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Formulation of Complementary Foods for Children 6-12 Months Using Local Staple Foods in Damaturu the North- Eastern Nigeria

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ABSTRACT

Malnutrition in children continues to be a global health concern. Undernutrition is thought to be the cause of 45% of all paediatric fatalities in low- and middle-income nations. For babies and young children between the ages of six and twenty-four months, complementary nutrition is crucial to their growth and development. The proximate, vitamin, and mineral composition of a locally produced supplemental food made from maize, wheat, soybean, egg white, sweet potato, and groundnut were evaluated in this study. Utilising conventional laboratory techniques. The blends (1 to 10) were prepared and assessed using nine scaled hedonic points for colour, taste, flavour, and consistency. The top five were then assessed using standard Association of Analytical Chemists (AOAC) procedures for proximate composition, certain vitamins, and minerals. The favoured formulas were 2, 8, 1, 3, and 7, according to the results of the sensory examination. Micronutrient analysis showed that all three (1, 3, and 7) formulas had vitamin A contents ranging from 204.97 to 1309.77 IU, while moisture contents ranged from 4.6 to 9.5%, ash contents ranged from 2.65 to 3.50%, fibre contents ranged from 5.21 to 8.31%, protein contents ranged from 16.11 to 35.41%, fat contents ranged from 10.20 to 15.10%, and carbohydrate contents ranged from 43.51 to 64.51%. Iron ranged from 4.22 to 8.54 mg/100g, zinc ranged from 2.0 to 2.75 mg/100g, and calcium ranged from 344.67 to 507 mg/100g. The formulation offers vital nutrients when compared to suggested dietary requirements, however its vitamin, iron, and zinc content has to be improved. The results imply that iron supplementation and fortification with B_{12}-rich sources and enhancers could improve its nutritional adequacy. Although more research is required to evaluate microbial load and storage durability. This study reveals that locally produced components can be used to create affordable supplemental foods.

Keywords: Complementary food, Minerals, Proximate analysis, Vitamins, Infant nutrition, Staple foods

INTRODUCTION

Malnutrition in children continues to be a global health concern. According to estimates, under nutrition accounts for 45% of all deaths in children under five in low- and middle-income nations (WHO, 2021). Malnutrition can take many different forms, such as stunting, wasting, and deficits in certain micronutrients. It has an impact on cognitive development, a person's ability to defend off illnesses, and general living standards. A "window of opportunity" for optimal growth and development during the first 1,000 days is acknowledged to be provided by appropriate complementary feeding methods. Around six months of age, when breast milk is no longer sufficient to cover the child's nutritional demands, complementary foods are introduced. Complementary foods are very inadequate in many impoverished nations, leading to deficits of numerous nutrients and malnutrition. Economic limitations, restricted access to fortified foods, and reliance on boring diets high in cereals and tubers deficient in vital nutrients like protein, vitamins, and minerals all exacerbate this issue (Gibson & Hotz, 2001). In Nigeria and other parts of West Africa, "Tom Brown," a popular cereal-based supplemental food, is traditionally prepared using a combination of maize, wheat, soybean, and groundnuts. Given the presence of these staple items in the kitchens of most households, there is a significant preference and demand for this preparation, mostly because of its affordability and readiness among its impoverished elements (Nnam, 2001). While soybeans and groundnuts supply the proteins and lipids necessary for growth and development, especially of the brain, maize and wheat supply the carbohydrates needed for energy. Additionally, several vital vitamins and trace elements like iron and zinc that are critical for immunological responses and brain development are present in these ingredients. However, there is little proof that it is nutritious enough to meet new-born's and young children's dietary needs. According to Gibson et al. (2010), traditional processing methods like roasting and fermenting have long been known to improve the nutritional value and bioavailability of vegetables by reducing anti-nutritional elements like phytates and tannins. The extent to which this enhances the nutritional value of "Tom Brown" hasn't gotten much attention, though. Given the high rate of malnutrition in Nigeria, this is crucial. The NDHS reports that 37% of children under five are stunted, 7% are wasted, and 22% are underweight, demonstrating the critical need for effective nutritional interventions (UNICEF, 2021). This makes evaluating and optimising supplemental foods that are produced locally, like "Tom Brown," a sustainable best option for enhancing children's nutrition. By utilising locally accessible resources, this strategy improves feeding practices at the community level, guarantees food safety, and lessens dependency on costly imported goods. This study describes the proximate content, vitamin, and mineral profile of "Tom Brown," which is made from ingredients like wheat, groundnuts, soybeans, egg flour, sweet potatoes and maize.

MATERIALS AND METHODS

Ethical considerations

According to the ethical standards laid down in the 1964 Declaration of Helsinki, ethical clearance was obtained and the informed consent forms were signed by the participants who took part in this study.

Area of study

The research study area is Damaturu, Yobe State, a town in north eastern Nigeria that is a significant commercial centre for the state. It is situated at roughly 11.7470 latitude and 11.9662 longitude. The town is well-known for its agricultural pursuits, especially the production of crops like rice, wheat, soybeans, groundnuts, and maize.

Design of research

The study adopted an experimental research design. The macronutrient and micronutrient contents of the formulations were evaluated through laboratory investigations, and the nutritional profiles were compared to recommended dietary allowances (RDAs) for children between the ages of 6 and 24 months using statistical techniques to compare the formulations.

Sample collection

Five (5) samples of grain, weighing five kilograms each, including groundnuts, wheat, soybeans, and maize, were bought from the city's market. After being properly labelled, the samples were stored at room temperature until further analyses.

Sample preparation

The grains, which included maize, wheat, soybeans, and groundnuts, were destoned, surface washed using the Samson et al. (2010) procedure, and allowed to air dry at room temperature.

Cleaning

Sorting of Dirt's
↓
Washing
↓
Drainage of Water for 30 minutes
↓
↓
Roasting
↓
Cracking to Remove Chaff
↓
Winnowing
↓
Blending
↓
Tom Brown Powder

Figure: 1 Flow Chart for Tom Brown Preparation

Formulation process

To attain the intended macronutrient and micronutrient balance, flours from maize, wheat, soybeans, sweet potatoes, dates, and groundnuts were combined in precise ratios. Multiple formulations were developed and optimised based on preliminary experiments and existing criteria for supplemental foods. To get the dirt off the tubers, the sweet potatoes were cleaned. After peeling, they were cooked for twenty minutes and then sliced into little pieces. After that, they were dried for two days at 80°C in an oven.

Table 1 below is a summary of how the flours and juices were mixed in ten different proportions to give ten different food blends. Blend 1 for example, consisted of 58g of malted corn flour, 10g of egg white flour, 10g of soybeans flour, 8g of sugar, 5ml of soybeans oil. After mixing of flours, juices and artificial flavours, the mixtures were homogenized using an electric blender, placed on sterile trays and dried at 50°C for 24 hours using a hot-air oven. The resulting dry matter were ground using a dry blender, sieved and the fine flours stored in sterile zip-lock bags at room temperature.

Table 1. Formulation table for formulation of ten different complementary food blends

Food samples/ Blends	**1**	**2**	3	**4**	5	6	**7**	**8**	**9**	**10**
Maize Flour (g)	58	0	0	0	29	29	29	0	0	0
Wheat Flour (g)	0	58	0	0	29	0	0	29	29	0
SP Flour (g)	0	29	58	0	0	29	0	0	29	0
Egg White Flour (g)	10	7	8	6	10	8	6	5	3	5
Soy Beans Flour (g)	10	7	8	6	10	8	6	5	3	5
Date (g)	8	10	0	7	10	5	7	5	7	5
Soybeans oil (ml)	5	5	5	5	5	5	5	5	5	5
Pineapple juice (ml)	0	10	0	10	0	0	0	10	0	0

Sensory Assessment

Twenty qualified panellists per take in the sensory assessment room at Yobe State College of Agriculture Science and Technology, Gujba's School of Health Science. Mothers with infants between the ages of 0 and 24 months made up the panellists. According to Dzung et al. (2004), the 9-point hedonic scale was used. Using a 9-point hedonic scale, with 1 denoting "dislike extremely," 5 denoting "neither like nor dislike," and 9

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denoting "like extremely," each of the 20 panellists assessed the ten formulas for colour, flavour, texture, and taste. Phosphatine was used as a control complementary food. After analysing the sensory analysis data, the top five formulas were selected by dividing the total score for taste, colour, flavour, and texture by 4 to determine a value that represented each formula's overall acceptability. The mean of the overall acceptability score was then calculated by adding up each panelist's overall acceptability score and dividing by 20. Nutrient analyses were conducted using the five formulas with the greatest mean overall acceptance, which were deemed to be the most desired.

Proximate analysis

The AOAC, 2019 techniques were applied for proximate analysis.

Determination of moisture content

Oven drying was used to assess the moisture content (AOAC, 2029). After being cleaned, the wet dishes were kept in an oven dryer at 105˚C for an hour. After cooling in a desiccator, the dishes' initial weight was noted (W_1). The petri dish was filled with two grams of the sample, and its weight was noted (W_2). After that, the plates were kept in an oven dryer at 105˚C for the entire night. Following drying, the moisture containing the dried samples was taken out of the oven dryer, cooled in a desiccator, and the final weight was noted (W_3).

The percentage moisture content of the sample were calculated using the formula below;

$$moisture\ content\ (\%) = \frac{W3 - W1}{W2 - W1} \times 100$$

Where W_1 = weight of empty petri dish

W_2 = weight of petri dish + sample before drying

W_3= weight of petri dish + sample after drying

Ash content

A pre-ignited porcelain crucible that had been dried and weighed was filled with the sample (2g). After that, the crucible was heated to 600°C for three hours in a muffle furnace. After cooling in a desiccator, the ash-filled crucibles were weighed again. Difference in mass were calculated as percentage ash content.

$$\%Ash = \frac{W2 - W1}{weight\ of\ sample} \times 100$$

Where; W_1= weight of weight of empty crucible and W_2= weight of crucible + ashed sample

Crude Protein determination

After weighing the sample (0.25g) into a Kjeldahl flask, 6 ml of 98% H_2SO_4 and the digestion mixture (3.5 g potassium sulphate, 0.105 g copper sulphate, and 0.105 g titanium oxide) were added. The mixture was broken down until the solution's colour changed to clear. The mixture was poured into a standard volumetric flask and filled to the 50 ml level with distilled water. After the digest was distilled, the ammonia that was released was collected in 2% boric acid and titrated against 0.01 N hydrochloric acid. The titre values were recorded and the percentage nitrogen was calculated (as shown below).

$$\%crude\ protein = \frac{titre\ value\ (ml) \times 0.00056 \times 6.25 \times 100}{weight\ of\ sample}$$

Where 0.00056 and 6.25 are the conversion factors that convert percentage Nitrogen to protein.

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Crude fat content determination

Sample (2g) were weighed into a filter paper, capped with cotton wool and deposited into a thimble holder. A pre-weighed 500 ml round-bottom flask with 200 ml of petroleum ether (40-60ºC) was connected to the thimble holder. For four hours, the contents of the thimble were refluxed. The sample was taken out, dried in an oven to remove any remaining petroleum ether, then cooled in a desiccator before being weighed. The proportion of crude fat was computed and variations in the filter paper's weight were noted.

$$\%fat = \frac{weight\ of\ filter\ paper\ and\ sample - weight\ of\ filter\ paper\ and\ defatted\ sample}{weight\ of\ sample} \times 100$$

Crude fibre determination

A 250 ml conical flask was filled with the defatted sample (2g), 200 ml of 1.25%

H_2SO_4 was added, and the mixture was boiled for 30 minutes. After the mixture was sieved through muslin fabric, the residue was cleaned with a quantity of boiling water until the filtrate was no longer acidic. After being scraped back into the flask, the residue was heated with 1.25% sodium hydroxide for an additional half hour. The residue was scraped into the crucible after the solution was sieved using muslin cloth and cleaned with hot water. After that, the residue was moved to a porcelain crucible and dried in a hot air furnace at 105°C for one hour. After cooling in a desiccator, the crucible was reweighed after being placed in a muffle furnace at 600°C for 30 minutes. The difference in mass before and after ignition in the furnace was used to compute the percentage of crude fibre.

$$\%Fibre = \frac{weight\ of\ residue}{weight\ of\ sample} \times 100$$

Weight of residue = weight of dried sample – weight of sample after ashing

Carbohydrate content determination

By deducting the total percentage of crude protein, crude fat, crude fibre, moisture, and ash contents from 100%, the carbohydrate content was calculated using the difference technique. Carbohydrate = 100 – (%moisture + %crude fibre + %crude protein + %crude fat +%ash).

Analysis of minerals

Method

A mixture of 10 mL of hydrochloric acid (HCl), nitric acid (HNO_3), and perchloric acid ($HClO_4$) was heated for two hours to digest 0.5 g of each of the cooled ash extracts. Five (5 g) of the locally produced tom browns were ashes in an oven at 540^0C for three hours before being subjected to various organic solvents. The digested mixtures were stored in a 100 mL beaker after being evaporated down to 5 mL using a rotator evaporator. They were then built up to 10 mL using 2M HNO_3 and 30 mL of distilled water. Atomic absorption spectrophotometers (AAS) (A. Analyst 400 Model) were used to analyse the elements in the resultant solutions at wavelengths between 213.9 and 324.8, temperature, and lamp-current. Additionally, reagent blank samples were made and tested for iron (Fe), calcium (Ca), potassium (K), phosphorus (P), and zinc (Zn), from the locally produced complementary foods (AOAC, 1998).

Analysis of vitamins

A.O.A.C, (1990) method were adopted for determining the vitamins in the locally produced tom brown.

Vitamin A (retinol) Determination

One gram of the sample was weighed, and it was macerated for ten minutes in a test tube with twenty millilitres of n-hexane. Then 3mls of the hexane extract was put into a dry test tube in triplicates and evaporated to dryness. After that, 2 millilitres of 50% trichloroacetic acid (TCA) in chloroform and 0.2 millilitres of acetic anhydride chloroform reagent were added. At 620 nm, the absorbance was measured every 15 and 30 seconds intervals at the same wavelength.

Vitamin C (ascorbic acid) determination

After weighing about 0.5g of the sample, it was macerated with 10 mL of 0.4% oxalic acid in a test tube for ten minutes, centrifuged for five minutes, and the mixture was filtered. After transferring 1 millilitre of the filtrate in triplicate into a dry test tube, 9 millilitres of 2,6-dichlorophenol indophenol were added, and absorbance measurements were made at intervals of 15 and 30 seconds at 520 nm.

Vitamin B_{12} (Cobalamin) determination by HPLC

Pepsin and amylase were used to digest the sample (1 g to 30 g, depending on the amount of vitamin B_{12}) in sodium acetate buffer at pH 4 while excess cyanide was present. After passing the filtered extract through an AIC carridge, it was cleaned with water and then eluted with methanol. The vitamin B_{12} was redissolved in 0.5–1 mL of extraction buffer for HPLC after the methanol was removed by evaporation.

Vitamin B_1 determination

Pepsin and amylase were used to digest the sample (1 g to 30 g, depending on the amount of vitamin B_1) in sodium acetate buffer at pH 4 while excess cyanide was present. After filtering, the extract is run through an AIC cartridge that has been cleaned with water and then eluted with methanol. The vitamin B_1 was re-dissolved in 0.5–1 mL of extraction buffer for HPLC after the methanol was eliminated by evaporation.

Anti-Nutrient

Standard chemical techniques were used to categorise the presence of anti-nutritional substances such as tannins and phytates:

Phytates

Determined using a spectrophotometric technique with ferric chloride. Potassium permanganate titration were used to measure tannins.

Data Analysis

Data were presented as mean ± standard deviation (S.D) of three (3) experiments were subjected to one-way analysis of variance and Turkey's post hoc test. The data was considered statistically significant at $p < 0.05$ using Statistical Package for Social Sciences, version 21.0 (SPSS Inc., Chicago, IL, USA) to determine differences between means.

RESULTS AND DISCUSSION

Sensory Evaluation

The sensory aspects of food are crucial because, regardless of how nutritious it may be, no one will eat something that doesn't taste, smell, or look good. The sensory qualities of complementary foods are just as significant as their energy densities (Larvae *et al*., 2018). The majority of the women engaged had low reading levels, making sensory evaluation challenging. The 20 panellists' assessments of colour, flavour, taste, and consistency led to the following findings, which are displayed in Table 2 below. Based on their general acceptability, the results showed that, in order of merit, the most likeable formulas were 2, 8, 1, 3, 7, 5, 4, 6, 9, and 10. This suggests that formula 10 was the least accepted and formula 2 was the most accepted. Their supplemental diet, which was made from fermented maize, wheat, soybeans, and fishmeal, had an 87% acceptability rating (Amankwah *et al.*, 2011). Out of the ten formulae, phosphatine, the control, had the highest acceptance overall since it scored the highest in all four metrics. Out of the ten formulations, formula 2 had the best colour, followed by formula 1, while formulas 9 and 10 had the poorest. Formulas 9 and 10 were tied for the worst tastes, with Formula 2 having the best. Formula 2 had the best flavour, followed by formula 1, while formula 10 had the worst. Formula 10 had the weakest consistency, whereas formulas 2, 3, and 8 were tied for the best. There was no pineapple juice in the least acceptable formulae (6, 9, and 10). Therefore, it may be concluded that the pineapple juice employed in this formulation improved the formulae' flavour, texture, or taste, all of which contributed to their increased general acceptability.

Table 2. Mean and standard deviations of sensory scores of porridges made from the formulated diets and a commercial complementary food (Phosphatine)

Food Formulas	Mean Colour	Mean Taste	Mean Flavour	Mean Consistency	Overall Acceptability	Rank
F1	7.50±1.2	7.00±1.2	7.25±1.9	6.90±1.5	7.16±0.2	3rd
F2	7.80±1.0	7.35±0.9	7.70±0.6	7.30±0.7	7.46±0.4	1st
F3	7.00±1.3	7.00±1.2	6.70±2.5	7.25±0.6	6.99±0.2	4th
F4	6.00±1.3	6.40±1.2	6.70±2.0	6.65±1.1	6.44±0.3	7th
F5	6.85±2.1	7.15±1.1	6.60±1.6	6.50±1.6	6.78±0.3	6th
F6	6.60±1.0	6.40±0.9	6.50±1.7	6.65±1.3	6.54±0.1	8th
F7	7.05±1.1	7.00±0.6	6.70±2.0	7.10±1.0	6.96±0.2	5th
F8	7.50±1.4	7.15±2.3	7.25±1.2	7.25±1.3	7.29±0.1	2nd
F9	6.4±2.4	6.30±2.1	6.25±1.8	6.65±1.8	6.40±0.2	9th
F10	6.15±1.8	6.30±2.0	5.50±2.6	6.50±1.4	6.11±0.4	10th
11(Phosphatine)	8.36±1.3	8.10±0.6	7.65±0.8	7.38±1.0	7.81±1.6	

The proximate makeup of the formulations is summarised in Table 3 below. Four of the five formulations had moisture contents that exceeded the WHO's recommended maximum of 5% for supplemental foods. The exception was Formula 3, which had a moisture content of 4.6%. The moisture content was 6.4% in formula 7, 7.6% in formula 1, 5.50% in formula 2, and 9.5% in formula 8. However, there was no statistically significant difference ($P > 0.05$) between the reference value and the formulas' moisture contents. The most popular formula 2 was slightly suitable for long-term preservation since its moisture level of 5.50% was little higher than the advised 5%. This suggests that formula 8 would readily encourage the growth of bacteria, resulting in a reduced shelf life, while formula 3 would have the longest shelf life. These results are consistent with those of Laryea et al., who found that a supplementary diet produced from sweet potatoes and soybeans had a moisture content of 4.8% (Onabanjo *et al*., 2017). This is comparable to formula 8's moisture content of 9.5%, which was primarily derived from sweet potatoes and wheat (Table 3). It's possible that the majority of the moisture in formula 8 comes from wheat because the formula prepared with sweet potatoes had the lowest moisture content while the formula made with sweet potatoes and wheat had the lowest. This is supported by formula 2 which has the second-lowest moisture content (5.50%) after formula 3 and whose primary starch is wheat.

Although the difference was not statistically significant ($P>0.05$) for all five formulations, three of them had ash contents that were greater than the suggested value of 2.9. The only two formulas whose ash contents were within the reference range were formulas 1 and 8, which had the lowest ash contents (2.65%). Three had an ash content of 3.10% and seven had 2.95%. Table 3 shows that formula 2 had the greatest ash content at 3.50%. Formulas 1 and 8 were consequently the best in terms of ash content. The designed supplemental foods could be utilised to combat micronutrient deficiencies in children because the presence of ash in the formulae indicates the presence of minerals. For supplemental foods, the WHO recommends an ash content of 2.9g per 100g of food sample; all five formulae have ash contents within this range, while some are significantly higher, such as formula 2 (the most popular formula), which had an ash content of up to 3.5%. While Tiencheu et al. reported higher ash contents (4.32%–4.85%) for their own formulations made from egg whites, fermented maize, pawpaw, and beans, Mahmoud et al. discovered an ash content of 2.91% for their complementary food formulated from rice, sweet potatoes, faba beans, and peanut oil (Tiencheu *et al*., 2016). Complementary foods made from yellow maize, soybeans, guinea corn, millet, groundnuts, carrots and crayfish similarly had higher ash concentrations (5.21–7.52%) (Akinola *et al*., 2014). All of the formulations had more fibre than the suggested amount of 3.8% for supplemental foods.

Nevertheless, none of the formulations' fibre content differed significantly (P>0.05) from the reference value. Formula 8 had the highest fibre content (8.31%), followed by formula 2 (6.41%), formula 3 (6.19%), and formulas 1 and 7 (6.23% and 6.43%, respectively) with the lowest fibre contents (Table 3). The amount of undigestible carbohydrates in a sample is determined by its fibre content.

All of the formulations had more fibre than the suggested amount of 3.8% for supplemental foods. Nevertheless, none of the formulations' fibre content differed significantly (P>0.05) from the reference value. Formula 8 had the highest fibre content (8.27%), followed by formula 2 (6.41%), formula 3 (6.19%), and formulas 1 and 7 (5.60% and 5.21%, respectively) with the lowest fibre contents (Table 3). The samples had a very high fibre content—much more than the WHO's recommended 3.8%. In order to allow the baby to eat as often as necessary without worrying about feeling overly full due to sluggish digestion caused by an excessive amount of fibre in the food, complementary foods should be low in fibre. The results of this investigation were in contrast to those of Shewangzaw et al., who had lower fibre concentrations in the range of 2.75 to 4.52 in their supplemental food formulations derived from a mixture of soybeans, teff, white maize, and honey bee larvae (Shewangzaw *et al*., 2021). Since overnutrition is still a type of malnutrition and excessive levels of any of these nutrients could be harmful, the high fibre content of all five formulas makes them less suitable for a supplemental food diet required for newborns. According to Mahmoud et al., the protein content of rice and sweet potato flours was 7.48% and 4.94%, respectively, suggesting that rice contains more crude proteins than sweet potatoes. Given that the rice-based formula had more protein than the sweet potato-based formula, this makes sense. The mix with maize as the primary starch source had the second-highest protein content, after the one with wheat, due to the germination and malting of the maize utilised in this study. In their complementary food made from beans (Phaseolus vulgaris), sorghum (Sorghum bicolour), and carrots (*Daucus carota*), Tadesse and Gutema had lower protein contents, ranging from 8.34 to 12.56%. In terms of protein contents, all samples had extremely high protein contents, exceeding the WHO-recommended standard value of 15% for complementary foods. However, for four of the five formulas, the difference between the formulas and the standard value was negligible (P>0.05).

The only formula that demonstrated a significant difference (P<0.05) between its protein content and the reference value was formula 2, which had a protein content of 35.46%. Formula 3 had the lowest protein amount (15.72%), whereas formula 8 had the highest protein level (16.11%) (Table 3). Given the high prevalence of protein energy deficiency in Africa, the five recipes' high protein content may be seen as a benefit. Even though newborns require a high-protein diet, overnutrition is still a form of malnutrition, and excessive doses of any of these nutrients may be hazardous. According to Mahmoud et al., the protein content of rice and sweet potato flours was 7.48% and 4.94%, respectively, suggesting that rice contains more crude proteins than sweet potatoes. Given that the rice-based formula had more protein than the sweet potato-based formula, this makes sense. The mix with maize as the primary starch source had the second-highest protein content, after the one with rice, thanks to the germination and malting of the maize utilised in this study. Tadesse and Gutema's supplemental diet, which was made from beans (*Phaseolus vulgaris*), sorghum (*Sorghum bicolour*), and carrots (*Daucus carota*), had lower protein amounts than WHO guidelines, ranging from 8.34 to 12.56% (Tadesse and Gutema, 2020).

The results obtained from the analysis of the fat content of the formulas showed them having fat contents in the range of 10.20% - 15.10%, all of which are above the reference value of 8%. The only formula which showed a statistically significant difference (P<0.05) between its fat content and the standard value was formula 7, with the highest value 15.10%. 1 and 3 had fat contents of 12.15% and 12.11%, respectively, whereas 2 had a fat percentage of 12.5%. The lowest fat content was recorded in 8 (10.20%), though this was still higher than the reference (Table 3). rice, soybeans, Irish potatoes, and carrots (Aduni *et al*., 2016). Using sweet potatoes, mung beans, soybeans, and wheat in their formulation, Jahan et al. found comparable fat content results in the range of 9.29 to 11.40% (Jahan *et al*., 2021).

The carbohydrate contents were all lower than the standard value of 64.68%, with the least carbohydrate content obtained from formula 3 (29.16%), and the highest content from 2 (64.51%). Seven has a carbohydrate content of 60.53%, compared to 8's 47.24%. The lowest values were 29.14% for 3 and 47.74% for 7 (Table 3). There was no statistically significant difference (P>0.05) between formulas 1, 2, and 7, the standard mean when these values were compared to the reference value; but, formula 3, with its extremely low carbohydrate content, was statistically different from the reference value at $p < 0.05$. Anigo et al.'s formula, which combined soybeans, groundnuts, guinea corn, sorghum, corn, and millet in varying ratios, produced inconsistent results regarding the amount of carbohydrates. According to Anigo et al. (2010), their mixes' carbohydrate levels ranged from 88.75% to 90.89%. With the exception of formula 3, which had a notably low carbohydrate content, the other four mixes had adequate but subpar carbohydrate levels; this, along with a blend of sufficient protein content, makes the novel formulae appropriate for supplementary feeding. Even though the most favoured formula was 2, it has significant carbohydrate content, which makes it a perfect supplemental food for a developing infant.

Table 3. Proximate analysis of the formulated complementary foods

Samples	Moisture Content %)	Ash Content (%)	Fibre Content (%)	Protein Content (%)	Fat Content (%)	Carbohydrate. Content (%)
WHO standard	**5**	**2.9**	**3.8**	**15**	**8**	**64.68**
Formula 1	6.6±0.80[a]	2.65±0.15[a]	5.60±1.43[a]	25.82±3.07[a]	12.15±0.67[a]	61.14±2.92[a]
Formula 2	5.50±0.15[a]	3.50±0.30[a]	6.41 ±0.52[a]	35.41±9.54[b]	12.50±1.59[a]	64.51±8.49[b]
Formula 3	4.60±0.70[a]	3.10±0.00[a]	6.19±0.45[a]	15.72±0.66[a]	12.11±2.28[a]	29.16±2.04[a]
Formula 7	6.4±0.20[a]	2.95±0.05[a]	5.21±1.07[a]	20.13±0.44[a]	15.10±3.13[b]	60.48±0.29[a]
Formula 8	9.5±0.00[b]	2.65±0.05[a]	8.31±0.21[a]	16.11±1.05[a]	10.20±1.30[a]	43.24±1.50[a]

The superscripts a = statistical significance at $p < 0.05$ and b = significance at $p < 0.01$ compare to WHO reference value

Analysis of micronutrients

The vitamins and vitamin analyses of the five samples, pap, and the WHO standard values for each of these micronutrients are summarised in Table 4.

For the vitamin analysis three vitamins were tested; A, B and C, with A representing the fat soluble vitamins and B and C representing the water soluble vitamins. International units (IU) were used to assess and record the vitamin A content of each of the five formulations. The examination of vitamin A content in the five formulations showed an excellent vitamin A concentration in all five samples. The only formula whose vitamin A concentration was below the required value of 300IU was 1, with a vitamin A level of 204.97IU. The other four formulas had values above 1000IU. The sample with maximum vitamin A concentration was formula 2, with a value of 1309.77IU, followed by formula 3 with 1134.21IU, then formula 7 with 1110.88IU, and then formula 8 1109.22IU. Comparing these values obtained for vitamin A with the standard value found no statistically significant difference ($P>0.05$) between sample A and the standard value, but all the other formulas exhibited statistically difference ($P<0.01$) with the standard. The presence of vitamin A in sufficient proportions in the food is quite significant, as this might go a long way in aiding in the fight against micronutrient deficiencies in Nigerian children. The formula which was made up of wheat and sweet potatoes 2 was highest in vitamin A content, followed by the formula which just included sweet potato as main starch source 3, and this is understandable, as among all the starch sources employed, sweet potatoes have been discovered to have the greatest vitamin A content. Similar results were observed for vitamin A content, for complementary food mixes which were sweet potato based (Wang *et al.*, 1989). They contained vitamin A content in the range 500 – 1766 IU, appropriate values of vitamin A for any complementary food. The range of values found for vitamin A content for the five novel formulas make them good choices for complementary foods, with the exception of formula A whose vitamin A content was much lower than the required value of vitamin A for complementary foods.

Micrograms (mcg) were used to assess the vitamin B_{12} concentration of the five formulations. All four samples—aside from sample 3—had excellent vitamin B_{12} contents, according to the study of the five formulations. With a vitamin B_{12} amount of 0.01 mcg, formula 3 was the only one whose vitamin B_{12} content fell short of the suggested level of 2.8 mcg. The values of the other four formulas were more than 1.79 mcg, which is below the WHO standard threshold. Formula 1 has the highest vitamin B_{12} concentration (1.96 mcg), followed by formula 2 (1.8 mcg), formula 7 (0.57 mcg), and formula (8) (0.48 mcg). There was no statistically significant difference (P>0.05) between sample A and the standard value when these vitamin B_{12} values were compared to the standard; nevertheless, all other formulas had statistically significant differences (P<0.01) with the standard. DNA synthesis, proper red blood cell production, and the development, myelination, and operation of the central nervous system all depend on vitamin B_{12} (Stabler, 2020).

Two of the five formulae had positive results from the vitamin C content. Since there was no amount of DCP within the range that could make any of the three formulae colourless, none of them demonstrated any positive results for the presence of vitamin C. Three (1, 3, and 7) of the five recipes had very little or no vitamin C, according to the data. The vitamin was either completely absent or present in insufficient amounts to turn DCP from pink to colourless. This is detrimental, particularly for a developing child who needs all the nutrients in the right amounts for healthy growth and development. This suggests that in order to balance the RDA for vitamin C, the complementary food either has to be fortified with vitamin C or the child consumes it with another supplemental food that is high in vitamin C. According to Bassey et al. (2013), their supplemental food mix made from groundnuts, cowpeas, and cooked bananas had a vitamin C level of 1.54 mg/100g. This figure is comparable to the one found in this study since 1.54 mg/100g is closer to zero than the WHO-recommended standard value of 15 mg/100g.

The calcium content of the formulas exceeded the reference value (341.2 mg/100 g) according to the mineral analysis of the samples. With the exception of formula 2, whose difference with the reference value was statistically significant at P<0.05, this difference was not statistically significant (P>0.05). Among the five formulas, formula 2, which used wheat as its primary starch source, had the highest calcium content (507 mg/100g), followed by formula 3 (361 mg/100g), formulas 7 and 8 (344 mg/100g, 342 mg/100g), and formula 1 (342.0 mg/100g), which had the lowest calcium content. Since calcium is crucial for the development of an infant's brain and bones, it is crucial that the new formulas have an adequate calcium concentration. Plahar (2018) discovered reduced calcium concentration in comparable sweet potato-based formulations without groundnuts, but equivalent results for his formulae using groundnuts. He found that the calcium content of the older formulations was 256.57 mg/100g and 357.89 mg/100g, whereas the calcium content of the latter recipes was 100.73 and 91.96 mg/100g. Ajiwe and Nwaigbo (2014) found that varied ratios of yellow maize, millet, red sorghum, wheat, brown spotted African yam bean, bambara groundnut, pigeon pea, and soybeans had diverse results. The calcium levels of the ten mixes ranged from 42.19 to 140.76 mg/100g; the blend combining wheat, millet, and pigeon pea had the lowest value, while the blend containing millet, pigeon pea, and African yam bean had the greatest calcium amount.

With the exception of formula 3, which had an iron level of 8.54 mg/100g and 8.51 mg/100g with sweet potatoes and wheat as the primary starch source, the iron content of the formulas was often lower than the reference value of 8.5 mg/100 g. However, there was no statistically significant variation in iron content between the reference value and all five formulations (P>0.05). The iron level ranged from 3.73 mg/100g (formula 8) to 8.59 mg/100g (formula 3), with 7 coming in below 2 with an iron concentration of 8.51 mg/100g, followed by 7 with 4.78 mg/100g, and 1 with maize as the primary ingredient with 4.22 mg/100g. Since fermentation has been demonstrated to increase the bioavailability of certain micronutrients that are typically coupled to phytates in the unfermented grains, this could be explained by the fermentation process carried out on the maize. Similar outcomes were observed by Satter et al. (2014) with their complementary diet, which was made from wheat, soybeans, sugar, mango, skim milk, and jack fruit. Their iron level readings ranged from 7.56 to 8.22 mg/100g. Ikujenlola and Adurotoye (2014) found that their supplemental diet made from steamed cowpea and high-protein maize had significantly higher iron content values.

The study of zinc concentration found that all five samples were lower than the acceptable limit of 3.7mg/100g specified by WHO. The five samples had zinc contents ranging from 2.0 mg/100g to 2.71 mg/100g. For two of the five samples (3 and 7), the difference between the standard value and the values derived from the samples was statistically significant (P<0.05); however, it was not statistically significant for the other three formulas (1, 2, and 8). Out of the five formulations, formula 2 had the highest zinc content (2.71 mg/100g), followed by formula 1 (2.47 mg/100g). Formulas 3 and 7 had the lowest zinc concentrations, at 2.00 and 2.08 mg/100 g, respectively, while formula 8 came in second with a zinc value of 2.37 mg/100 g. While Asouzu and Nkemjika had comparable results, ranging from 1.52 to 2.61 mg/100g in their complementary food formulated with maize and supplemented crayfish and carrot flour (Asouzu and Nkemjika, 2002), Gemede had slightly higher values, in the range of 2.73 to 3.00 mg/100g for the zinc content of his complementary food formulated from maize, pea, and anchote flours (Gemede, 2019).

Table 4. Vitamins and mineral analysis of the formulated complementary foods

Samples	WHO standard	Formula 1	Formula 2	Formula 3	Formula 7	Formula 8
Vit. A (IU)	300	204.97±9.63[a]	1309.77±32.43[c]	1134.21±50.46[c]	1110.88±66.65[c]	1109.22±45.6[c]
Vit. B_{12} (mcg)	2.8	1.96±0.21[a]	1.8±0.21[a]	0.01±0.00[a]	0.57±0.11[a]	0.48±0.01[a]
Vit. C (mg/100g)	15	0.00±0.00[c]	17.13±0.21[a]	0.00±0.00[c]	0.00±0.00[c]	6.25±0.45[b]
Ca (mg/100g)	341.2	378.0±14.0[a]	507.0±37.51[b]	361.71±19.0[a]	344.67±46.0[a]	342.0±34.0[a]
Fe (mg/100g)	8.5	4.22±0.21[b]	8.51±0.78[a]	8.54±1.0[a]	4.78±0.8	3.73±0.21[a]
Zn (mg/100g)	3.7	2.35±0.63[a]	2.75±0.25[a]	2.00±0.02[b]	2.08±0.18[b]	2.37±0.52 [a]

The superscripts a = statistical significance at $p < 0.05$, b = significance at $p < 0.01$ and c = significance at $P < 0.001$,

CONCLUSION AND RECOMMENDATION

The prepared complementary foods offers the vital nutrients needed for a baby's growth, but it has to be improved, especially in the areas of iron, zinc, vitamin B_{12}, and C. Comparisons with earlier research point to areas that require improvement, such as enhanced mineral content to suit baby nutritional demands, B_{12} enhancement, and fortification with high-iron compounds. Additionally, the study demonstrates that complementary foods with adequate nutritional profiles can be created using locally sourced components, making them a more affordable option than commercial ones. Therefore, based on these findings complementary foods produced are a rich source of macro and micro nutrients, and need to be exploited more as a source of food for feeding of infants and young children.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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