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Functional and Rheological Evaluation of Complementary Food Based on Soybeans, Finger Millet, Sorghum, and Irish Potato Flour Blends

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Abstract

Protein Energy Malnutrition is prevalent, particularly among children who switch abruptly to starchy diets. Many families in Nigeria cannot afford the steep costs of cow's milk and artificial supplements, leading to a demand for an alternative energy source derived from locally sourced cereals, legumes, and tubers. For this purpose, three kilograms (3 kg) each of finger millet, sorghum, Irish potatoes, and soybeans were acquired to formulate a complementary diet and analyse its rheological, functional, and proximate compositions. The following ratios were blended to produce flour, coded as samples A (70: 10: 10: 10), B (60: 15: 15: 10), C (50: 20: 20: 10), and D (40: 25: 25: 10). The control sample used was a commercial diet known as Nestlé Cerelac. Comparative results were evaluated against Codex standards after conducting proximate, functional, and rheological tests on both the prepared food samples and the control (Cerelac). Among the samples, Sample A exhibited the highest protein content (11.33%) and fat percentage (11.57%). Sample B demonstrated the highest levels of ash (3.42%), fibre (1.62%), and energy (398.89 kcal). The highest carbohydrate percentage (73. 04%) was found in Sample D. All samples displayed good swelling capacity (ranging from 3. 40 to 3. 87 g/ml), bulk density (between 0. 83 and 0. 99 g/ml), and water absorption capacity (from 2. 01 to 2. 2.59 g/ml). The formulated samples showed the following pasting properties: breakdown value of 20.25 - 43. 45 RVU, peak viscosity of 49. 80 - 258. 10 RVU, trough viscosity of 8.30 - 135.47 RVU, and pasting temperature between 69. 33 and 88.43 ° C. When compared to the commercial diet (Nestlé Cerelac), the meal samples from this study indicated advantages in terms of ash, fibre, fat, and carbohydrate content. They also possess significant potential owing to their exceptional pasting and practical attributes. By combining locally available grains, legumes, and tubers, it is possible to create supplementary foods that can substitute for costly commercial products, thereby enhancing the nutritional status of infants and developing children.

Keywords: Finger Millet, Cerelac, Feed, Proximate, Rheological, Soybeans.

INTRODUCTION

Adequate nutrition is essential for healthy growth and brain development of children, particularly within the first 5 years of life, for them to attain full potential (WHO, 2023). A complementary food is a food, either liquid or solid, that is provided to infants and young children (6–24 months) in addition to breast milk (WHO, 2023). As children get older, breast milk's ability to provide essential nutrients diminishes. Gruel, or traditional supplementary foods in Nigeria, are primarily porridges made from single cereals that lack lysine and other vital minerals (Adepeju et al., 2022). There are situations where the gruel is overly bulky or too watery, which lowers the infant's rate of ingestion (Taha, 2020). In addition to causing illness and mortality, improper nutrition during the supplementary feeding phase also delays mental and motor development (Hayashi et al., 2020).

Rheology is the study of changes in the form and flow of viscosity, elasticity, and plasticity. When a force is applied to a food material, rheology focuses on the flow and deformation of the matter, with viscosity representing a subfield that specifically examines these processes (Okwunodulu, 2015).

Originally from eastern Asia, soybeans, often known as soya beans (Glycine max), are a species of legume. According to Mmari (2017), it is a significant source of affordable, high-quality protein and oil, with an average protein content of 40% and oil content of 20%. In addition to being a good source of all the essential amino acids, soybeans are high in calcium, iron, phosphorus, lysine, and vitamins (Ayele, 2022). About 3% of it contains lecithins, which are beneficial for brain development, particularly in young children (Kim, 2021).

A staple grain in both Africa and Asia, sorghum (*Sorghum bicolor*) is used in a variety of dishes, including baked products, couscous, and porridges (Violet, 2020). According to reports, sorghum is the fifth most consumed grain globally, behind rice, wheat, maize, and barley. Jood and Khetarpaul (2012) describe sorghum as a gluten-free cereal that is low in lysine and tryptophan but high in phenolic compounds (phenolic acids, flavonoids, and tannins), B vitamins, phytonutrients, fibre, and many minerals, including manganese, magnesium, iron, copper, phosphorous, potassium, and calcium.

The millet group includes finger millet (*Eleusine coracana* L.), which is often referred to as ragi or tamba (Ramashia, 2019). Because it can be stored safely for several years without being infested by insects or other pests, finger millet is considered a poor man's crop. High levels of calcium, phosphorus, and iron found in finger millet are vital for developing youngsters, expectant mothers, and the elderly because they fortify bones and guard against anaemia (Ramashia, 2019). Additionally, finger millet is high in important fatty acids, vitamin A, and B-complex vitamins.

The tuberous crop known as Irish potatoes (*Solanum tuberosum* L.) is cultivated worldwide. According to Gabriela Burgos (2020), Irish potato tubers are rich in water-soluble vitamins like C, B1, B2, and B3, as well as vital minerals like potassium, iron, phosphorus, and a reasonable quantity of calcium (Akyol, 2016). They also contain dietary fibre, carbohydrates, protein, lipids, and phytochemicals like flavonoids and polyphenols (Umme Salma, 2020).

Therefore, the purpose of this study was to develop and assess the proximate, functional, and rheological content of inexpensive, locally accessible complementary foods made from a combination of tuber (Irish potatoes), legume (soybeans), and cereals (sorghum, finger millet).

MATERIALS AND METHODS

Source of raw Materials

The sorghum (*Sorghum bicolor*), Irish potatoes (*Solanum tuberosum*), finger millet (*Eleusine coracana*), and soybean (*Glycine max*) were purchased from Rimi Market in Kano state, Nigeria. Additionally, a Nestle commercial diet, Cerelac, was purchased from the same place.

Sample preparation

A modified version of the Bello and Gernah (2020) method was used to manufacture soybean flour. Three kilograms of soybean seeds were sifted for grit, stones, and other physical defects. The beans were cooked for 25 minutes at 60 °C. The hulls were manually removed, and the beans were cleaned. Following a 10-hour oven drying process at 50°C, the beans were crushed into flour using an attrition mill, packed, and stored.

The process of making Irish potato flour was done using Gabriela Burgos and Thomas's (2020) methodology. Irish potatoes weighing three kilograms were peeled and cut into smaller pieces. After being cleaned and blanched for three minutes at 80°C and oven-dried for twelve hours at 50°C, the sliced Irish potatoes were ground into flour using an attrition mill, then they were packaged and kept in storage.

According to Musa and Aminu (2022) methodology, finger millet flour was harvested. Finger millet grains weighing three kilograms (3 kg) were cleansed, cleaned, and oven-dried (at 50 °C for ten hours). They were then ground into flour using an attrition mill, packaged, and kept for further examination.

The modified method of Violet (2020) was used to produce sorghum flour. Three kilograms (3 kg) of sorghum grains were washed after being cleaned of sand, broken grains, and other foreign objects. The cleaned grains were ground into flour using an attrition mill after being oven dried for ten hours at 50°C. For further examination, the Sample was kept at room temperature after being wrapped in a polyethylene bag.

Formulation of Complementary Food

Blends of finger millet, soybeans, and Irish potatoes in the following ratios were created using the flour samples: 70:10:10:10, 60:15:15:10, 50:20:20:10, and 40:25:25:10.

Sample	Soy Beans	Sorghum	Finger Millet	Iris Potatoes	Total
A	70	10	10	10	100
B	60	15	15	10	100
C	50	20	20	10	100
D	40	25	25	10	100

Determination of proximate composition

The AOAC (2015) publication's analytical method was used to test the supplemental foods' moisture, protein, fat, ash, and crude fibre content. The total amount of carbohydrates was calculated by subtracting the percentages of fat, moisture, ash, crude fibre, and protein content from 100.

Determination of Moisture

The Association of Official Analytical Chemists' approach (AOAC 2015) was used to determine the samples' and the control's approximate composition. Five (5) grams of the samples were placed in dry crucibles that had been previously weighed and cooked for three hours at 105 °C in a hot air oven (Gellenkamp, UK). After three consecutive weight measurements, the dried samples were cooled and weighed every 30 minutes until there was no change in weight. Weighing was done using an electronic balance (NBY323/64: Avery East Africa). The dried samples' ultimate weight was recorded, and the moisture content was computed as follows:

$\% MC = ((W1) - (W2))/(W3) \times 100/1$

Determination of Crude Protein:

Five-gram samples were weighed, digested in strong sulfuric acid using a single Kjeldahl tablet, neutralised with 40% sodium hydroxide, and then distilled. 0.1N hydrochloric acid was used to titrate the resultant solution using a mixed indicator (methyl red and bromocresol green). Using the following formula, the percentage nitrogen (N) concentration was determined:

$\%\ nitrogen = (S - B) \times N \times 0.014 \times D \times 100/W \times V$

Where:

D = dilution factor,

T = titre value = (S-B),

W = weight of Sample,

0.014 = constant value.

Crude protein was obtained by multiplying the corresponding total nitrogen (N) content by a conventional factor of 6.25

Determination of Crude Fat

Five (5) grams of dried samples were weighed into a preconditioned and weighed (W0) extraction thimble and placed in the Soxhlet extraction apparatus (AOAC 2015). The fat content of the samples was extracted using organic solvent (petroleum ether) and boiled under reflux for 6 hrs. The extraction thimbles were then removed and dried in an oven at 105°C for 30 minutes, then cooled and weighed. The percentage of fat content was calculated using the formula:

Crude fat (%) = (weight of fat in sample)/(Weight of dry sample) × 100/1

Determination of Total Ash

Five (5) grams of the samples were weighed into dry crucibles, carbonised on a hot plate and heated on a muffle furnace at 600 ^{0}C for 8 hours, after which it was cooled in a dessicator and weighed. The formula for the calculation of ash content is given below.

% ash content = (weight of incinerated sample)/(weight of fresh sample)× 100/1

Determination of carbohydrate content

The total carbohydrate content was estimated by the difference method, as described by AOAC (2015), according to the following equation:

Carbohydrate (g/100g) = 100 - (Protein (g) + Fat (g) + Ash (g) + Fibre (g))

Determination of Energy Content

Total Energy value was determined by calculation from fat, carbohydrate and protein contents using Atwater’s conversion factors AOAC (2015).

Determination of functional properties of the blends

Determination of bulk density

The procedure described by Haq and Muhammad (2015) was used to determine the bulk density (loose and packed bulk density) of the blends. One gram (1) of the blend was taken into a pre-weighed ($W1$) measuring cylinder, and the weight of the cylinder ($W2$) as well as the volume of the flour ($V1$) were noted. Loose bulk density (LBD) was calculated as g/cc using:

$$\text{LBD}\left(\frac{g}{cc}\right) = \frac{\text{W2}-\text{W1}}{\text{V1}} \quad \text{IV}$$

Water absorption capacity (WAC)

Water absorption was determined according to the method described by Adeniran et al. (2022). Ten (10) millilitres of distilled water were added to 1 g of the Sample in a beaker. The suspension was agitated using a magnetic stirrer for 3 min. The suspension obtained was thereafter centrifuged at 2,058 × g for 30 min, and the supernatant was measured into a 10 ml graduated cylinder. The absorbed water by the flour was considered as the change between the initial volume of the water and the volume of the supernatant. The water density was taken as 1.0 g/ml.

$$WAC = sample/volume \ x \ \frac{100}{1} \quad \text{V}$$

Swelling capacity

Swelling capacity was determined according to the method of Adeniran et al. (2022). Ten (10) grams of the Sample were measured into a 100 ml graduated cylinder at room temperature; distilled water was added to give a total volume of 50 ml. The graduating cylinder was tightly covered at the top and mixed by inverting the cylinder repeatedly for 2 min, left to stand for another 8 min, and the volume was recorded per gram of its original dry weight.

$$\text{Swelling capacity (SC)} = \frac{\text{weight of wet Sample}}{\text{weight of dry Sample}} \times \frac{100}{1} \quad \text{VI}$$

Rheological properties determination

Gruels prepared from the complementary food samples were subjected to rheological studies by measurement of their viscosity using a viscometer. This was done at different share rates (5, 10, 20, 50, and 100 rpm) using spindles as described in the method used by Okoronkwo (2023) with slight modifications. The relationship between viscosity and shear rates of gruel samples obtained from the complementary food formulations was investigated using the Power law model described by Ndombow (2024).

Statistical analysis

Each determination was conducted in three replicates, and results were reported as an average value (mean ± standard deviation). Data were analysed using an Analysis of Variance (ANOVA) model with SPSS Version 20. Fisher's Least Significant Difference (LSD) was applied for multiple mean comparison tests. Statistical significance was set at $p<0.05$.

RESULTS

Table 1 shows significant differences in proximate composition between the formulated diets and the commercial diet (Cerelac) ($p<$ 0.05). Moisture content varied from 5.29% to 6.48%, with Sample C having the highest value at 6.48%, significantly different from Sample A at 5. 29%, and both Sample B and Sample D did not differ significantly at (5.37%). The commercial diet (Cerelac) displayed the lowest moisture value of 5.29%.

The total ash content in the food samples ranged from 1.79% to 3.42%. The commercial diet (Cerelac) had the lowest total ash content at 1.79% compared to the formulated complementary food samples: Sample A, C, and D, showing 3.30%, 2.92%, and 2.62%, respectively. Sample B exhibited the highest ash content at 3. 42%.

The commercial diet (Cerelac) had the highest protein content at 14.52%, which was significantly different ($p<$ 0.05) from Sample B at 11.10.63%, Sample C at 10.63%, and Sample D with the lowest protein at 9. 96%. Sample A recorded a protein content of 11. 33%.

The fat content among the food samples ranged from 8.03% to 11.57%. Sample D had the lowest fat content at 8. 03% when contrasted with the formulated food samples B, C, and the commercial control (Cerelac), which had fat contents of 10.43%, 9.33%, and 10.01%, respectively. Sample A had the highest fat value at 11. 57% and differed significantly ($p < 0.05$). Crude fibre content in the food samples varied from 1.06% to 1.62%. Sample B exhibited the highest fibre content at 1.62% when compared with Samples A, C, and the commercial control

(Cerelac), which showed values of 1.52%, 1.43%, and 10.01%, respectively. Sample D had the lowest crude fibre content at 1.06%, differing significantly (p< 0.05).

Carbohydrate content among the food samples ranged from 66.94% to 79.24%. Sample D had the highest carbohydrate value of 79.24%, which significantly differed (p< 0.05) from Samples A, B, and C with values of 75.14%, 77.62%, and 75. 69%. In contrast, the commercial control (Cerelac) had the lowest carbohydrate value at 66.94%.

Energy values for the samples, as shown in Table 1, ranged from 379.42 kcal to 415.97 kcal, with the commercial diet (Cerelac) having the highest value, 415.97 kcal. Among the formulated samples, Sample B (398.89 kcal) had the highest energy value, with the least energy value, 379.42 kcal, recorded for Sample A. Sample C and D (388.59 kcal and 385.59 kcal) had no significant difference (p = 0.05).

Table 1: Proximate composition of the formulated diets

Parameter	A	B	C	D	Cerelac	Codex	LSD
Moisture	5.32 ± 0.02[d]	5.37 ± 0.14[b]	6.48 ± 0.02[a]	5.37 ± 0.02[c]	5.29 ± 0.01[e]	< 5 %	0.007
Ash	3.02 ± 0.02[d]	3.42 ± 0.07[a]	2.92 ± 0.14[c]	2.62 ± 0.06[d]	1.79 ± 0.00[e]	< 5 %	0.138
Protein	12.33 ± 0.17[b]	11.19 ± 0.15[e]	10.63 ± 0.15[d]	9.96 ± 0.02[e]	14.52 ± 0.01[a]	> 15 %	0.229
Fat	11.57 ± 0.10[a]	10.43 ± 0.02[b]	9.33 ± 0.04[d]	8.03 ± 0.06[e]	10.01 ± 0.07[e]	≤ 15 %	0.123
Fiber	1.52 ± 0.01[b]	1.62 ± 0.01[a]	1.43 ± 0.02[c]	1.06 ± 0.06[d]	1.43 ± 0.02[c]	< 5 %	0.062
CHO	75.14 ± 0.14[c]	77.62 ± 0.19[b]	75.69 ± 0.05[c]	79.24 ± 0.08[a]	66.94 ± 0.05[d]	≥ 65 %	0.218
Energy	379.42±0.35[e]	398.89 ± 0.40[b]	388.59 ± 0.67[c]	385.59 ± 0.27[d]	415.97 ± 0.45[a]	400–425	0.827

The values given in the table are the mean of replicates ± SD. Means with the same letter in a row are not significantly different (p<0.05).

Key: Sample A = (70:10:10:10), **Sample B** = (60:15:15:10), **Sample C** = (50:20:20:10), **Sample D** = (40:25:25:10), and **Control: A** commercial diet-Nestlé Cerelac made from a maize and wheat blend.

Table 2 displays the findings from the assessment of the functional characteristics of the prepared food samples and the control food sample (Cerecal). In comparison to food samples B and C, which had bulk density values of 0.95 and 0.96 g/ml, respectively, sample A and the control (cerelac) exhibited the lowest bulk density values (0.83 and 0.87 g/ml), while sample D had the highest bulk density value (0.99 g/ml), which was significantly (p<0.05) different from that of sample D. The water absorption capacity of the food samples ranged from 2.01 g/ml to 2.59 g/ml. Compared to the results from samples A, B, and the control (cerelac), which measured 2.10, 2.10, and 2.31 g/ml, respectively, sample C's water absorption capacity of 2.59 g/ml was substantially greater (p<0.05), while sample D's water absorption capacity was the lowest at 2.01 g/ml. Swelling capacity values ranged from 3.40 to 3.87 g/ml, with samples A and the control (Cerelac) exhibiting the highest values (3.87 and 3.85 g/ml), which did not differ significantly (p=0.05). Sample D had the lowest value (3.40 g/ml), while the recorded values for Samples B and C (3.62 g/ml and 3.60 g/ml) did not differ significantly (p=0.05).

Table 2: Functional characteristics of commercial control (Cerealac) and designed supplemental food samples

Samples	Bulk density	Water absorption capacity (g/ml)	Swelling capacity
A	0.87±0.012[c]	2.10±0.010[c]	3.87±0.01[a]
B	0.95±0.015[b]	2.10±0.000[c]	3.62±0.00[b]
C	0.96±0.012[a]	2.59±0.015[a]	3.60±0.01[b]
D	0.99±0.021[a]	2.01±0.015[d]	3.40±0.00[c]
Cerelac	0.83±0.012[c]	2.31±0.010[b]	3.85±0.01[a]
LSD	0.003	0.021	0.019

The values given in the table are the mean of replicates ± SD. Means with the same letter in a column are not significantly different (p<0.05).

Key: Sample A = (70:10:10:10), **Sample B** = (60:15:15:10), **Sample C** = (50:20:20:10), **Sample D** = (40:25:25:10), and **Control: A** commercial diet-Nestlé Cerelac made from a maize and wheat blend.

Table 3 shows the rheological properties of complementary Food developed from blends of soybeans, finger millet, Irish potatoes, and Sorghum with the commercial diet (Cerelac).

Peak viscosity, which indicates starch content, ranged from 49.80 to 258.10 RVU. The commercial diet (Cerelac) had the least value of 49.80 RVU, which was significantly different from samples B, C and D with values (200.02, 196.30, and 177.45), respectively, while sample A had the highest Peak viscosity value of 258.10 RVU.

Processing treatments also had a significant ($p \leq 0.05$) effect on trough viscosity, which ranged from 8.30 to 135.47 RVU. The commercial diet (Cerelac) had a significantly ($p \leq 0.05$) lower trough of 8.30 RVU than the formulated complementary samples of samples B, C, and D (127.03, 120.38, and 110.30) RVU, respectively. Sample A had the higher trough viscosity value of 135.47 RVU.

The breakdown value obtained from the formulated food samples and the commercial diet (Cerelac) ranged from 20.25 to 43.45 RVU. Sample A had a significantly ($p \leq 0.05$) higher breakdown of 43.45 RVU than other formulated food samples of B and C, 36.15 and 32.45 RVU, respectively. Sample D and the control diet (Cerelac) had the least breakdown values of 23.55 and 20.25 RVU, respectively.

The final viscosity results obtained from the formulated food samples and the commercial diet (Cerelac) ranged from 95.50 RVU to 245.50 RVU. Samples B and C, obtained with values (244.50 and 245.50) RVU, did not significantly differ ($p=0.05$) but were significantly ($p \leq 0.05$) higher than A and D (234.50 and 235.50), respectively. The control diet (Cerelac) had the lowest value of 95.50 RVU.

The setback viscosity results of the formulated food samples and the commercial control (Cerelac) were significantly different from each other ($p<0.05$), ranging from 5.50 RVU to 39.25 RVU. The highest value, 39.25 RVU, was observed in sample A, which significantly differed ($p<0.05$) when compared with other formulated food samples B, C, and D, with values of 31.41, 28.30, and 21.44 RVU, respectively. The control diet (Cerelac) had the lowest setback viscosity value of 5.50 RVU.

The peak time results obtained from the formulated food samples and the commercial diet (Cerelac) ranged from 1.00 min to 3.55 mins. The highest values (3.55 and 3.28 mins) were observed in samples A and B, which did not differ significantly ($p=0.05$) but were significantly higher ($p<0.05$) than samples C and D, with values of 2.88 and 2.33 mins, respectively. The control diet (Cerelac) had the least peak time value of 1.00 min.

Pasting temperature (°C) results of the formulated food samples and the control (Cerelac) were significantly ($p<0.05$) different from each other and ranged from 69.33 °C to 88.43 °C Sample A had the highest record value of 88.43 °C, which differed significantly ($p<0.05$) from the rest of the formulated food samples of B, C, and D (83.33, 78.43, and 78.50) °C, respectively and the control diet (Cerelac) had the least pasting temperature record of 69.33°C.

Table 3: Rheological properties of the Formulated Samples and Commercial Diet (Cerelac)

Parameter	A	B	C	D	Cerelac	LSD
Peak viscosity	258.10 ± 0.02^a	200.02 ± 0.31^b	196.30 ± 0.98^c	177.45 ± 1.20^d	49.80 ± 0.98^e	2.000
Trough viscosity	135.47 ± 1.31^a	127.03 ± 1.70^b	120.38 ± 0.00^c	110.30 ± 0.70^d	8.30 ± 1.70^e	0.045
Breakdown	43.45 ± 1.34^a	36.15 ± 1.34^b	32.45 ± 1.34^c	23.55 ± 1.34^d	20.25 ± 1.34^e	1.348
R.V.U	234.50 ± 1.14^b	244.50 ± 0.07^a	245.50 ± 0.00^a	235.50 ± 1.07^b	95.50 ± 0.01^c	2.109
Final viscosity	39.25 ± 0.01^a	31.41 ± 0.01^b	28.30 ± 0.14^c	21.44 ± 1.14^d	5.50 ± 1.14^e	0.037
Setback viscosity	3.55 ± 0.07^a	3.28 ± 0.04^a	2.88 ± 0.04^b	2.33 ± 0.00^b	1.00 ± 0.04^c	1.548
Peak Time (min)	88.43 ± 0.00^a	83.33 ± 1.01^b	78.43 ± 0.98^c	78.50 ± 1.14^c	69.33 ± 0.01^d	1.048

The values given in the table are the mean of replicate ± SD. Means with the same letter in a row are not significantly different ($p<0.05$).
Key: Sample A= (70:10:10:10), **Sample B**= (60:15:15:10), **Sample C**= (50:20:20:10), **Sample D**= (40:25:25:10) and **Control: A** commercial diet-Nestlé Cerelac made from maize and wheat blend, **RVU**=Rapid Viscosity Unit.

DISCUSSION

The moisture content of the samples ranged from 5.29% to 6.48%. These values were within the range of moisture values of (5.0 to 6.0%) reported by Ani and Alfa (2022), for complementary diets made from orange-fleshed sweet potato major component. The values slightly exceeded the moisture value of <5% set by Codex for complementary foods (CAC, 2024). The lower moisture content of the Sample A, B, and D samples is a desirable phenomenon, as it will enhance the quality of the samples since water for microbial activity is low.

The food samples had ash contents ranging from 1.79% to 3.42%. Comparable findings from other investigations with lower ash concentrations were reported by Olatunde (2020) at 1.50-2.50% and Marcel (2022) at 1.36%. These amounts, however, fall under the 5% ash level threshold that Codex recommends for prepared supplemental foods for babies and young children (Codex, 2024).

The food samples had protein contents ranging from 9.96% to 14.52%. The findings of this study are less than those of Adepeju and Adewa (2024), who created diets using locally sourced compositions and reported values ranging from 12.71 to 19.34%. The study's protein levels fell short of Codex and were below the 14.5% protein level in complementary foods that is advised by the commercial diet (Cerelac), which is less than 15%, as indicated in Table 1. The meal samples had fat contents ranging from 8.03% to 11.57%. Gemede (2020), who processed complementary diets from a variety of cereal crops and vegetable products, including maize, rice, soya beans, acha grains, benniseed, crayfish, carrot, bambara nut, and garden egg, reported values that were in line with the findings of this study (9.5%–24.8). Fats have a major role in Food's energy content and supply vital fatty acids for babies' and kids' healthy neurological, immunological, and functional development (USDA, 2019).

The crude fibre content of the food samples ranged from 1.06% to 1.62%. The results of this study were lower than the values (2.75% to 3.41%) reported by Gemede (2020), who processed complementary diets from maize, pea, and anchote flours. Complementary foods with low fibre content are very important, as they help ensure the safety of children, considering their appetite to consume more to feel satisfied and meet their daily energy requirements (Noah, 2017).

The carbohydrate content of the food samples ranged from 66.94% to 79.24%which was higher than the value obtained by Ijarotimi (2022) for complementary Food produced from orange-fleshed sweet potato, sorghum, full-fat milk, soycake/oil. All the formulated complementary foods in this study meet the carbohydrate content recommended by CODEX CAC/GL (2024) (≥65%).

Energy values for the samples, as shown in Table 1, ranged from 379.42 kcal to 415.97 kcal, with the commercial diet (cerelec) having the highest value, 415.97 kcal. These energy levels were greater than those of Ani and Alfa (2015), who created complementary foods using orange-fleshed sweet potatoes as a key ingredient. Their values were 254.711 kcal and 285.951 kcal. Since low-energy diets tend to limit overall energy intake and nutrient utilisation, it has been suggested that foods supplied to infants and children should be energy-dense (WHO, 2023).

The suitability of the diet, particularly for growing children, is significantly affected by the functional properties of food products (Oyeyinka, 2020). Factors such as production, transportation, storage, stability, texture, flavour, and taste of food products are all influenced by the functional characteristics of food ingredients. The type, variety, particle size, chemical composition, and processing methods of flour all directly or indirectly impact these features (Awoyale and Hakeem, 2020).

The bulk density readings of the food samples ranged from 0.83 to 0.99 g/ml. A lower loose bulk density would result in fewer food samples being packed in a constant volume, ensuring cost-effective packing. Nutritionally, food products with lower loose bulk density are easier to digest, particularly for young infants, whose digestive systems are still maturing (Ikegwu, 2021).

The water absorption capacity of the meal samples varied from 2.01 to 2.59 g/ml. The absorption capacity values for the commercial diet (Cerelac) and Food samples A, B, and C were not significantly different ($p>0.05$), while sample D's value of 2.59 g/ml was significantly different ($p<0.05$). The treated and untreated pigeon pea and sorghum grains produced similar results (Mbaeyi, 2005). Importantly, food products with low water absorption capacity tend to have reduced microbial activity, thus extending shelf life (Umerah and Alawuba 2020).

A vital factor in determining how much water food samples can absorb and how much they swell over a given time is their swelling capacity. The swelling capacity values ranged from 3.40 to 3.87 grams per millilitre. The lower values (0.10-0.30 ml/g) were recorded for supplementary foods derived from roasted pearl millet (*Pennisetum glaucum*) and soybean (Glycine max) using response surface modelling (Esther et al., 2022). Various factors, including temperature, type of starch and other carbohydrates, proteins, and water availability, influence swelling capacity (Elina and Theobald, 2016).

The rheological characteristics of flours influence the sensory acceptability of cooked starchy products and are used to determine their suitability as functional ingredients in Food and other industrial products (Asouzu, 2020). The study's peak viscosity ranged from 49.80 to 258.10 RVU, indicating a low and appropriate consistency for newborn feeding (Adebayo, 2013). The trough, which varied from 8.30 to 135.47 RVU, was also significantly ($p \leq 0.05$) impacted by processing methods. Both the rheological profile of this study and the values reported by Adegunwa (2017) (312.50 RVU) and Fadimu (2018) (251.08 RVU) for UPF were much lower. The commercial diet (Cerelac) and the designed meal samples yielded breakdown values ranging from 20.25 to 43.45 RVU. Products' resistance to heat and shear stress during cooking decreases as breakdown values increase.

The final viscosity readings from the commercial diet (Cerelac) and the prepared food samples varied between 95.50 RVU and 245.50 RVU. The RVU values (37.56-70.16 RVU) reported by Umerah and Alawuba (2020) from formulated supplemental diets made from Maize (Zea mays) supplemented with Crayfish (*Euastacus spp*) and Carrot (*Daucus carota*) were lower than the results of this investigation. This link confirms that the development of starchy gel during heating and cooling is unaffected by the final viscosity (Asouzu, 2020). The setback viscosity values, which varied from 5.50 RVU to 39.25 RVU, showed a significant difference ($p<0.05$) between the commercial control (celerac) and the prepared food samples. The RVU values (76 to 222) reported by Onwurafor and Umego (2017) from formulated supplemental diets made from sorghum, maize, mungbean, and malt were higher than the results of this investigation. The lower value that was noted is significant because it suggests a decreased propensity for retrogradation, which raises the digestibility of starch (Umerah, 2020).

The designed food samples and the commercial control (Cerelac) had low peak times, ranging from 1.00 to 3.15 minutes. This study's outcome was less than the values (5.13 to 6.87) minutes found in Onwurafor and Umego's (2017) designed supplementary meals made from malt, mungbean, maize, and sorghum. The product's ease of cooking is indicated by its low peak time (Okoronkwo 2023).

The temperature at which starch reaches its maximum viscosity when heated with water to create a paste, known as the pasting temperature, varied between 69.33 and 88.43 degrees Celsius. The study's findings fell within the range of UPF values (82.38 °C) reported by Adegunwa (2017). It also shows the minimal temperature needed for the Sample to cook.

CONCLUSION

Four complementary foods made with combinations of soybean, finger millet, Irish potatoes, and sorghum flour were evaluated against the commercial diet (Cerelac) to assess their proximate, functional, and rheological properties. The samples developed showed advantages over the commercial diet (Nestlé Cerelac) in terms of carbohydrates, fat, fibre, and ash content. The complementary foods created have significant potential due to their functional properties and high-quality pasting characteristics. Their peak and setback viscosities suggested a minimal tendency for retrogradation and a lower likelihood of syneresis, indicating that they are suitable for supplementary feeding. These local diets can be reformulated and enhanced to create more cost-effective and nutrient-rich meals that can aid in the recovery of malnourished children while also addressing supplemental needs.

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