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Research Article

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Nutrients and Phytochemical Compositions and Sensory Properties of Formulated Complementary Foods Produced From Rice, Soybeans, Groundnut and Periwinkle

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Abstract

Background/Objectives: *Inadequate complementary feeding contributes to nutrient deficiencies and impaired child growth. This study assessed the proximate, mineral, vitamin, phytochemical composition, and sensory acceptability of complementary foods formulated from rice, soybean, groundnut, and periwinkle.*

Methods: *Rice, soybean, groundnut, and periwinkle were processed using standard preparation methods, including sorting and washing, and used to formulate two complementary food blends with varying ingredient proportions. Nutrient and phytochemical analyses were conducted using standard laboratory procedures, while sensory evaluation was performed using a 9-point hedonic scale. Data were analyzed using descriptive statistics and ANOVA at $p < 0.05$.*

Results: *The formulations, $R_{65}S_{15}G_{10}P_{10}$ and $R_{60}S_{20}G_{10}P_{10}$, contained moisture (50.74% and 45.86%), protein (16.47–18.62 mg/100 g), fat (20.33–20.92 mg/100 g), crude fiber (0.14–0.25 mg/100 g), ash (0.57–0.63 mg/100 g), and carbohydrate (11.59–13.90 mg/100 g). Both blends provided appreciable amounts of calcium, iron, zinc, potassium, and sodium, with significant differences between formulations. Vitamins A, C, E, and B1 varied across samples: $R_{60}S_{20}G_{10}P_{10}$ had higher vitamins A and B1, whereas $R_{65}S_{15}G_{10}P_{10}$ contained more vitamins C and E. Phytochemical contents were low, and sensory evaluation showed both formulations were acceptable, with $R_{65}S_{15}G_{10}P_{10}$ receiving slightly higher overall ratings.*

Conclusion: *The formulated foods demonstrated good nutritional quality and sensory acceptability, supporting their suitability as infant complementary foods.*

Keywords: Complementary food, Nutrient, Phytochemical, Sensory, Formulation

1. Introduction

Optimal nutrition during the first two years of life is essential for the growth, development, and long-term health of children. After six months of age, breast milk alone becomes insufficient to meet an infant's increasing nutritional needs, making the introduction of appropriate complementary foods necessary [1]. However, in many developing countries such as Nigeria, complementary feeding practices are often inadequate in quality, quantity, and timing. Recent findings from the Nigeria Demographic and Health Survey (NDHS, 2023–2024) indicate a persistent burden of malnutrition, with 40% of children under five stunted, 8% wasted, and 27% underweight, reflecting poor dietary intake during this critical period [2].

The World Health Organization recommends that complementary feeding should begin at six months of age using safe, locally available, and nutrient-dense foods, while continuing breastfeeding up to two years or beyond [3]. It further emphasizes that complementary foods should be energy-dense and nutritionally adequate, providing appropriate proportions of macronutrients approximately carbohydrates (45–65% of total energy), fats (30–45% of total energy), and sufficient protein for growth (about 5–15% of total energy) alongside essential micronutrients such as iron, zinc, and vitamin A, which are critical for preventing deficiencies and supporting optimal physical and cognitive development in infants and young children [3]. Inadequate complementary feeding is largely driven by poverty, limited nutrition knowledge, and reliance on low-nutrient, cereal-based foods. These foods are often deficient in essential proteins, micronutrients, and bioactive compounds necessary for proper growth and immune function. Consequently, infants are at increased risk of micronutrient deficiencies, infections, impaired cognitive development, and higher morbidity and mortality rates [4].

The use of locally sourced ingredients such as rice, soybean, groundnut, and periwinkle offers a promising approach to improving the nutritional quality of complementary foods. Rice provides easily digestible carbohydrates for energy, while soybean and groundnut contribute high-quality plant protein, healthy fats, and essential micronutrients [5]. Periwinkle, an underutilized animal-source food, is particularly rich in high-quality protein, essential amino acids, iron, zinc, and omega-3 fatty acids, which are crucial for growth, brain development, and immune support.

The strategic combination of cereals, legumes, and animal-source foods can enhance the overall nutrient profile by improving protein quality and micronutrient density. Such formulations can help address both macronutrient and micronutrient deficiencies, commonly referred to as "hidden hunger," among infants and young children. Furthermore, developing affordable and culturally acceptable complementary foods from these ingredients supports sustainable nutrition interventions in resource-constrained settings.

Therefore, this study focuses on formulating complementary foods from rice, soybean, groundnut, and periwinkle, with the aim of improving nutrient intake, supporting optimal child development, and addressing the challenges of malnutrition associated with inadequate complementary feeding practices.

2. Methods

2.1. Study Design

Experimental design was used for this study to develop and evaluate formulated complementary foods produced from rice, soybean, groundnut, and periwinkle.

2.2. Raw Materials Collections

Local rice grains (*Oryza sativa*), soybean seeds (*Glycine max L.*), groundnut (*Arachis hypogaea*) and periwinkle (*Littorina littorea*) that was used for this study were procured from Ubani Main Market in Umuahia North Local Government Area, and Cerelac was purchase from a No.16, Amagwom, Umudike in Umuahia, Abia State.

2.3. Processing and Formulation of Raw Material

Local rice, soybean, groundnut, and periwinkle flours were prepared using modified standard methods reported in previous studies. Rice grains were sorted, washed, soaked, parboiled, dried at 80°C for 24 hours, and milled [6]. Soybean grains were sorted, soaked, dehulled, boiled, dried, roasted, and milled [7]. Groundnuts were sorted, washed, sun-dried, toasted, cooled, peeled, and milled [7]. Periwinkles were sorted, washed, boiled, de-shelled, oven-dried at 80°C for 48 hours, and milled [8]. All processed samples were milled using a hammer mill, combined where necessary, and packaged in airtight zip-lock bags. The final flours were stored at room temperature (25°C) away from light and humidity until further use. Flour blends were formulated by mixing rice, soybean, groundnut and periwinkle flour at different ratio.

2.4. Calculation for the Rice flour (RF), Soybean Flour (SF), Groundnut (G) and Periwinkle Flour (PF) Blends Formulation

Raw protein (R = 6.5g/100g, SB = 36.5g/100g, G = 25.8g/100g, P = 15.2g/100g)

According to the World Food Program (WFP) which states that 100g powder of complementary food should contain 16g protein as shown in the calculation below [9] :

Thus, for sample A: (65%RF, 15%SF, 15%GF, 10%PF).

RF = 65/100 x 16g = 10

SF = 15/100 x 16g = 2.4

GF = 15/100 x 16g = 2.4

PF = 10/100 x 16g = 1.6

If 100g of RF = 6.5, 10g

RF = 10 x 100/6.5 = 153.85g

If 100g of SF = 36.5, 2.4

SF = 2.4 x 100/36.5 = 6.58g

If 100g of GF = 25.8, 2.4

GF = 2.4 x 100/25.8 = 9.30g

If 100g of PF = 15.2, 1.6

PF = 1.6 x 100/15.2 = 10.53g

Sample A: 153.85: 6.58: 9.30: 10.53

Sample B: (60%RF, 20%SF, 10%GF, 10%PF).

RF = 60/100 x 16g = 9.6
SF = 20/100 x 16g = 3.2
GF = 10/100 x 16g = 1.6
PF = 10/100 x 16g = 1.6
If 100g of RF = 6.5, 9.6
RF = 9.6 x 100/6.5 = 147.69g
If 100g of SF = 36.5, 3.2
SF = 3.2 x 100/36.5 = 8.77g
If 100g of GF = 25.8, 1.6
GF = 1.6 x 100/25.8 = 6.20g
If 100g of P = 15.2, 1.6
PF = 1.6 x 100/15.2 = 10.53g

Sample B: 147. 69: 8. 77: 6.20: 10.53

Samples	Rice Flour	Soybean Flour	Groundnut	Periwinkle Flour
Cerelac (Control)	100	0	0	0
$R_{65}S_{15}G_{10}P_{10}$	153.85g	6.58g	9.30g	10.53g
$R_{60}S_{20}G_{10}P_{10}$	147.69g	8.77g	6.20g	10.53g
Keys: $R_{65}S_{15}G_{10}P_{10}$: (Local rice: 65%, Soybeans: 15%, Groundnut: 10%, Periwinkle: 10%); $R_{60}S_{20}G_{10}P_{10}$: (Local rice: 60%, Soybeans: 20%, Groundnut: 10%, Periwinkle: 10%)				

Table 1: Flour Blends Formulation

Samples	RF	SF	G	PF	Date Syrup	Vegetable Oil	Water
Cerelac(Control)	100	0	0	0	15ml	20ml	300ml
$R_{65}S_{15}G_{10}P_{10}$	153.85g	6.58g	9.30g	10.53g	15ml	20ml	300ml
$R_{60}S_{20}G_{10}P_{10}$	147.69g	8.77g	6.20g	10.53g	15ml	20ml	300ml
Footnote: Rice flour (RF), Soybean flour (SF), Groundnut (G) and Periwinkle flour (PF)							

Table 2: Recipe for the Preparation of Complementary Food Blends Produced From Rice, Soybean, Groundnut and Periwinkle

2.5. Method for the Preparation of Rice, Soybean, Groundnut and Periwinkle Based Complementary Food Used for Sensory Evaluation

Prior to the sensory evaluation, informed consent was obtained from forty (40) women of reproductive age. The evaluation was conducted in the Diet Therapy Laboratory of the Department of Human Nutrition and Dietetics, Michael Okpara University of Agriculture, Umudike. Each porridge sample was prepared by reconstituting 100 g of the control flour and each formulated composite flour separately with 300 ml of cold water in a medium-sized pot. The mixtures were boiled for 7 minutes and stirred continuously to prevent lump formation before being removed from the heat. After cooling, the porridges were served individually to the 40 women of reproductive age for evaluation.

2.6. Determination of nutrients and phytochemicals of the complementary food

- Determination of Proximate Compositions: Proximate composition was determined using Association of Official Analytical Collaboration methods [11]. Moisture content was determined using the gravimetric method after oven drying the reconstituted extracts at 105°C to a constant weight. Nitrogen content was determined using the Kjeldahl method, in which protein in the samples was converted to ammonium sulphate during acid digestion, and the liberated ammonia was trapped in boric acid solution during distillation. The titrated values were then multiplied by 6.25 as a conversion factor to obtain crude protein content. Lipid determination was carried out by extraction using petroleum ether in a Soxhlet apparatus, and fat content was determined gravimetrically. Ash content was determined by weighing 1 g of each extract into crucibles and incinerating in a muffle furnace at 600°C to a constant weight. Crude fibre was determined using the acid-alkaline gravimetric method in line with AOAC principles, while carbohydrate content was determined by difference[11].
- Determination Minerals: Calcium and magnesium content of the infant food was determined by the complexometric titration method of Onwuka [12]. Phosphorus content of the infant food was determined according to the method of Onwuka [12] by using hydroquinone as a reducing agent. Potassium was determined by procedure described by Onwuka [12]. Potassium standard was prepared. The standard solution was used to calibrate the instrument read out. The meter reading was at 100 % E (emission) to aspire the top concentration of the standards. The % E of all the intermediate standard curves was plotted on linear graph paper with these readings. Sodium and potassium was determined by flame photometry method, 1.0g of the sample would be digested with 20ml concentrated H2SO4 and aliquots of the diluted clear digest would be taken for photometry using flame analyzer [11]. Iron determination was done using AOAC atomic absorption spectrophotometer method (AAS).
- Determination of Vitamins: Thiamine (vitamin B1), Vitamin A and Vitamin C contents were determined using the method as described by AOAC [11]. For thiamine, five grams of sample was homogenized in 5 ml normal ethanoic NaOH solution.

For vitamin A, One gram (1 gm) of each sample was weighed into sample glass bottles. For vitamin C (ascorbic acid), about 0.5g of the sample was weighed, macerated with 10mls of 0.4% oxalic acid in a test tube for 10 minutes, centrifuged for 5 minutes and the solution filtered.

- Determination of phytochemicals: The phytate, tannin, saponin and oxalate were determined using the methods described by [13]. Spectrophotometric method was used for the determination of phytate and tannin. For the phytate, one gram of each sample was extracted in duplicate for 4 h with 20 ml of 0.1M nitric acid with constant agitation, and for the tannin, one gram of each sample was separately measured into different centrifuge tubes with 2 ml of the method distilled water. It was then centrifuged at 1500 rpm for 10 min. The saponin content of the sample was determined using the colorimetric method. The sample (1 g) was weighed and put into a test tube followed by the addition of 10 ml of distilled water. The oxalate was determined by precipitation.

2.7. Sensory Evaluation

The sensory evaluation of the complementary food samples was carried out according to the method described by Iwe [14]. A total of 20 trained and untrained panelists from the Department of Human Nutrition and Dietetics, Michael Okpara University of Agriculture, Umudike performed the sensory test to determine the appearance, taste, consistency, mouth-feel and general acceptability of the doughnut on 9-point Hedonic scale (1 = dislike extremely and 9 = like extremely).

2.8. Statistical Analysis

All experiments in this study were reported as mean of duplicate analyses. One way analysis of variance (ANOVA) was carried out using the IBM-Statistical Package of Social Science (IBM-SPSS) version 22.0 to separate the means at 95% confidence level ($P<0.05$).

3. Results

Table 3 shows the proximate composition of the formulated complementary foods. The moisture content obtained ranged from 45.86% to 50.74%. $R_{65}S_{15}G_{10}P_{10}$ had the highest (50.74%) moisture content while R60 S20 G10 P10 had the lowest (45.86%) moisture content. Significant differences ($p < 0.05$) was observed between the two samples. The protein content of the samples ranged from 16.47g/100g to18.62g/100g with $R_{60}S_{20}G_{10}P_{10}$ having the highest (18.62g/100g) protein content while $R_{65}S_{15}G_{10}P_{10}$ had the lowest (16.47g/100g) protein content. Significant differences ($p < 0.05$) was observed between the two samples. The fat content of the samples ranged from 20.33g/100g to 20.92g/100g in $R_{65}S_{15}G_{10}P_{10}$ to $R_{60}S_{20}G_{10}P_{10}$ respectively. A borderline significant difference ($p=0.05$) was observed between the two formulated complementary food. The crude fiber content of the formulated complementary foods ranged from 0.14g to 0.25g/100g, with $R_{65}S_{15}G_{10}P_{10}$ containing a higher fiber content of 0.25g/100g compared to 0.14g/100g observed in $R_{60}S_{20}G_{10}P_{10}$. Significant difference ($p<0.05$) was observed between the two formulated complementary food. The ash content of the formulated complementary foods was found to range from 0.57g/100g to 0.63g/100g, with no significant difference ($p > 0.05$) observed between $R_{65}S_{15}G_{10}P_{10}$ (0.63g/100g) and $R_{60}S_{20}G_{10}P_{10}$ (0.57g/100g). The carbohydrate content of the formulated complementary foods ranged from 11.59g/100g to 13.90g/100g. A significant difference ($p < 0.05$) was observed between $R_{65}S_{15}G_{10}P_{10}$ (11.59g/100g) and $R_{60}S_{20}G_{10}P_{10}$ (13.90g/100g), with $R_{60}S_{20}G_{10}P_{10}$ exhibiting a higher carbohydrate content.

Parameters	$R_{65}S_{15}G_{10}P_{10}$	$R_{60}S_{20}G_{10}P_{10}$	p-value
Moisture	50.74 ± 0.04	45.86 ± 0.03	0.000
Crude protein	16.47 ± 0.02	18.62 ± 0.01	0.000
Fat	20.33 ± 0.01	20.92 ± 0.03	0.050
Crude fibre	0.25 ± 0.03	0.14 ± 0.02	0.044
Ash	0.63 ± 0.02	0.57 ± 0.01	0.093
Carbohydrate	11.59 ± 0.02	13.90 ± 0.04	0.000
Keys: Sample A: (Local rice: 65%, Soybeans: 15%, Groundnut: 10%, Periwinkle: 10%); Sample B: (Local rice: 60%, Soybeans: 20%, Groundnut: 10%, Periwinkle: 10%)			

Table 3: Proximate Composition of Complementary Food Produced From Rice, Soybean, Groundnut and Periwinkle As Consumed

Table 4 shows the mineral composition of the formulated complementary foods. The calcium content ranged from 25.31mg/100g to 27.47mg/100g. A significant difference ($p < 0.05$) was observed between $R_{65}S_{15}G_{10}P_{10}$ (27.47%) and $R_{60}S_{20}G_{10}P_{10}$ (25.31%), with $R_{65}S_{15}G_{10}P_{10}$ exhibiting a higher calcium content. The iron content of the formulated complementary foods ranged from 0.83mg/100g to 0.98mg/100g. $R_{60}S_{20}G_{10}P_{10}$ had the higher iron content (0.98mg/100g), while $R_{65}S_{15}G_{10}P_{10}$ had the lowest iron content (0.83mg/100g). Significant difference ($p < 0.05$) was observed between the two formulated complementary foods. The zinc content of the formulated complementary foods ranged from 1.33g/100g to 1.47g/100g. $R_{60}S_{20}G_{10}P_{10}$ had the higher zinc content (1.47mg/100g), while $R_{65}S_{15}G_{10}P_{10}$ had the lowest zinc content (1.33g/100g). Significant difference ($p < 0.05$) was observed between the two formulated complementary foods. The potassium content of the formulated complementary foods ranged from 78.41mg/100g to 85.58mg/100g. Significant difference ($p<0.05$) was observed between $R_{65}S_{15}G_{10}P_{10}$ (85.58mg/100g) and $R_{60}S_{20}G_{10}P_{10}$ (78.41mg/100g), with $R_{65}S_{15}G_{10}P_{10}$ exhibiting higher potassium content. The sodium content of the formulated complementary foods ranged from 5.78g/100g to 7.33mg/100g. A significant difference ($p < 0.05$) was observed between $R_{60}S_{20}G_{10}P_{10}$ (7.33g/100g) and $R_{65}S_{15}G_{10}P_{10}$ (5.78mg/100g), with $R_{60}S_{20}G_{10}P_{10}$ exhibiting higher sodium content.

Samples	Calcium	Iron	Zinc	Potassium	Sodium
$R_{65}S_{15}G_{10}P_{10}$	25.31 ± 0.01	0.83 ± 0.01	1.33 ± 0.01	85.58 ± 0.04	5.78 ± 0.03
$R_{60}S_{20}G_{10}P_{10}$	27.47 ± 0.02	0.98 ± 0.04	1.47 ± 0.02	78.41 ± 0.01	7.33 ± 0.04
p-value	0.000	0.042	0.017	0.000	0.000
Keys: $R_{65}S_{15}G_{10}P_{10}$: (Local rice: 65%, Soybeans: 15%, Groundnut: 10%, Periwinkle: 10%); $R_{60}S_{20}G_{10}P_{10}$: (Local rice: 60%, Soybeans: 20%, Groundnut: 10%, Periwinkle: 10%).					

Table 4: Mineral Composition of Complementary Food Produced From Rice, Soybean, Groundnut and Periwinkle as Consumed

Table 5 shows the vitamin composition of the formulated complementary foods. The vitamin A content ranged from 10.71mg/100g to 12.03mg/100g. A significant difference ($p < 0.05$) was observed between $R_{60}S_{20}G_{10}P_{10}$ (12.03mg/100g) and $R_{65}S_{15}G_{10}P_{10}$ (10.71mg/100g), with $R_{60}S_{20}G_{10}P_{10}$ exhibiting higher vitamin A content. The vitamin C content of the formulated complementary foods obtained ranged from 30.21mg/100g to 31.55mg/100g. A significant difference ($p < 0.05$) was observed between $R_{65}S_{15}G_{10}P_{10}$ (31.55mg/100g) and $R_{60}S_{20}G_{10}P_{10}$ (30.21mg/100g), with $R_{65}S_{15}G_{10}P_{10}$ exhibiting the higher vitamin C content. The vitamin E content of the formulated complementary foods obtained ranged from 1.50mg/100g to 1.67mg/100g. A significant difference ($p<0.05$) was observed between $R_{65}S_{15}G_{10}P_{10}$ (1.67mg/100g) and $R_{60}S_{20}G_{10}P_{10}$ (1.50mg/100g), with $R_{65}S_{15}G_{10}P_{10}$ exhibiting the higher vitamin E content. The vitamin B1 content of the formulated complementary foods obtained ranged from 0.65mg/100g to 0.88mg/100g. A significant difference ($p<0.05$) was observed between $R_{60}S_{20}G_{10}P_{10}$ (0.88mg/100g) and $R_{65}S_{15}G_{10}P_{10}$ (0.65mg/100g), with $R_{60}S_{20}G_{10}P_{10}$ exhibiting the higher vitamin B1 content.

Samples	Vitamin A	Vitamin C	Vitamin E	Vitamin B1
$R_{65}S_{15}G_{10}P_{10}$	10.71 ± 0.01	31.55 ± 0.00	1.67 ± 0.01	0.65 ± 0.03
$R_{60}S_{20}G_{10}P_{10}$	12.03 ± 0.03	30.21 ± 0.02	1.50 ± 0.01	0.88 ± 0.02
p-value	0.000	0.000	0.007	0.012
Keys: $R_{65}S_{15}G_{10}P_{10}$: (Local rice: 65%, Soybeans: 15%, Groundnut: 10%, Periwinkle: 10%); $R_{60}S_{20}G_{10}P_{10}$: (Local rice: 60%, Soybeans: 20%, Groundnut: 10%, Periwinkle: 10%)				

Table 5: Vitamin Composition of Complementary Food Produced From Rice, Soybean, Groundnut and Periwinkle as Consumed

Table 6 shows the phytochemical compositions of the formulated complementary foods. The alkaloid content of the formulated complementary foods obtained ranged from 0.01mg/100g to 0.02mg/100g. There was no significant difference ($p>0.05$) observed between $R_{65}S_{15}G_{10}P_{10}$ (0.02mg/100g) and $R_{60}S_{20}G_{10}P_{10}$ (0.01mg/100g), with $R_{65}S_{15}G_{10}P_{10}$ exhibiting the higher alkaloid content. The flavonoid content of the formulated complementary foods obtained ranged from 0.14mg/100g to 0.29mg/100g with no significant difference ($p > 0.05$) was observed between $R_{65}S_{15}G_{10}P_{10}$ (0.29mg/100g) and $R_{60}S_{20}G_{10}P_{10}$ (0.14mg/100g), with $R_{65}S_{15}G_{10}P_{10}$ exhibiting the higher flavonoid content. The terpenoid content of the two formulated complementary foods was 0.02mg/100g for both $R_{65}S_{15}G_{10}P_{10}$ and $R_{60}S_{20}G_{10}P_{10}$ showing no significant difference ($p > 0.05$) between the two formulations. The tannin content of the formulated complementary foods obtained ranged from 0.01mg/100g to 0.02mg/100g. There was no significant difference ($p > 0.05$) between $R_{60}S_{20}G_{10}P_{10}$ (0.02mg/100g) and $R_{65}S_{15}G_{10}P_{10}$ (0.01mg/100g), with $R_{60}S_{20}G_{10}P_{10}$ exhibiting the higher tannin content. The phytate content of the two formulated complementary foods was 0.02mg/100g for both $R_{65}S_{15}G_{10}P_{10}$ and $R_{60}S_{20}G_{10}P_{10}$, showing no significant difference ($p > 0.05$) between the two formulations. The oxalate content of the formulated complementary foods obtained ranged from 0.02mg/100g to 0.04mg/100g. No significant difference ($p > 0.05$) was observed between $R_{65}S_{15}G_{10}P_{10}$ (0.04mg/100mg) and $R_{60}S_{20}G_{10}P_{10}$ (0.02mg/100mg), with $R_{65}S_{15}G_{10}P_{10}$ exhibiting the higher oxalate content. The saponin content of the formulated complementary foods obtained ranged from 0.03mg/100g to 0.04mg/100g with no significant difference ($p > 0.05$) observed between $R_{65}S_{15}G_{10}P_{10}$ (0.04mg/100g) and $R_{60}S_{20}G_{10}P_{10}$ (0.03mg/100g) with $R_{65}S_{15}G_{10}P_{10}$ exhibiting the higher saponin content.

Parameters	$R_{65}S_{15}G_{10}P_{10}$	$R_{60}S_{20}G_{10}P_{10}$	p-value
Alkaloid	0.02 ± 0.01	0.01 ± 0.01	0.553
Flavonoid	0.29 ± 0.04	0.14 ± 0.04	0.051
Terpenoid	0.02 ± 0.00	0.02 ± 0.01	0.423
Tannin	0.01 ± 0.00	0.02 ± 0.01	0.423
Phytate	0.02 ± 0.01	0.02 ± 0.00	0.423
Oxalate	0.04 ± 0.01	0.02 ± 0.00	0.095
Saponin	0.04 ± 0.01	0.03 ± 0.02	0.493
Keys: $R_{65}S_{15}G_{10}P_{10}$: (Local rice: 65%, Soybeans: 15%, Groundnut: 10%, Periwinkle: 10%); $R_{60}S_{20}G_{10}P_{10}$: (Local rice: 60%, Soybeans: 20%, Groundnut: 10%, Periwinkle: 10%).			

Table 6: Phytochemical Compositions of the Formulated Complementary Foods from Rice, Soybean, Groundnut and Periwinkle

Table 7 shows the sensory evaluation of the formulated complementary foods. The appearance content of the formulated complementary foods obtained ranged from 6.45 to 6.75. A significant difference ($p < 0.05$) was observed between $R_{65}S_{15}G_{10}P_{10}$ (6.75) and $R_{60}S_{20}G_{10}P_{10}$ (6.45), with $R_{65}S_{15}G_{10}P_{10}$ exhibiting the higher appearance content. The taste content of the formulated complementary foods obtained ranged from 5.43 to 6.30. A significant difference ($p < 0.05$) was observed between $R_{65}S_{15}G_{10}P_{10}$ (6.30) and $R_{60}S_{20}G_{10}P_{10}$ (5.43), with $R_{65}S_{15}G_{10}P_{10}$ exhibiting the higher taste content. The color content of the formulated complementary foods obtained ranged from 6.20 to 6.25. A significant difference ($p < 0.05$) was observed between $R_{60}S_{20}G_{10}P_{10}$ (6.25) and $R_{65}S_{15}G_{10}P_{10}$ (6.20), with $R_{60}S_{20}G_{10}P_{10}$ exhibiting the higher color content. The mouthfeel content of the formulated complementary foods obtained ranged from 6.10 to 6.60. A significant difference ($p < 0.05$) was observed between $R_{65}S_{15}G_{10}P_{10}$ (6.60) and $R_{60}S_{20}G_{10}P_{10}$ (6.10), with $R_{65}S_{15}G_{10}P_{10}$ exhibiting the higher mouthfeel content. The aroma content of the formulated complementary foods obtained ranged from 6.53 to 6.98. A significant difference ($p < 0.05$) was observed between $R_{65}S_{15}G_{10}P_{10}$ (6.98) and $R_{60}S_{20}G_{10}P_{10}$ (6.53), with $R_{65}S_{15}G_{10}P_{10}$ exhibiting the higher aroma content. The general acceptability content of the formulated complementary foods obtained ranged from 6.15 to 6.57. A significant difference ($p < 0.05$) was observed between $R_{65}S_{15}G_{10}P_{10}$ (6.57) and $R_{60}S_{20}G_{10}P_{10}$ (6.15), with $R_{65}S_{15}G_{10}P_{10}$ having the higher general acceptability content.

Parameters	$R_{65}S_{15}G_{10}P_{10}$	$R_{60}S_{20}G_{10}P_{10}$
Appearance	6.75 ± 1.65	6.45 ± 1.26
Taste	6.30 ± 2.16	5.43 ± 1.85
Colour	6.20 ± 0.99	6.25 ± 1.21
Mouthfeel	6.60 ± 1.37	6.10 ± 1.60
Aroma	6.98 ± 1.56	6.53 ± 1.65
General acceptability	6.57 ± 1.12	6.15 ± 1.14
Keys: $R_{65}S_{15}G_{10}P_{10}$: (Local rice: 65%, Soybeans: 15%, Groundnut: 10%, Periwinkle: 10%); $R_{60}S_{20}G_{10}P_{10}$: (Local rice: 60%, Soybeans: 20%, Groundnut: 10%, Periwinkle: 10%).		

Table 7: Sensory Evaluation of the Formulated Complementary Foods from Rice, Soybean, Groundnut and Periwinkle

4. Discussion

The results of this study offer valuable information on the nutritional composition, including proximate, mineral, vitamin, and phytochemical properties, as well as the sensory acceptability of the formulated complementary foods from rice, soybean, groundnut and periwinkle, and their potential adequacy for infant and young child nutrition.

The proximate composition of the formulated complementary foods showed variations that are largely influenced by the proportion of ingredients used in the formulations. The moisture content obtained indicates relatively high moisture content, with $R_{65}S_{15}G_{10}P_{10}$ exhibiting the highest value. This is considerably higher than values reported by Adeyeye and Ajewole (6.50-8.20%) and Olorunfemi et al. (7.10-9.45%) for dried complementary foods [15,16]. High moisture content has been associated with reduced shelf stability and increased susceptibility to microbial spoilage. However, some studies have suggested that higher moisture content in ready-to-eat complementary gruels may enhance palatability and ease of swallowing for infants, which is consistent with the favorable sensory scores observed in this study [17].

The protein content observed in the present study is relatively high for complementary foods and suggests that the inclusion of soybean and groundnut significantly enhanced protein quality. Protein enrichment is essential in complementary feeding because of the high protein demand during infancy and early childhood growth. Comparable studies have shown that legume-fortified complementary foods consistently improve protein content and overall nutritional adequacy [18,19]. The higher protein content in $R_{60}S_{20}G_{10}P_{10}$ may be attributed to its increased soybean proportion, which is known to be a rich source of essential amino acids. However, some studies have reported that high legume inclusion may reduce protein digestibility due to residual antinutritional factors [20]. This potential limitation may be minimal in the present study due to the low phytate levels observed.

The fat content suggests that the formulations are energy-dense, which is desirable in infant diets due to their small gastric capacity. These values are higher than the 8.00-12.50 g/100 g reported in similar studies, indicating superior energy contribution. Dietary fats play a crucial role in energy provision and absorption of fat-soluble vitamins [17]. However, this relatively high fat content slightly exceeds recommended levels, as infant diets should provide fat within approximately 30-45% of total energy to ensure adequate energy density while maintaining a balanced nutrient profile [3]. The crude fiber content was relatively low, which is appropriate for infant feeding as excessive fiber may interfere with nutrient absorption. This is in contrast with the values 1.20-2.80 g/100 g reported by Onyango et al. in similar studies. While higher fiber may benefit digestion, the low levels observed in this study align with infant nutritional recommendations [21].

Ash content, which reflects total mineral content, showed no significant difference between samples, indicating similar mineral contributions from the ingredients used. Although these values are lower than 1.80–3.20 g/100 g reported in a similar study by Ijarotimi and Keshinro, the mineral analysis suggests that essential minerals are still present in appreciable amounts [17].

Carbohydrate content indicates that the formulations provide adequate energy sources, with $R_{60}S_{20}G_{10}P_{10}$ having higher carbohydrate levels. This may be due to increased cereal proportion, as cereals are primary carbohydrate contributors in blended foods. Similar findings have been reported in cereal-legume complementary foods where carbohydrate levels vary inversely with protein enrichment [21].

The mineral profile revealed appreciable levels of calcium, iron, zinc, potassium, and sodium. These minerals are essential for bone development, oxygen transport, immune function, and electrolyte balance in infants. The higher calcium in $R_{65}S_{15}G_{10}P_{10}$ may be attributed to ingredient proportion differences, particularly legumes and periwinkle inclusion, which are known mineral sources. Iron and zinc are critical micronutrients in preventing anemia and supporting cognitive development. The relatively higher iron and zinc in $R_{60}S_{20}G_{10}P_{10}$ align with reports that soybean enrichment improves micronutrient density in composite foods [3]. However, the levels observed may still require dietary diversification or fortification to meet recommended dietary allowances for infants. Potassium and sodium levels indicate a balanced electrolyte composition, although potassium was higher in $R_{65}S_{15}G_{10}P_{10}$. This may support fluid balance and neuromuscular function. Similar mineral trends have been reported in studies involving cereal-legume blends for infant feeding [17].

The vitamin content showed appreciable levels of pro-vitamin A, vitamin C, vitamin E, and vitamin B1. Pro-vitamin A levels in this study (10.71-12.03 mg/100 g) are higher than (2.50-8.40 mg/100 g) reported by Emebu and Anyika [22], suggesting improved micronutrient density. Vitamin C content was also relatively high compared to values of 10.00-25.00 mg/100 g reported in similar studies, indicating strong antioxidant potential which may enhance immune protection [23]. Vitamin E and B1 values fall within acceptable ranges and contribute to antioxidant defense and energy metabolism. Overall, the vitamin compositions suggest that the formulations could contribute meaningfully to micronutrient intake in infants.

The phytochemical analysis revealed low concentrations of alkaloids, flavonoids, tannins, saponins, phytates, oxalates, and terpenoids across formulations, with no significant differences in most cases. These low levels are desirable in complementary foods, as excessive antinutritional factors may impair mineral bioavailability. However, the presence of flavonoids and saponins suggests potential antioxidant and antimicrobial benefits. Flavonoids are known to improve oxidative stability and may contribute to health protection. Similar findings have been reported in plant-based complementary foods where processing reduces antinutrients while retaining beneficial phytochemicals [24]. The very low phytate and oxalate levels indicate improved mineral bioavailability, which is crucial for infant nutrition.

The sensory evaluation showed that both formulations were generally acceptable, with mean scores above average for all attributes. The formulated complementary food ($R_{65}S_{15}G_{10}P_{10}$) consistently recorded higher scores in appearance, taste, mouth-feel, aroma, and overall acceptability. These values are comparable to sensory scores (5.00-7.50) reported in similar studies [23]. The higher acceptability may be attributed to better balance of ingredients, which improved flavor and texture. However, Nnam and Obi reported reduced acceptability with increased legume inclusion due to beany-flavor, which contrasts with the findings of this study and suggests that processing methods may have minimized such off-flavors [20]. Overall, the results indicate that both formulations are suitable for complementary feeding, with $R_{65}S_{15}G_{10}P_{10}$ showing greater consumer preference.

5. Conclusion

The formulated complementary foods showed good nutritional values, containing appreciable amounts of proteins, essential minerals, vitamins, and bioactive compounds, while also maintaining acceptable sensory properties. Both formulations therefore showed potential use in complementary feeding, although $R_{65}S_{15}G_{10}P_{10}$ demonstrated slightly higher sensory scores. Interventions aimed at scaling up the production of these formulated complementary foods to enhance the nutritional outcomes of children under five should be prioritized.

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