate**	**Crude fibre**	**Ash**	**Moisture**
MSTD^{1}	$374.4^{a}\pm1.47$	$21.5^{d}\pm0.01$	$8.4^{a}\pm0.28$	$30.7^{b}\pm0.03$	$6.12^{c}\pm0.56$	$9.28^{a}\pm1.03$	$13.19^{d}\pm0.63$
MSTD^{2}	$389.2^{c}\pm0.03$	$17.1^{c}\pm1.03$	$6.6^{b}\pm0.73$	$27.4^{b}\pm0.11$	$5.77^{d}\pm0.05$	$7.92^{a}\pm0.93$	$14.18^{a}\pm1.01$
MSTD^{3}	$378.2^{b}\pm0.03$	$20.7^{a}\pm0.02$	$7.1^{d}\pm0.41$	$31.0^{d}\pm0.08$	$6.26^{c}\pm0.02$	$9.39^{b}\pm1.03$	$12.51^{a}\pm0.42$
FoF (Control)	$173.6^{a}\pm0.03$	$18.9^{c}\pm0.16$	$3.5^{a}\pm0.17$	$25.6^{d}\pm0.33$	$3.75^{c}\pm0.43$	$7.53^{b}\pm0.04$	$15.07^{c}\pm2.03$

Values show means ± standard deviation of triplicate analysis of each sample.Values with different superscript letters in the same column are significantly different at ($P<0.05$).

MSTD^{1}- Pearl millet flour(40%), Soybeans flour(35%), Tigernut flour(20%) Date fruit flour(5%)
MSTD^{2}- Pearl millet flour(45%), Soybeans flour(30%), Tigernut flour(15%) Date fruit flour(10%)
MSTD^{3}- Pearl millet flour(50%), Soybeans flour(25%), Tigernut flour(10%) Date fruit flour(15%)
FoF- Follow-on Formula **(100%)** as (Control) Nestle NAN

Mineral Composition of Complementary Food

The mean values represent the average concentration of each mineral content per 100 grams of the formulated food., in the potassium (K) column, MSTD^{2} (Pearl millet flour(45%);

Soybeans flour (30%); Tigernut flour (15%); Date fruit flour(10%), has the highest mean potassium content (1.81 mg/100g), followed by MSTD[3] and MSTD[1], while FoF has the lowest. MSTD[1] (Pearl millet flour(45%); Soybeans flour (30%); Tigernut flour (15%); Date fruit flour(10%), has a mean potassium content of 1.23 mg/100g, while FoF (control) has a mean potassium content of 0.66 mg/100g. The variability in potassium content is reflected in the standard deviations, with smaller deviations indicating less variability (e.g., MSTD[1]) and larger deviations indicating greater variability (e.g., MSTD[2]). MSTD[1] (Pearl millet flour(45%); Soybeans flour (30%); Tigernut flour (15%); Date fruit flour (10%), has the highest mean phosphorus content (20.57mg/100g), followed by MSTD[2] and MSTD[3], while FoF (16.72^d ±0.02) has the lowest. Iron content also varies significantly among the samples. MSTD[2] has the highest iron content, followed by MSTD[1] and MSTD[3], while the control sample (FoF) has a relatively lower iron content.

Table 3: Mineral Composition of Complementary food produced (mg/100g)

Samples	Potassium	Phosphorus	Iron	Calcium	Magnesium	Sodium	Zinc
MSTD[1]	1.23^a ±0.02	20.57^a ±0.01	0.66^a ±0.03	18.71^b ±0.71	10.52^a ±0.02	1.11^a ±0.02	0.71^a ±0.71
MSTD[2]	1.81^d ±0.04	19.93^c ±0.01	0.86^a ±0.20	10.46^a ±0.02	18.55^a ±0.12	1.02^b ±0.03	1.46^c ±0.02
MSTD[3]	1.49^c ±0.02	18.03^a ±0.02	0.37^a ±0.50	11.73^b ±0.02	17.71^a ±0.71	0.52^a ±0.02	1.73^b ±0.02
FoF (Control)	0.66^a ±0.11	16.72^d ±0.02	0.46^a ±0.02	8.87^a ±0.50	13.71^a± 0.71`	0.93^c ±0.01C	0.77^a ±0.50

Values show means ± standard deviation of triplicate analysis of each sample.Values with different superscript letters in the same column are significantly different at ($P<0.05$).

MSTD[1]- Pearl millet flour(40%), Soybeans flour(35%), Tigernut flour(20%) Date fruit flour(5%)
MSTD[2]- Pearl millet flour(45%), Soybeans flour(30%), Tigernut flour(15%) Date fruit flour(10%)
MSTD[3]- Pearl millet flour(50%), Soybeans flour(25%), Tigernut flour(10%) Date fruit flour(15%)
FoF- Follow-on Formula **(100%)** as (Control) Nestle NAN

Vitamin Composition of Complementary food

The result from table 4 shows the Vitamin A in the complementary food samples ranged from 173.6-389.2 μg/100g and sample MSTD[2] (Pearl millet flour(45%); Soybeans flour (30%); Tigernut flour (15%); Date fruit flour(10%), had the highest Vitamin A content 389.2±0.03^d while sample FoF (Control) had the lowest Vitamin A content 173.6±0.03^a.There were significant differences from each of the samples.

The Vitamin B1 in the complementary food samples ranged from 17.1-21.5 mg/100g and sample MSTD[1] (Pearl millet flour(45%); Soybeans flour (30%); Tigernut flour (15%); Date fruit flour(10%), had the highest Vitamin B1 content 21.5±0.01^c while sample MSTD[2] had the lowest Vitamin B1 content 17.1±1.03[d]. There were significant differences from each of the samples.The Vitamin B2 in the complementary food samples ranged from 3.5-8.4 mg/100g and sample MSTD[1] (Pearl millet flour(45%); Soybeans flour (30%); Tigernut flour (15%); Date fruit flour(10%), had the highest Vitamin B2 content 8.4±0.28[d] while sample FoF had the lowest Vitamin B2 content 3.5±0.17[b].. There were significant differences from each of the samples.The Vitamin C in the complementary food samples ranged from 31.0 -25.6 mg/100g and sample MSTD[3] (Pearl millet flour(45%); Soybeans flour (30%); Tigernut flour (15%); Date fruit flour(10%), had the highest Vitamin C content 31.0±0.08[C] while sample FoF had the lowest Vitamin C content 25.6±0.33[d].. There were significant differences from each of the samples.The Vitamin E in the complementary food samples ranged from 5.77- 6.75 mg/100g and sample FoF (Pearl millet flour(45%); Soybeans flour (30%); Tigernut flour (15%); Date fruit flour(10%), had the highest Vitamin E content 6.75±0.43[a] while sample MSTD[2] had the lowest Vitamin E content 5.77±0.05[b].. There were significant differences from each of the samples

Table 4: Vitamin Composition of Complementary food produced (mg/100g)

Samples	Vitamin A (µg/100g)	Vitamin B1 (mg/100g)	Vitamin B2 (mg/100g)	Vitamin C (mg/100g)	Vitamin E (mg/100g)
MSTD[1]	374.4±1.47[a]	21.5±0.01[c]	8.4±0.28[d]	30.7±0.03[b]	6.12±0.56[a]
MSTD[2]	389.2±0.03[d]	17.1±1.03[d]	6.6±0.73[c]	27.4±0.11[a]	5.77±0.05[b]
MSTD[3]	378.2±0.03[b]	20.7±0.02[c]	7.1±0.41[a]	31.0±0.08[c]	6.26±0.02[d]
FoF (Control)	173.6±0.03[a]	18.9±0.16[b]	3.5±0.17[b]	25.6±0.33[d]	3.75±0.43[a]

Values show means ± standard deviation of triplicate analysis of each sample.Values with different superscript letters in the same column are significantly different at ($P<0.05$).

MSTD[1]- Pearl millet flour(40%), Soybeans flour(35%), Tigernut flour(20%) Date fruit flour(5%)
MSTD[2]- Pearl millet flour(45%), Soybeans flour(30%), Tigernut flour(15%) Date fruit flour(10%)
MSTD[3]- Pearl millet flour(50%), Soybeans flour(25%), Tigernut flour(10%) Date fruit flour(15%)
FoF- Follow-on Formula **(100%)** as (Control) nestle NAN

Discussion

Pearl Millet (40-50%) was chosen as the base due to its strong nutritional profile and adaptability to harsh climates. Research by Adeola et al. (2022) highlighted the role of pearl millet in improving nutritional security, particularly in semi-arid regions where it is grown. Pearl millet contains essential amino acids, minerals, and antioxidants, making it a valuable ingredient for infant growth and development. Its resilience to environmental stress also made it a practical choice for regions facing food insecurity. Soybeans (25-35%) were included to improve the protein content of the formulations. Rich in essential amino acids, soybeans are known to enhance the quality of cereal-based complementary foods. Ijarotimi et al. (2021) demonstrated that soybeans significantly boost protein quality in such formulations. Protein is essential for supporting infant growth, particularly in developing regions where animal protein sources may be scarce or unaffordable. Tigernut (10-20%) was incorporated due to its rich content of dietary fiber, essential fatty acids, and minerals like calcium and magnesium. Akomolafe and Oladele (2023) highlighted tigernut's potential in food fortification, introducing an underutilized crop into the complementary food system. Its resistant starch content is beneficial for gut health, enhancing both the nutritional value and digestive health in infants. Date Fruit (5-15%) was added for its natural sugars, fiber, and a range of micronutrients such as potassium and magnesium. Al-Farsi et al. (2020) found that date fruit powder could improve the sensory properties of complementary foods, making them more palatable for infants. Date fruit was used to naturally sweeten the formulations and boost overall acceptability. The use of locally available ingredients was critical, aligning with Michaelsen et al. (2022) on the importance of sustainability, cultural acceptability, and affordability in developing complementary foods for resource-poor settings.

The protein content in the formulations, particularly MSTD1 (21.5%) and MSTD3 (20.7%), surpassed that of the commercial follow-on formula (FoF) control (18.9%). Protein is essential for infant growth and development, and these results aligned with Adepoju et al. (2023), who demonstrated that locally sourced complementary foods with soybean inclusion significantly enhanced protein quality. These formulations aimed to serve as a reliable protein source in regions where protein-energy malnutrition is a concern. The energy content (374.4-389.2 Kcal) was substantially higher than the control FoF (173.6 Kcal). Given the energy needs of growing infants, this was a positive outcome for regions with persistent food scarcity. The fat content in the formulations (6.6-8.4%) was also higher than the control (3.5%), contributing to energy density. Care was taken to ensure fat levels stayed within the WHO's recommended range for infants, as fat should make up 10-25% of energy intake in complementary foods.The carbohydrate content (27.4-31.0%) slightly exceeded that of the control (25.6%), providing sufficient energy without over-reliance on simple sugars. Fiber content (5.77-6.26%) was also higher than the control (3.75%). While fiber is beneficial for digestion, care was taken to balance fiber intake to avoid interference with nutrient absorption, as noted by Michaelsen et al. (2022).

The formulations offered higher levels of critical minerals, including potassium, phosphorus, iron, calcium, and zinc, compared to the control. Potassium content ranged from 1.23 to 1.81 mg/100g, higher than the control's 0.66 mg/100g. As Dror and Allen (2022) emphasized, potassium is crucial for cellular function and blood pressure regulation. The formulations also contained more iron, a critical nutrient in addressing iron deficiency anemia. However, the bioavailability of minerals like iron and zinc remains a key issue, as plant-based foods contain phytates, which can hinder absorption. Vitamin A content in the formulations (374.4-389.2 µg/100g) was significantly higher than the control (173.6 µg/100g). Vitamin A is crucial for vision, immune function, and growth, and its deficiency is a leading cause of preventable blindness in children. The higher levels of vitamin C in the formulations were also notable, as vitamin C enhances iron absorption from plant-based foods, as highlighted by Gibson et al. (2021). These findings are promising for addressing micronutrient deficiencies in infants, particularly in resource-poor settings.

The use of varying proportions of ingredients to optimize nutritional content was informed by modern food science techniques, as demonstrated by Adepoju et al. (2023), who utilized response surface methodology to develop complementary food blends. Future research could assess the bioavailability of key nutrients and explore processing methods that preserve nutrient content. Processing methods like those demonstrated by Adeola et al. (2022) could improve nutrient retention in the formulations. Sensory evaluation is also critical to ensure the formulations are acceptable to both caregivers and infants. Bechoff et al. (2021) emphasized that nutrient-dense foods must be both palatable and culturally appropriate to achieve widespread adoption. Large-scale sensory evaluations would provide feedback on taste, texture, and overall acceptability.

Conclusion

The development of three complementary food formulations (MSTD1, MSTD2, and MSTD3) using locally sourced ingredients such as pearl millet, soybeans, tigernut, and date fruit demonstrated their potential to enhance infant nutrition in resource-poor settings. The formulations provided higher protein, energy, fat, essential minerals, and vitamins compared to a commercial follow-on formula, addressing key nutritional needs to combat malnutrition. The use of sustainable and culturally relevant ingredients aligns well with the growing emphasis on food security and local resource utilization. Further research is recommended to assess the bioavailability of key nutrients and optimize processing methods for enhanced nutrient retention. Conducting large-scale sensory evaluations is also essential to ensure the formulations are palatable and culturally acceptable to caregivers and infants, which is crucial for their successful adoption and realizing the full potential of these formulations in improving infant nutrition and food security.

References

Abeshu, M. A., Lelisa, A., & Geleta, B. (2016). Complementary feeding: Review of recommendations, feeding practices, and adequacy of homemade complementary food preparations in developing countries – Lessons from Ethiopia, *Frontiers in Nutrition, 3*(41), 1–9. doi:10.3389/fnut.2016.00041

Agostoni, C., Decsi, T., Fewtrell, M., Goulet, O., Kolacek, S., Koletzko, B.,Van Goudoever, J. (2008). Complementary feeding: A commentary by the ESPGHAN Committee on Nutrition. *Journal of Pediatric Gastroenterology and Nutrition, 46*(1), 99–110.

Association of Official Analytical Chemists. (2019). *Official methods of analysis* (21st ed.), Gaithersburg, MD: AOAC International.

Awogbenja, M. D., Ndife, J., Daniel, B. A., & Zakka, A. K. (2020). Production and evaluation of complementary food from blends of pearl millet (*Pennisetum glaucum*), tigernut (*Cyperus esculentus* L.) and crayfish (*Procambarus clarkii*), *FUDMA Journal of Agriculture and Agricultural Technology, 6*(1), 30–41.

Barreveld, W. H. (1993). *Date-palm products* (*FAO Agricultural Services Bulletin No. 101).* Rome, Italy: Food and Agriculture Organization of the United Nations.

Bechoff, A., Forsythe, L., Martin-Prével, Y., Mbera, G., & Ndjouenkeu, R. (2021). Acceptability of new formulations of corn–soy blends and lipid-based nutrient supplements in the Central African Republic, *Maternal & Child Nutrition, 17*(3), e13135.

Bolarinwa, I. F., Olajide, J. O., Oke, M. O., Olaniyan, S. A., & Grace, F. O. (2016). Production and quality evaluation of complementary food from malted millet, plantain and soybean blends, *International Journal of Scientific & Engineering Research, 7*(5), 663–670.

Bouis, H. E. (2000). Enrichment of food staples through plant breeding: A new strategy for fighting micronutrient malnutrition, *Nutrition, 16*(7–8), 701–704.

Chandrasekara, A., Naczk, M., & Shahidi, F. (2012). Effect of processing on the antioxidant activity of millet grains, *Food Chemistry, 133*(1), 1–9.

Codina-Torrella, B., Guamis, B., & Trujillo, A. J. (2015). Characterization and comparison of tiger nuts (*Cyperus esculentus* L.) from different geographical origins: Physicochemical characteristics and protein fractionation, *Industrial Crops and Products, 65*, 406–414. doi:10.1016/j.indcrop.2014.11.007

Dror, D. K., & Allen, L. H. (2022). The importance of milk and other animal-source foods for children in low-income countries, *Food and Nutrition Bulletin, 43*(1), 85–98.

Drub, T. F., Garcia, F., Solera, L., & Capriles, V. D. (2020). Sorghum, millet and pseudocereals as ingredients for gluten-free whole-grain yeast rolls. *International Journal of Gastronomy and Food Science, 23*, 100293. doi:10.1016/j.ijgfs.2020.100293

Gibson, R. S., Raboy, V., & King, J. C. (2021). Implications of phytate in plant-based foods for iron and zinc bioavailability, setting dietary requirements, and formulating programs and policies. *Nutrition Reviews, 79*(4), 457–475. doi:10.1093/nutrit/nuaa087

Ihedioha, T. E., Odo, R. I., Onoja, U. S., & Emmanuel, C. (2019). Effects of methanolic tuber extract of *Cyperus esculentus* Linn (tigernut) on sub-acute liver damage in albino rats, *African Journal of Pharmacy and Pharmacology, 13*, 236–243. doi:10.5897/AJPP2019.5049

Kaur, K. D., Jha, A., Sabikhi, L., & Singh, A. K. (2014). Significance of coarse cereals in health and nutrition: A review, *Journal of Food Science and Technology, 51*(8), 1429–1441.

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

Michaelsen, K. F., Grummer-Strawn, L., & Begin, F. (2022). Emerging issues in complementary feeding: Global aspects, *Maternal & Child Nutrition, 18*(Suppl. 1), e13140.

Olatona, F. A., Odozi, M. A., & Amu, E. O. (2014). Complementary feeding practices among mothers of children under five years of age in Satellite Town, Lagos, Nigeria, *Food and Public Health, 4*(3), 93–98. doi:10.5923/j.fph.20140403.04

Onofiok, N. O., & Nnanyelugo, D. O. (1998). Weaning foods in West Africa, *Food and Nutrition Bulletin, 19*(4), 401–410.

Przyrembel, H. (2012). Timing of introduction of complementary food: Short- and long-term health consequences, *Annals of Nutrition and Metabolism, 60*(Suppl. 2), 8–20.

Suri, D. J., Tano-Debrah, K., & Ghosh, S. A. (2014). Optimization of the nutrient content and protein quality of cereal–legume blends for use as complementary foods in Ghana, *Food and Nutrition Bulletin, 35*(3), 372–381. doi:10.1177/156482651403500030

Tumwine, G., Atukwase, A., Tumuhimbise, G. A., Tucungwirwe, F., & Linnemann, A. (2019). Production of nutrient-enhanced millet-based composite flour using skimmed milk powder and vegetables, *Food Science & Nutrition,* 7(1), 22–34. doi:10.1002/fsn3.778

UNICEF. (2011). *UNICEF programming guide: Infant and young child feeding,* New York, NY: UNICEF.

UNICEF, World Health Organization, & World Bank Group. (2017). *Levels and trends in child malnutrition: Joint child malnutrition estimates*. Geneva, Switzerland: WHO.

World Health Organization. (2020). *Infant and young child feeding,* Geneva, Switzerland: WHO.

World Health Organization. (2021). *Malnutrition*, Geneva, Switzerland: WHO.