DOI: https://dx.doi.org/10.4314/gjpas.v30i2.9

GLOBAL JOURNAL OF PURE AND APPLIED SCIENCES VOL. 30, 2024:191-201
COPYRIGHT© BACHUDO SCIENCE CO. LTD PRINTED IN NIGERIA ISSN 1118 – 0579, e-ISSN: 2992 - 4464
www.globaljournalseries.com.ng, Email: globaljournalseries@gmail.com

EXPLORING THE FEASIBILITY OF IMPLEMENTING FORMULATED COMPLEMENTARY DIETS IN REAL-WORLD SETTINGS TO ADDRESS MALNUTRITION IN YOUNG CHILDREN

LAWRENCE OLUSEGUN AJALA, NWOGO AJUKA OBASI, CHUKWUMA OKEREKE IBE, VINCENT OKO OBINNA, CHUKWUDUM ALBERT ANYIAM AND CYNTHIA CHIOMA ANYIAM
Email: segunajala001@gmail.com

(Received 6 March 2024; Revision Accepted 2 May 2024)

ABSTRACT

Malnutrition significantly impacts a child's growth, development, and overall survival. To address this issue beyond the age of six months, this study developed three distinct dietary supplements to complement breast milk for early-age children. Comprehensive multivariate assessments were conducted to evaluate the nutritional quality and safety of these infant diets, employing established standard methods. The findings revealed that the diets exhibited carbohydrate and protein contents ranging from 2.84 to 32.48% and 40.66 to 63.23%, respectively. Importantly, the diets contained low levels of tannins, phytate, and oxalate. Notably, the high corn diet exhibited significantly higher mineral elements, including calcium, magnesium, potassium, and iron ($p < 0.05$). There were no significant differences ($p > 0.05$) in bulk density and swelling capacity, but the medium corn diet displayed higher water absorption capacity and least gelation ($p < 0.05$). These diets were found to contain essential amino acid and vitamin requirements, conforming to FAO/WHO reference values. The sensory analysis yielded ratings within acceptable limits using a 9-point hedonic scale. Moreover, microbial load assessments complied with international microbiological standards (≤10^5 cfu/ml). These cost-effective and nutritionally sound dietary options present a pragmatic solution to addressing nutritional challenges faced by infants and children in developing nations.

KEYWORDS
Complementary food; malnutrition; chemical compositions; functional properties; sensory evaluation; vitamins

INTRODUCTION

During childhood and infancy, adequate nutrition is fundamental to a child's full potential development (Onoja et al., 2014). Undernutrition is one of the major problems facing infants and young children in developing countries (Parvin et al., 2014; Ishara et al., 2018). The level of undernutrition among children remains unacceptable throughout the world. Malnutrition affects a child's morbidity, mortality, cognitive development, reproduction, and physical work capacity (Desalegn et al., 2015; Ishara et al., 2018). Globally, approximately half of all deaths in children under the age of five are caused by undernutrition, resulting in the unnecessary loss of around three million young lives per year (Tadesse et al., 2018).

Lawrence Olusegun Ajala, Department of Science Laboratory Technology, Akanu Ibiam Federal Polytechnic, Unwana, Nigeria
Nwogo Ajuka Obasi, Department of Medical Biochemistry, Alex Ekwueme Federal University, Ndufu-Alike, Ikwo, Nigeria.
Chukwuma Okereke Ibe, Department of Science Laboratory Technology, Akanu Ibiam Federal Polytechnic, Unwana, Nigeria
Vincent Oko Obinna, Department of Food Technology, Akanu Ibiam Federal Polytechnic, Unwana, Nigeria
Chukwudum Albert Anyiam, Department of Food Technology, Akanu Ibiam Federal Polytechnic, Unwana, Nigeria
Cynthia Chioma Anyiam, Department of Science Laboratory Technology, Akanu Ibiam Federal Polytechnic, Unwana, Nigeria

Chronic malnutrition remains a prevalent problem for young children in sub-Saharan Africa (Achidi et al., 2016; Tiencheu et al., 2016). In sub-Saharan Africa, as in other developing countries, protein deficiency in diets is common. This deficiency is often associated with deficiencies in calories and micronutrients, leading to endemic protein-energy malnutrition and its associated health consequences, particularly in infancy (Onoja et al., 2014). According to Tadesse and Gutema (2020), malnutrition is the leading cause of death among children under five years old in Ethiopia. Lack of food and improper infant and child feeding practices critically affect child growth, development, and survival. This is coupled with high rates of infections during the first two years of life (Desalegn et al., 2015).

Undernutrition is a severe medical condition characterized by a lack of energy, essential proteins, fats, vitamins, or minerals in a diet. It poses a significant burden and is particularly hazardous for young, developing children (Adepoju & Ajayi, 2016). Diets that lack high-quality protein, essential fats, carbohydrates, vitamins, and minerals can impair growth and development, increase the risk of death from common childhood illnesses, or result in lifelong health consequences (Adepoju et al., 2016).

Breast milk has been scientifically proven to be the perfect food for infants during the first six months of life (Solomon, 2005; Ijarotimi & Keshiro, 2013). Breastfeeding and weaning practices are important elements of growth and development during infancy as well as later in life (Gain et al., 2020). However, as infants grow and become more active after the first six months of life, breast milk alone is insufficient to meet their full nutritional requirements. This gap continues to widen as infants and young children get older. Hence, complementary feeding plays a critical role in bridging these gaps (Solomon, 2005; Abeshu et al., 2016; Adepoju & Ajayi, 2016; Ikujenlola & Ogunba, 2018).

Complementary feeding enables infants to meet their nutritional requirements and regulate their appetite, while also being exposed to new tastes and textures in a staged and progressive manner (Tiencheu et al., 2016; Gain et al., 2020). Insufficient quantity and inadequate quality of complementary foods, along with poor feeding practices and increased rates of infection during this period, are direct risk factors for stunting (Gain et al., 2020).

Industrially produced complementary foods are expensive and often unaffordable for the middle and low-income population. As a result of this and other factors, indigenous complementary foods are formulated to serve as alternatives. Much research has been conducted on the formulation of complementary foods for children. However, there has been limited focus on combining local ingredients that are rich in all essential nutrients. This informed the selection of the various ingredients for formulating the diets in this study.

MATERIALS AND METHODS

Sample collection

The raw materials used in the study: corn, soybean, groundnut, carrot, sesame, and crayfish, were purchased from local markets in Abakaliki, Nigeria. The materials were prepared for complementary food formulation following a series of steps as outlined in Fig. 1

Formulation of complementary foods

The selection of ingredients used for formulating complementary food was based on CODEX (1991) guidelines. This ensures that all classes of food were incorporated into the diets. The ingredients (corn, soybean, groundnut, crayfish, sesame, and carrots) were weighed and blended in the proportions indicated in Table 1. Each formulated product was stored in an airtight container for subsequent analyses.

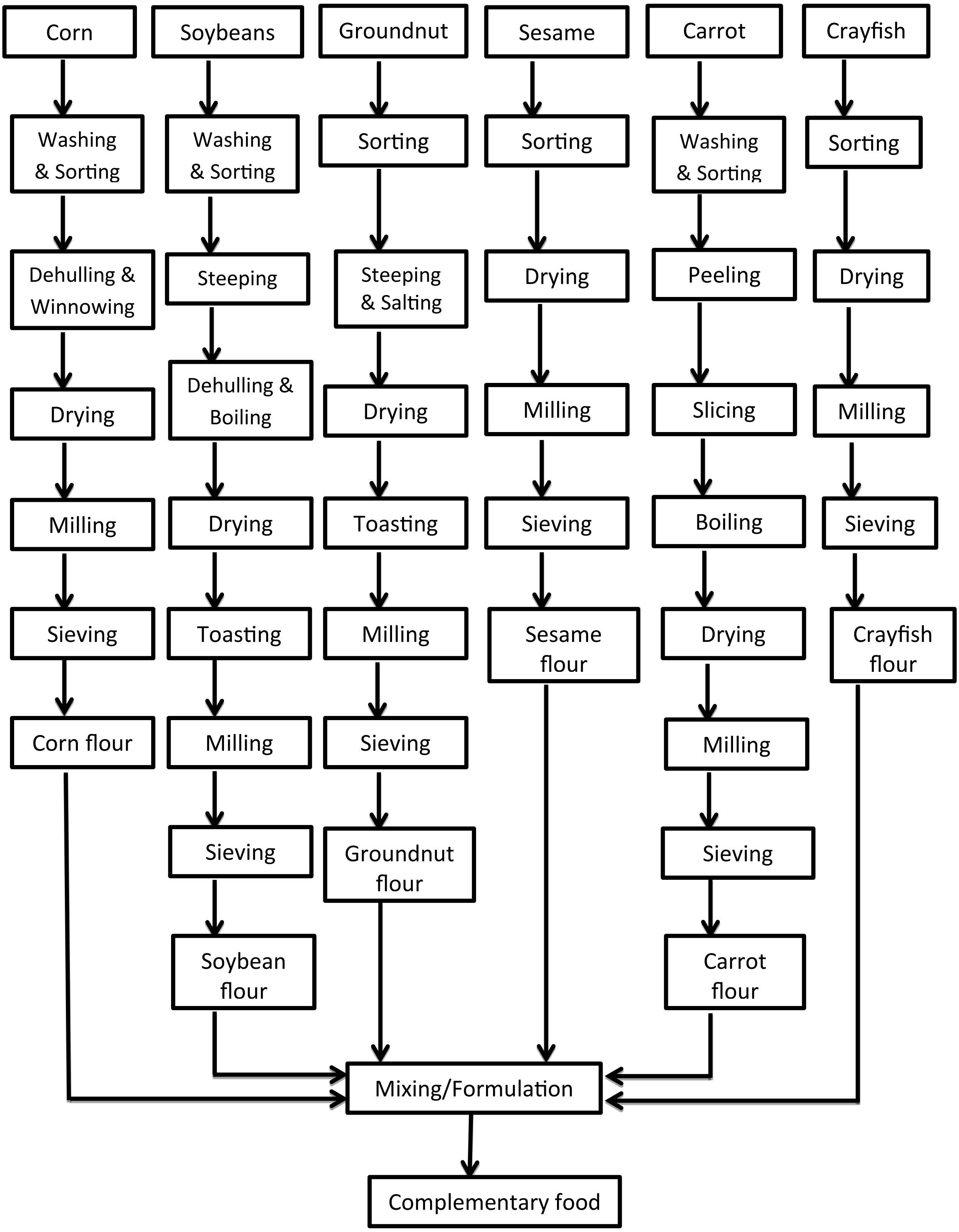

Fig. 1: Flowchart of instant complementary food formulation for young children

Table 1: Percent w/w proportion of ingredients in the diets' formulation

Blend	Corn	Soybean	Groundnut	Sesame	Carrot	Crayfish
LCD	30	20	15	15	10	10
MCD	40	15	10	15	10	10
HCD	50	10	5	15	10	10

LCD – low corn diet, MCD – medium corn diet, HCD – high corn diet.

Characterization of the diets

The standard methods were adopted to determine the proximate analyses (moisture, ash, protein, crude fibre, ether extract, nitrogen-free extract), functional properties (bulk density, water absorption capacity, swelling capacity, and least gelation), nutritional elements (potassium, calcium, magnesium, and iron), antinutrients (phytate, oxalate, and tannin), vitamins (pro-carotenoid, thiamine, riboflavin, cyanocobalamin, and vitamin D), amino acids profile and index, sensory attributes, and microbial studies of the formulated diets (Ijarotimi & Keshiro, 2013; Achidi et al., 2016; Adepoju & Ajayi, 2016; Ikujenlola & Ogunba, 2018; Ajala et al., 2021; Ukom et al., 2019).

RESULTS AND DISCUSSION

Proximate composition

Results of the chemical properties of the diets are shown in Table 2. The moisture content is known as a quality indicator for processed cereals. The low moisture content of complementary food improves its shelf life (Tiencheu et al., 2016). The moisture contents of all three formulations exceeded the guidelines for weaning food (FAO/WHO, 1985). The result was similar to what Ikujenlola and Ogunba (2018) reported, but lower than the 9.8 - 11.7% reported by Adepoju and Ajayi (2016) for locally formulated winged termite-enriched complementary foods. This implies that the diets could have a longer shelf life.

Crude protein levels were high in the diets. This could be attributed to the use of soybeans and crayfish in the formulations. Soybeans are reported to be helpful in the brain development of infants (Onoja et al., 2014). The amount of crude protein determined in the diets was higher than the values reported by many authors (Solomon, 2005; Onoja et al., 2014; Tiencheu et al., 2016; Soronikpoho et al., 2017; Mekuria et al., 2021).

The fat content of a diet can affect the shelf life of food because fat undergoes oxidative deterioration. Therefore, food samples with a high fat content are more likely to spoil than those with a lower fat content (Tiencheu et al., 2016; Ajala et al., 2013). The fat content of the formulated food (15.13 – 20.12%) compared favourably with the regulatory standard (FAO/WHO/UNU, 1985). Adepeju et al. (2016) reported lower values (9.00 – 12.67%) for weaning food prepared from sorghum, germinated soybeans, and defatted sesame seeds. The high-fat content in this study could be attributed to the fact that sesame and groundnut flours were not defatted before their use. Solomon (2005) also reported a high range (15.6 – 38.1%) of crude fat, which could be attributed to the similarity of ingredients used in the formulation.

Table 2: Results of percent chemical composition and energy (kCal) of diets formulated for young children

Composition	LCD	MCD	HCD	FWU
Moisture	9.84 ± 0.025^{c}	9.41 ± 0.03^{b}	8.56 ± 0.02^{a}	< 5
Crude protein	63.23 ± 0.01^{c}	55.75 ± 0.08^{b}	40.66 ± 0.01^{a}	> 15
Fat	20.12 ± 0.05^{c}	18.24 ± 0.01^{b}	15.13 ± 0.02^{a}	10 – 25
Crude fibre	1.54 ± 0.02^{c}	1.37 ± 0.03^{b}	1.12 ± 0.02^{a}	< 5
Ash	2.45 ± 0.01^{c}	2.25 ± 0.02^{b}	2.06 ± 0.03^{a}	< 3
Carbohydrate	2.84 ± 0.03^{c}	12.99 ± 0.02^{b}	32.48 ± 0.03^{a}	64
Energy	445.30 ± 0.01^{c}	439.08 ± 0.03^{b}	428.79 ± 0.13^{a}	400 – 425

The values are mean ± standard deviation of triplicate determinations. Values followed by different letters on the same row are significantly different ($p < 0.05$). FWU = FAO/WHO/UNU (1985) standards.

Low fibre content promotes the easy digestion and absorption of infant diets (Adepeju et al., 2016). Ijarotimi and Keshinro (2013) reported a crude fibre content ranging from 0.85 to 2.4%, with the upper limit being higher compared to the 1.12–1.54% determined in the three formulations. Similarly, Adepeju et al. (2016) and Ikujenlola and Ogunba (2018) reported higher proportions of fibre content in the ranges of 3.21– 5.00% and 4.18 – 5.79%, respectively.

The ash content of the diets ranged from 2.06 to 2.45%. This meets the FAO/WHO/UNU (1985) requirement for infant weaning food. The ash content of a diet determines the level of inherent minerals in foods (Ikujenlola & Ogunba, 2018; Ajala et al., 2013. The ash content of the diets was lower than the 4.32 to 4.85% reported by Tiencheu et al. (2016) for weaning food formulated with egg white, fermented maize, pawpaw, and beans. Similarly, Mahmoud and El-Anany (2014) reported a slightly higher ash content of 2.6 to 2.91%, while a similar proportion of ash content in the range of 2.05 to 2.60% was reported by Solomon (2005).

Carbohydrates are required by the body primarily as a source of energy. The formulated diets were low in carbohydrates but rich in proteins. This could be due to corn being the primary source of carbohydrates in the ingredients, and its proportion was higher in the three formulations. This research reported lower percentages of carbohydrates compared to documented reports (Mahmoud and El-Anany, 2014; Adepeju et al., 2016; Tadesse and Gutema, 2020), but fell within the range of values obtained by Onoja et al. (2014) in their formulated diets.

The energy values of the formulated diets were above the 400 – 425 kcal recommendation (FAO/WHO/UNU, 1985). However, lower ranges of 333.97 – 372.19 kcal were reported in another research (Tiencheu et al., 2016). The high energy value of the diets may be attributed to their high fat, protein, and carbohydrate contents.

Functional properties

For the appropriateness of food, especially for growing children, functional properties are crucial (Ijarotimi & Keshiro, 2013). Bulk density reflects the load that the food sample can carry (Achidi et al., 2016) and is important in the packaging (Ijarotimi & Keshiro, 2013). Bulk density range of 0.71 – 0.77 g/ml (Table 3) was lower compared with 0.91 – 0.77 g/ml reported elsewhere (Desalegn et al., 2015). However, the values (0.69 – 0.81 g/ml) reported by Ukom et al. (2019) were consistent with the range obtained in this study. Conversely, Ikujenlola and Ogunba (2018) reported a lower range of 0.42 – 0.69 g/ml.

Table 3: Functional properties of the formulated supplementary food

Sample	Bulk density (g/ml)	Water absorption capacity (cm^3/g)	Swelling capacity (cm^3/g)	Least gelation (%)
LCD	0.77 ± 0.02^a	0.14 ± 0.01^a	1.40 ± 0.03^a	11.5 ± 0.15^a
MCD	0.75 ± 0.02^{a,b}	0.56 ± 0.02^b	1.49 ± 0.11^a	14.0 ± 0.01^b
HCD	0.71 ± 0.03^b	1.03 ± 0.01^c	1.56 ± 0.02^a	14.5 ± 0.01^c

The results are in mean ± standard deviation. Values followed by different letters in the same column are significantly different ($p < 0.05$).

Water absorption capacity (WAC) indicates the amount of water available for gelatinization (Achidi et al., 2016). WAC of a food product is determined by the maximum amount of water it can absorb and retain (Ijarotimi & Keshinro, 2013; Ikujenlola & Ogunba, 2018; Ukom et al., 2019). The formulated diets had low WAC which can be attributed to the method of preparation. The values were comparable to 2.81 – 3.13 ml/g and 2.60 – 3.90 ml/g reported by Ukom et al. (2017) and Achidi et al. (2016), respectively. The advantage of having a low WAC in a diet, as reported by Ijarotimi and Keshinro (2013) is that it helps to reduce the activities of microorganisms, thereby increasing the shelf life of the product.

Swelling capacity is used to determine the amount of water that food samples can absorb and the extent of swelling within a specific period (Ijarotimi & Keshinro, 2013). The swelling capacity and least gelation of the formulated diets (Table 3) agreed with the respective values of 0.53 – 4.97 ml/g and 9.00 – 14.00% reported by Ijarotimi and Keshinro (2013). Ikujenlola and Ogunba (2018), on the other hand, reported a higher range (28.00 – 36.00)% of least gelation.

Mineral content

Minerals are essential for the synthesis of haemoglobin, myoglobin, and enzymes/coenzymes used in various metabolic pathways, as well as for enhancing the body's immune system (Tiencheu et al., 2016). As shown in Table 4, potassium was the most abundant mineral in the formulated diets, with levels ranging from 540.66 to 642.32 mg/100g. These ranges were above the minimum level required in complementary foods (FAO/WHO, 1991). This confirms the findings that potassium is the most abundant mineral in Nigerian agricultural products (Solomon, 2005; Ijarotimi & Keshinro, 2013; Adepoju & Ajayi, 2016; Tiencheu et al., 2016). Calcium was the second most abundant mineral in the formulated diets, ranging between 334.77 and 425.17 mg/100g.

However, these values were below the recommendation (FAO/WHO, 1991). Calcium is required for the development of strong bones and teeth and participates in muscle contraction, blood clotting, and nervous impulses (Adepoju & Ajayi, 2016). The amount of calcium in the formulated diet was similar to that reported in the study (Tiencheu et al., 2016). Iron content in the diets ranged from 7.13 to 8.26 mg/100g. These values were above 6.75 – 7.13 mg/100g, as reported by Desalegn et al. (2015), but were similar to the range of 7.5 – 8.0 mg/100g reported by Parvin et al. (2014)

Table 4: Results of minerals/elemental contents of the formulated food

Sample	Ca (mg/100g)	Mg (mg/100g)	K (mg/100g)	Fe (mg/100g)
LCD	334.77 ± 0.02^{a}	68.53 ± 0.02^{a}	540.66 ± 0.02^{a}	7.13 ± 0.03^{a}
MCD	380.64 ± 0.02^{b}	69.36 ± 0.02^{b}	591.24 ± 0.02^{b}	7. 66 ± 0.02^{b}
HCD	425.17 ± 0.02^{c}	67.96 ± 0.03^{c}	642.32 ± 0.02^{c}	8.26 ± 0.01^{c}
FAO/WHO	500	76	516	16

The results are in mean ± standard deviation (SD). Values followed by different letters in the same column are significantly different at $p < 0.05$. FAO/WHO (1991) standards.

Antinutrient composition

Reports have shown that excessive amounts of antinutrients like oxalate, phytate, and hydrocyanic acid can cause some adverse health effects on humans (Ebana et al., 2017). For these reasons and due to the delicate nature of infants' organs, the levels of tannins, phytates, and oxalates in the diets were determined. The levels of antinutrients in the formulated diets (Table 5) were found to be within acceptable limits, making the products suitable for consumption by infants. Ijarotimi and Keshinro (2013) reported lower levels of oxalate and tannins, but higher levels of phytate. Ebana et al. (2017) on the other hand reported higher amounts of oxalate but lower phytate (0.37 – 1.10 mg/100g). However, Desalegn (2015) and Onoja et al. (2014) reported higher levels of tannins and oxalates in complementary food made from protein maize and local staples, respectively.

Table 5: Result of anti-nutrient content of formulated food

Sample	Tannin (mg/100g)	Phytate (mg/100g)	Oxalate (mg/100g)
LCD	1.95 ± 0.02^{a}	1.25 ± 0.01^{a}	0.21 ± 0.02^{a}
MCD	2.31 ± 0.01^{b}	1.53 ± 0.02^{b}	0.35 ± 0.02^{b}
HCD	2.66 ± 0.02^{c}	1.85 ± 0.05^{c}	0.48 ± 0.03^{c}

The values are in mean ± standard deviation. Values followed by different letters in the same column are significantly different ($p < 0.05$).

Soronikpoho et al. (2017) also reported higher levels of oxalate and tannins. Thus, the reduced antinutrients in the formulated diets may be attributed to the processing methods. Ijarotimi and Keshinro (2013) supported the idea that fermentation and other processing methods improved the nutritional quality of legumes and cereals by causing significant changes in their chemical composition and eliminating anti-nutritional factors.

Vitamin content

The results of the vitamin analysis conducted on the diets formulated for young children are presented in Table 6. It is important to note that vitamin A is crucial for infants. In this study, the values obtained for the three diets were above 400 µg/100g, which is the minimum recommended value (1991). Adepoju and Ajayi (2016) reported vitamin A in the range of 216.23 to 227.60 µg/100g, while Desalegn et al. (2015) reported vitamin A in the range of 291.63 to 565.09 µg/100g. However, Onoja et al. (2014) reported lower concentrations of vitamin A (0.39 – 0.71 µg/100g). The high level of pro-carotenoids in this study could be attributed to the significant proportion of carrots in the formulated diets. Vitamin A was not detected in the formulated diet by Tadesse and Gutema (2020). They proposed that this could be attributed to two factors: over-sun-drying of the carrots used in the formulation, which led to the degradation and loss of vitamin A, and the insoluble nature of vitamin A in water. Vitamin A is an antioxidant that prevents cells from being damaged by free radicals. It is essential for maintaining healthy eyes and skin and is needed for normal growth and reproduction. Additionally, it promotes a healthy immune system and helps prevent infections (Adepoju & Ajayi, 2016).

Table 6: Vitamin composition of the formulated complementary food

Vitamins	LCD	MCD	HCD	CODEX
Vitamin A (µg/100g)	536.88 ± 5.13^{a}	465.52 ± 3.03^{a}	622.78 ± 8.62^{a}	400
Vitamin B$_1$ (mg/100g)	1.07 ± 0.01	0.58 ± 0.02^{a}	0.95 ± 0.02^{a}	0.5
Vitamin B$_2$ (mg/100g)	0.66 ± 0.00	0.56 ± 0.02^{a}	0.47 ± 0.03^{a}	0.5
Vitamin B$_{12}$ (mg/100g)	0.92 ± 0.03	0.76 ± 0.02^{a}	0.59 ± 0.02^{a}	0.9
Vitamin D (mg/100g)	1.23 ± 0.01	2.38 ± 0.02^{a}	3.43 ± 0.02^{a}	5

The values are in mean ± standard deviation. Values followed by different letters on the same row are significantly different ($p < 0.05$).

Both the MCD and LCD diets met the recommended values of 5 mg/100g and 0.9 µg/100g for vitamins B$_1$ and B$_{12}$, respectively. Similarly, diet MCD met the recommended value of 0.5 mg/100g for B$_2$ (riboflavin), while diet HCD did not. Adepoju and Ajayi (2016) reported a lower concentration of the entire vitamin complex. They attributed this to prolonged soaking, which led to the leaching of water-soluble vitamins (B complex and C).

Amino acid profile

The results of the amino acid profile of the formulated diets are presented in Table 7. The diets contained high concentrations of both essential and non-essential amino acids. The lowest abundance of tryptophan in this study closely aligns with some findings (Gernah et al., 2012; Ikujenlola & Ogunba, 2018), where tryptophan ranged from 1.08 to 1.35 g/100g and 1.28 to 1.32 g/100g, respectively. It was also identified as the least abundant amino acid in their studies. Solomon and Owoldwashe (2006) posited that the quantity and quality of protein are important considerations in child nutrition, as both are required for optimal growth and development. In this study, the most abundant amino acid in the MCD diet is threonine (46.32 g/100g), while in the HCD, alanine (80.20 g/100g) was found to be the most abundant. Essential amino acids are necessary because they cannot be produced in the human body at the required level but must be obtained through food (Solomon & Owoldwashe, 2006; Ikujenlola & Ogunba, 2018; Adedokun et al., 2020; Obasi et al., 2023). Generally, the levels of amino acids in the formulated diets were high. The results support the notion that the high protein content of legumes enhances the protein content of cereal-based complementary foods and addresses amino acid deficiency (Adedokun et al., 2020). It has been reported that the amino acids valine, leucine, and isoleucine are responsible for the synthesis of substrates for gluconeogenesis, while phenylalanine is needed to produce a pigment called melanin that contributes to eye, hair, and skin colour (Ikujenlola & Ogunba, 2018).

Table 7: Amino acid (g/100g protein) profile of the complementary flour blends

Amino acid	LCD		MCD		HCD		Hen's egg ^{a}
	Value	Score	Value	Score	Value	Score	
Leucine*	8.62	1.03	8.12	0.98	4.20	0.51	8.30
Isoleucine*	4.54	0.81	4.00	0.71	2.86	0.51	5.60
Lysine*	4.45	0.72	3.99	0.64	2.32	0.37	6.20
Threonine*	4.32	0.85	3.68	0.72	5.76	1.13	5.10
Histidine*	5.70	2.38	2.38	0.99	3.34	1.39	2.40
Aspartate	6.44	0.60	8.09	0.76	4.58	0.43	10.70
Valine*	4.36	0.58	4.27	0.57	3.80	0.51	7.50
Methionine*	1.34	0.42	2.22	0.69	2.72	0.85	3.20
Phenylalanine*	4.58	0.90	3.39	0.66	2.08	0.41	5.10
Glutamine	15.32	1.28	15.56	1.30	20.52	1.71	12.00
Glycine	5.66	1.89	3.60	1.20	4.81	1.60	3.00
Alanine	4.82	0.89	3.38	0.63	2.09	0.39	5.40
Tyrosine	2.80	0.70	3.11	0.78	1.64	0.41	4.00
Arginine	7.42	1.22	5.39	0.88	3.86	0.63	6.10
Cysteine*	2.01	1.12	1.20	0.67	3.54	1.97	1.80
Proline	2.72	0.72	2.77	0.73	3.14	0.83	3.80
Serine	3.86	0.49	2.80	0.35	3.01	0.38	7.90
Tryptophan*	1.74		0.97		1.46		NS
Total EAA	**41.66**		**34.22**		**32.08**		
Total NEAA	**49.04**		**44.70**		**43.65**		

*EAA (Essential amino acid), NEAA = non-essential amino acid, NS – Value not sated. ^{a} Hen's egg amino acid profiles are adopted as standard [18].

The values determined for threonine in the three diets were higher than the reference value (FAO/WHO, 1991). Threonine helps in the proper functioning of the central nervous system, boosts the immune system, assists in building strong bones and tooth enamel, and aids in the healing of wounds (Ajala et al., 2021). Tryptophan is the precursor for the synthesis of serotonin. Aspartate and glutamate serve as ammonia transporters to the liver and kidney for urea synthesis (Ikujenlola & Ogunba, 2018). Histidine, an essential amino acid, had excellent scores of 238, 99, and 139% in the LCD, MCD, and HCD, respectively. A similar trend was observed with glycine and glutamine in all three blends. However, serine had the lowest score among the amino acids in the three formulated meals. Since most of these amino acids had scores above average, therefore, the formulated diets are good for young children.

Microbial analysis

The results of the microbial analysis of the formulated diets are shown in Table 8. The microbial load of food is a useful indicator for assessing the quality and potential safety of food products from a human consumption perspective, as well as for determining the storage conditions of the product (Mekuria et al., 2021). From the results, the total viable count (TVC) of the diets met the international microbiological standard (1×10^5 cfu/ml). Parvin et al. (2014) reported $1x10^1$ cfu/g for cereal-based supplementary food for children, while Oyarekua (2011) reported a range of 3.5×10^8 to 2.8×10^9 cfu/g in co-fermented cereals/cowpea.

Table 8: Total viable count (TVC), total coliform count (TCC), mould and yeast count (MYC) of the blends

Sample	TVC (cfu/g)	TCC (cfu/g)	MYC (cfu/g)
LCD	4.00×10^3	3.00×10^3	2.50×10^4
MCD	3.00×10^3	2.00×10^3	1.70×10^4
HCD	3.00×10^3	3.00×10^3	2.00×10^4

The TCC of the LCD and MCD were below the permissible limit of $1.00x10^5$ cfu/ml. The low bacterial counts in this study could be attributed to the high standard of personal hygiene, the high temperature of the drying process, and quality maintenance of good manufacturing practices during the formulation process (Achidi et al., 2016). The TCC in this study was lower contrary to $1.30x10^6$ – $2.70x10^6$ cfu/g reported elsewhere (Oyarekua, 2011). However, Parvin et al. (2014) recorded no coliform count in their study.

MYC of the diets was within the permissible limit of 1.00×10^5 cfu/ml. This low value could be ascribed to the good quality of the raw materials used, hygienic processing conditions, and portable water used for the formulation. In their study, Achidi et al. (2016) reported 0.75 and $1.20x10^2$ cfu/ml for mould and yeast, respectively. Oyarekua (2011) also reported a lower range of 2.00×10^1 – 1.50×10^5 cfu/g of MYC. The formulated diets met the requirement of allowable microbial loads in food and therefore safe for consumption. More septic measures are encouraged to reduce the microbial load to the least possible level.

Sensory evaluation

The results of the sensory attributes of the diets are presented in Table 9. Appearance is an important sensory attribute of any food because it influences acceptability (Tiencheu et al., 2016; Mekuria et al., 2021. The appearance of the diets was in the range of ‘like slightly’ to ‘like moderately’ (5.63 to 7.27) with the MCD rating higher in the hedonic scale rating. This agreed with a similar report (Tiencheu et al., 2016). Adedokun et al. (2020) and Gernarh et al. (2012) had higher ratings of ‘like moderately’ to ‘like very much’ on gruel produced from rice and defatted Bambara nut flour meal, respectively.

Table 9: Sensory evaluation of the complementary flour blends

Sample	Appearance	Aroma	Taste	Mouthfeel	General Acceptability
LCD	5.72 ± 1.73^a	5.63 ± 0.80^a	5.90 ± 1.51^a	5.72 ± 1.19^a	6.00 ± 1.48^a
MCD	7.27 ± 1.10^b	6.09 ± 1.04^a	6.00 ± 0.77^a	5.72 ± 1.10^a	6.54 ± 1.30^a
HCD	5.63 ± 1.50^a	5.54 ± 1.91^a	5.09 ± 1.57^a	5.18 ± 1.30^a	5.72 ± 1.55^a

Value representation means ± standard deviation. Values followed with different superscripts on the same row are significantly different ($p < 0.05$).

The MCD was rated highest concerning aroma, taste, and mouthfeel in the three diets. Also, the MCD was most generally accepted with a 6.54 rating whereas HCD was the least generally accepted (5.72). Onoja et al. (2014) reported lower acceptability in the range of 4.00 to 4.75 for diets formulated from local staples fortified with calcium, iron, and zinc. Ijarotimi and Keshinro (2013) on the other hand reported general acceptability in the range of 5.4 to 7.1 for diets formulated from the combination of fermented popcorn, African locust, and Bambara groundnut seed flour. The general acceptability of the diets, which was above average, shows that the diets were of good quality and attractive as well.

CONCLUSION

The study used locally available ingredients commonly consumed in Nigeria to formulate complementary food for infants. The three diets were rich in high-quality protein with essential amino acids and energy values. The nutrient content of the formulated food products met the WHO reference standard, and their microbial contents were below the WHO permissible limit. These affordable and nutritious diets offer a practical solution to addressing nutritional challenges faced by infants and children in developing countries. The study demonstrated that it is feasible to establish small-scale entrepreneurs and home-scale industries to create complementary foods for young children using low-cost and locally available ingredients.

ACKNOWLEDGMENTS

We sincerely acknowledge the management of Akanu Ibiam Federal Polytechnic for allowing us to use the facilities in the Food Technology and Chemistry laboratories for this research. The technical support of Benjamin Aligwe, Gloria Ogbu, Clement Ewa, Courage Richard, and Regina Ani is noteworthy.

REFERENCES

Abeshu, M. A., Lelisa, A., and 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, DOI: 10.3389/fnut.2016.00041

Achidi, A. U., Tiencheu, B., Tenyang, N., Womeni, H. M., Moyeh, M. N., Ebini, L. T., and Tatsinkou, F., 2016. Quality evaluation of nine instant weaning foods formulated from cereal, legumes, tuber, vegetable, and crayfish. International Journal of Food Science and Nutrition Engineering, 6: 21–31. DOI: 10.5923/j.food.20160602.01

Adedokun, I. I., Mmuotoh, A. B., Adedokun, C. J., Ogbonna, P. C., Ekemeyen I. A., and Madu, U. D., 2020. Amino acids profile, functional and sensory properties of infant complementary gruel produced from rice and defatted Bambara nut flour meal. Journal of Dietitians Association of Nigeria, 11: 11–19.

Adepeju, A. B., Abiodun, O. A., Dauda, A. O., and Fatiregun, A. A., 2016. Nutritional evaluation of weaning food prepared from fermented sorghum, germinated soybean, and defatted sesame seed. FUTA Journal of Research in Sciences, 12: 260–269.

Adepoju, T. O., and Ajayi, K., 2016. Nutrient composition and adequate of two locally formulated winged termite (Macrotermes bellicious) enriched complementary foods. Journal of Food Research, 5: 79–89. DOI: 10.5539/jfr,v5n4p79

Ajala L. O., Oyeleke G. O., and Olagunju E. O., 2013. Nutritional assessment of juice extract from Hibiscus sabdariffa. International Journal of Biology Pharmacy and Allied Sciences, 2: 10 – 19.

Ajala, L. O., Igidi, J. O., Fasuan, T. O., and Ominyi, C. E., 2021. Osmo-predried fluted pumpkin (Telfairia occidentalis) leaf and its nutri-economic evaluation. Nutrition and Food Science, 51: 289–299. DOI: 10.1108/NFS-03-2020-0076

CODEX Alimentarius, 1991. Guidelines for development of supplementary foods for older infants and young children. In report of the 19th session. Rome, Italy.

Desalegn, B. B., Abegaz, K., and Kinfe, E., 2015. Effect of blending ratio and processing technique on physicochemical composition, functional properties and sensory acceptability of quality protein maize (QPM) based complementary food. International Journal of Food Science and Nutrition Engineering, 5: 121–129. DOI: 10.5923/j.food.20150503.03

Ebana, R. U. B., Edet, O. U., Ekanemesang, U. M., Ikon, G. M., Umoren, E. B., Ntukidem, N. W., and Brown, N. U., 2017. Proximate composition and nutritional analysis of seeds and testas of Dacryodes edulis and Garcinia kola. Asian Journal of Biology, 2: 1–8. DOI: 10.9734/AJOB/2017/31159

FAO/WHO, 1991. Protein quality evaluation. Report of Joint FAO/WHO Expert Consultation. FAO Food and Nutrition Paper 51, Rome, Italy, pp. 1– 66.

FAO/WHO/UNU, 1985. Energy and protein requirements. Reports of a joint FAO/WHO/UNU expert consultation. World Health Organization Technical Report Series 724:1-206, Geneva, Switzerland.

Gain, K., Khatun, S., Hossain, M. S., and Mallick, D. R., 2020. Mothers experience about complementary feeding practice in Bangladesh. Open Journal of Pediatrics, 10: 423–437. DOI: 10.4236/ojped.2020.103043

Gernah, D. I., Ariahu C. C., Ingbian, E. K., 2012. Nutritional and sensory evaluation of food formulations from malted and fermented maize, Zea mays L., fortified with defatted sesame (Sesamun indicum L.) flour. African Journal of Food, Agriculture, Nutrition and Development, 2: 6614–6631.

Ijarotimi, S. O., and Keshinro, O. O., 2013. Determination of nutrient composition and protein quality of potential complementary foods formulated from the combination of fermented popcorn, African locust and bambara groundnut seed flour. Polish Journal of Food and Nutrition Sciences, 63: 155–166. DOI: 10.2478/v10222-012-0079-z

Ikujenlola, A. V., and Ogunba, B. O., 2018. Potential complementary food from quality protein maize (Zea mays L.) supplemented with sesame (Sesamum indicum) and mushroom (Oudemansiella radicata). Journal of Nutrition and Food Sciences, 8: 1–7. DOI: 10.4172/2155-9600.1000698

Ishara, J. R. M., Sila, D. N., Kenji, G. M., Buzera, A. K., and Mushagalusa, G. N., 2018. Nutritional and physical attributes of maize-mushroom complementary porridges as influenced by mushroom species and ratio. American Journal of Food and Nutrition, 6: 17–27. DOI: 10.12691/ajfn-6-1-4

Mahmoud, A. H., and El Anany, A. M., 2014. Nutritional and sensory evaluation of a complementary food formulated from rice, Faba beans, sweet potato flour, and peanut oil. Food and Nutrition Bulletin, 35, DOI: 10.1177/156482651403500402

Mekuria, A. S., Kinyuru, N. J., Mokua, K. B., and Tenagashaw, W. M., 2021. Nutritional quality and safety of complementary foods developed from blends of staple grains and honeybee larvae (Apis mellifera). International Journal of Food Science, DOI: 10.1155/2021/5581585

Obasi N. A., Aloke C., Obasi S. E., Famurewa A. C., Elom S. O., Aja P. M., and Ajala L. O., 2023. Nutritional assessment of pulps and partial characterization of seed oils from varieties of pear fruits. Journal of Pharmacy and Nutrition Science, 13: 13–20. DOI: 10.29169/1927-5951.2023.13.02

Onoja, U. S., Akubor, P. I., Gernar, D. I., and Chinmma, C. E., 2014. Evaluation of complementary food formulated from local staples and fortified with calcium, iron and zinc. Journal of Nutrition and Food Sciences, 4: 1–6. DOI: 10.4172/2155-9600.1000326

Oyarekua, M. A., 2011. Evaluation of the nutritional and microbiological status of co-fermented cereals/cowpea ‘OGI’. Agriculture and Biology Journal of North America. 2: 61–73. DOI: 10.5251/abjna.2011.2.1.61.73

Parvin, R., Satter, M. A., Jabin, S. A., Abedin, N., Islam, F., Kamruzzaman, M., and Paul, D. K., 2014. Studies on the development and evaluation of cereal based highly nutritive supplementary food for young children. International Journal of Innovation and Applied Studies, 9: 974–984.

Solomon, M., 2005. Nutritive value of three potential complementary foods based on cereals and legumes. African Journal of Food and Nutritional Sciences, 5: 1–14.

Solomon, M., and Owoldwashe, H., 2006. The analyses of amino acid, fatty acid and mineral in a legume-cereal based complementary food blend used in Jos, Nigeria. The Internet Journal of Nutrition and Wellness, 4: 1–8.

Soronikpoho, S., Elleingand, E. F., Fatoumata, C., and Ernest, K., 2017. Evaluation of nutritive value of yam based weaning food fortified with soy and vegetables minerals sources. American Journal of Food and Nutrition, 5: 126–135. DOI: 10.12691/ajfn-5-4-3

Tadesse, A. Y., Ibrahim, A. M., Forsido, S. F., and Duguma, H. T., 2018. Nutritional and sensory quality of complementary foods developed from bulla, pumpkin and germinated amaranth flours. Nutrition and Food Science, 46: 30–42. DOI: 10.1108/NFS-01-2018-0001

Tadesse, A., and Gutema, T., 2020. Formulation and sensory evaluation of complementary food from locally available ingredients in South Ari Woreda, Southern Ethiopia. International Journal of Public Health and Safety, 5: 1–4.

Tiencheu, B., Achidi, U. A., Fossi, T. B., Tenyang, N., Ngongang, T. F. E., and Womeni, M. H., 2016. Formulation and nutritional evaluation of instant weaning foods processed from maize (Zea mays), pawpaw (Carica papaya), red beans (Phaseolus vulgaris) and mackerel fish meal (Scomber scombrus). American Journal of Food Science and Technology, 4: 149–159. DOI: 10.12691/ajfst-4-5-5

Ukom, A. N., Adiegwu, E. C., Ojimelukwe, P. C., and Okwunodulu, I. N., 2019. Quality and sensory acceptability of yellow maize ogi porridge enriched with orange-fleshed sweet potato and African yam bean seed flours for infants. Scientific African, 6: e00194.