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Overall acceptability and shelf life evaluation of cakes produced from wheat, cocoyam, plantain, and Bambara nut composite flours

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Abstract
Cakes are widely consumed bakery products typically made from wheat flour, yet dependence on imported wheat can create economic and nutritional challenges in many developing countries. This study evaluated the acceptability and shelf life of cakes produced from composite flours based on wheat, cocoyam, plantain, and Bambara nut (WCPB1–WCPB6) compared with 100% wheat flour (WF) as control. Cakes were prepared and evaluated by 15 panelists using a 9-point hedonic scale, and shelf life attributes were monitored over 20 days at 4-day intervals. All samples were highly acceptable during the initial storage period, and sensory scores generally remained within the acceptable range throughout storage, with WF tending to receive the highest ratings. Statistical analysis showed significant differences in taste among formulations at later storage times ($p \leq 0.05$), whereas other sensory attributes were largely comparable. Although quality declined and mold growth appeared after prolonged storage, several composite-flour cakes remained above the sensory cut-off for acceptability at day 20. These findings indicate that cocoyam, plantain, and Bambara nut composite flours can partially substitute wheat in cake production without compromising product quality, while supporting the utilization of indigenous crops and contributing to food and nutrition security.

1. Introduction

Ohamobi et al. (2020) highlighted the need for innovation and adaptation within local food systems to enhance self-reliance and global competitiveness. In the same spirit, dependence on imported wheat has spurred interest in locally sourced flours such as cocoyam, plantain, and Bambara nut. These alternatives, according to Okafor et al. (2021), support sustainability and resource optimization, although challenges persist in product quality and shelf life, echoing Enwereji et al. (2022) and Osegbue et al. (2025) on the importance of technology-driven improvement in food systems. While cakes made from wheat flour are widely studied, limited attention has been given to how composite flours behave in terms of sensory properties, staling, moisture retention, and microbial stability (Adegunwa et al., 2019). Much of the existing research reports only proximate composition or one-time sensory assessments, leaving a gap in studies that simultaneously evaluate consumer acceptability and systematic shelf life performance of composite cakes.

Shelf life is an integral part of sensory and chemical examination that must be considered during the development of novel foods such as composite cakes, to determine how long they remain fit for consumption before spoilage (Chawla, 2021). Haouet et al. (2018) defined shelf life as the period during which a food product is considered acceptable for consumption under appropriate storage conditions, and D'Souza and Banerjee (2017) similarly described it as the time frame within which food can be used while maintaining quality. As consumers increasingly demand high food quality, they expect this quality to be maintained between production or purchase and consumption (Phimolsiripol & Suppakul, 2016). Cakes are perishable, and spoilage from mould or bacterial growth often occurs within a few days of baking. Microbial spoilage is a major limiting factor in the shelf life of intermediate and high-moisture bakery products (Sorensen, 2015; Kalu et al., 2025). The progressive deterioration of cakes reduces quality and shortens marketability. Okonkwo and Idigo (2025) emphasize that such degradation reflects inefficiencies that can be managed through improved systems and controls along the food chain, while Idigo (2022, 2024) underlines, in broader resource-management contexts, the importance of proactive and sustainable management of perishable resources for long-term stability and safety. In the context of composite cakes, assessing shelf life is therefore essential.

Research on plantain flour in baked goods shows that partial substitution at moderate levels, typically 20–30%, can produce cakes with desirable sensory attributes similar to 100% wheat controls while increasing fibre and resistant starch (Adegunwa et al., 2021). However, the functional properties of plantain flour, particularly its effects on batter rheology, can influence crumb structure and storage stability. Cocoyam flour has also been tested in composite cake formulations, with wheat–cocoyam blends between 8 and 30% reported to preserve acceptable colour and taste and enhance nutritional profiles, but differences in water absorption and pasting behaviour alter batter viscosity, specific volume, and crumb porosity, thereby affecting consumer liking and shelf stability (Akinjayeju et al., 2020). Microbial shelf life trials show that cocoyam-based cakes often last only a few days at room temperature unless packaging or formulation is adjusted, underscoring the need for integrated sensory and storage evaluations (Akusu et al., 2016). Bambara groundnut flour offers protein enrichment and valuable micronutrients but presents functional challenges: its low foaming capacity and distinct protein behaviour can impair batter aeration and reduce cake volume, although the use of Bambara protein concentrates or emulsifiers can improve texture and overall acceptability (Ayanwale et al., 2016). Processing methods such as dehulling, roasting, and defatting also alter the functional properties of Bambara groundnut, shaping sensory attributes and storage behaviour (Bader et al., 2018). Thus, although cocoyam, plantain, and Bambara nut are nutritionally promising, their technical limitations must be carefully managed to achieve consumer-acceptable cakes with stable shelf lives.

A smaller but growing body of work has investigated composite blends combining wheat with plantain, cocoyam, and Bambara flours. These studies suggest the possibility of formulating nutritionally superior cakes without significantly sacrificing sensory acceptability, for example using 70% wheat, 20% plantain, and 10% Bambara protein concentrate (Damfami & Namo, 2020). However, such findings are mostly limited to immediate sensory assessments. Few studies have systematically monitored these products during storage to examine water activity, staling rates, lipid oxidation, or microbial load under retail-like conditions (Adegunwa et al., 2019; Akusu et al., 2016; Damfami & Namo, 2020). Previous research has therefore focused on proximate composition, functional properties, or single-time sensory evaluation of composite cakes, but none has combined longitudinal sensory assessment with practical shelf life monitoring of wheat–cocoyam–plantain–Bambara nut composite cakes under conditions relevant to sub-Saharan markets. This lack of longitudinal data makes it difficult to determine the practical shelf life of these products, creating uncertainty for producers and limiting large-scale adoption (Ebewore, 2020).

Conceptually, the present work is grounded in food-to-food fortification. For centuries, many families, especially in sub-Saharan Africa, have blended different foods at household level to enrich staple grains with key nutrients. Food-to-food fortification is now viewed as an emerging strategy complementing existing approaches against micronutrient deficiencies (Kruger et al., 2020). Food fortification is defined as the process of increasing one or more macro- or micronutrients in commonly consumed foods at levels that are natural or near natural for that food or ingredient (FAO, 2012) and is considered a key preventive approach against nutritional deficiencies (World Food Programme, 2022). Food-based strategies, bio-fortification, conventional fortification, and dietary diversification or modification are increasingly recognized for their ability to improve micronutrient status using local resources (Kruger et al., 2020; Ogbonyomi et al., 2023). Nevertheless, food fortification in developing countries faces challenges related to availability, accessibility, affordability, and acceptability of fortificants (Chadare et al., 2019). Food-to-food fortification differs from conventional fortification in that it seeks to increase both micronutrient content and bioavailability through nutrient-dense food ingredients rather than isolated micronutrients (Kruger et al., 2020), offering an alternative to chemical fortificants (Lebot & Lawac, 2017). The overall aim is not only deficiency prevention but also broader health improvement (Dwyer et al., 2014). Several authors agree that food-to-food fortification can improve nutritional quality and combat malnutrition when it is innovative, affordable, culturally acceptable, low-tech, and sustainable (Amlogu, 2015; Kiin-Kabari & Banigo, 2015; Adegunwa et al., 2019; Mashau et al., 2020; Chadare et al., 2019; Kruger et al., 2020). In this context, the choice of cocoyam, plantain, and Bambara nut is based on their availability, accessibility, suitability, and cost-effectiveness as raw materials for composite flour.

The primary premise of fortification is that there is a gap in nutrient intake in a substantial proportion of the population and that fortifying widely consumed foods can shift intake toward adequacy (Neufeld et al., 2017). In this study, the target group is teenagers, and the guiding principle is to develop acceptable nutrient-dense cakes as functional snacks by applying appropriate, low-technology processing to enhance the nutrient profile of wheat flour, which is relatively low in threonine, through food-to-food fortification. Composite food technology is important for providing nutritious foods, curbing malnutrition, ensuring food security, and supporting economic sustainability, but consumer acceptance cannot be taken for granted. Teenagers' preferences and possible rejection must be considered when introducing fortified snacks (D'Auria et al., 2020). They have specific expectations regarding taste and texture, and may reject products if changes are too pronounced (Pellegrino & Luckett, 2020). Familiarity and perception also strongly influence their snacking decisions; foods perceived as unfamiliar may be avoided even if they are nutritionally superior (Pellegrino & Luckett, 2020). These considerations reinforce the need to evaluate both the shelf life stability and sensory acceptability of composite cakes in the intended consumer group.

From this literature, the main gap and novelty of the present study become clear, previous work has rarely linked composite-flour formulation, sensory acceptability, and longitudinal shelf life behaviour in a single, systematic investigation of wheat–cocoyam–plantain–Bambara nut cakes under practical storage conditions. To address this gap, the study focuses on cakes produced from different blends of wheat, cocoyam, plantain, and Bambara nut flours (WCPB1, WCPB2, WCPB3, WCPB4, WCPB5, and WCPB6) and cakes made from 100% wheat flour (WF) as control. It is guided by two research questions: (1) What are the mean ($\bar{x}$) ratings of overall acceptability of cakes produced from the different composite flour blends (WCPB1–WCPB6) compared with cakes made from 100% wheat flour (WF)? and (2) What is the shelf life of cakes made from different blends of wheat, cocoyam, plantain, and Bambara nut composite flours (WCPB1–WCPB6) compared with cakes made from 100% wheat flour (WF)? Accordingly, the specific objectives are to determine the overall acceptability of cakes produced from these composite flours and to examine their shelf life performance relative to 100% wheat cakes. To statistically interrogate these questions at $p \leq 0.05$, two null hypotheses were formulated: H_{01}, that there is no significant difference in the mean ($\bar{x}$) ratings of overall acceptability of cakes produced from different composite flour blends (WCPB1–WCPB6) and cakes made from 100% wheat flour (WF); and H_{02}, that there is no significant difference in the shelf life of cakes made from different composite flour blends (WCPB1–WCPB6) and cakes made from 100% wheat flour (WF). Figure 1 presents the conceptual model of the food-to-food composite cake.

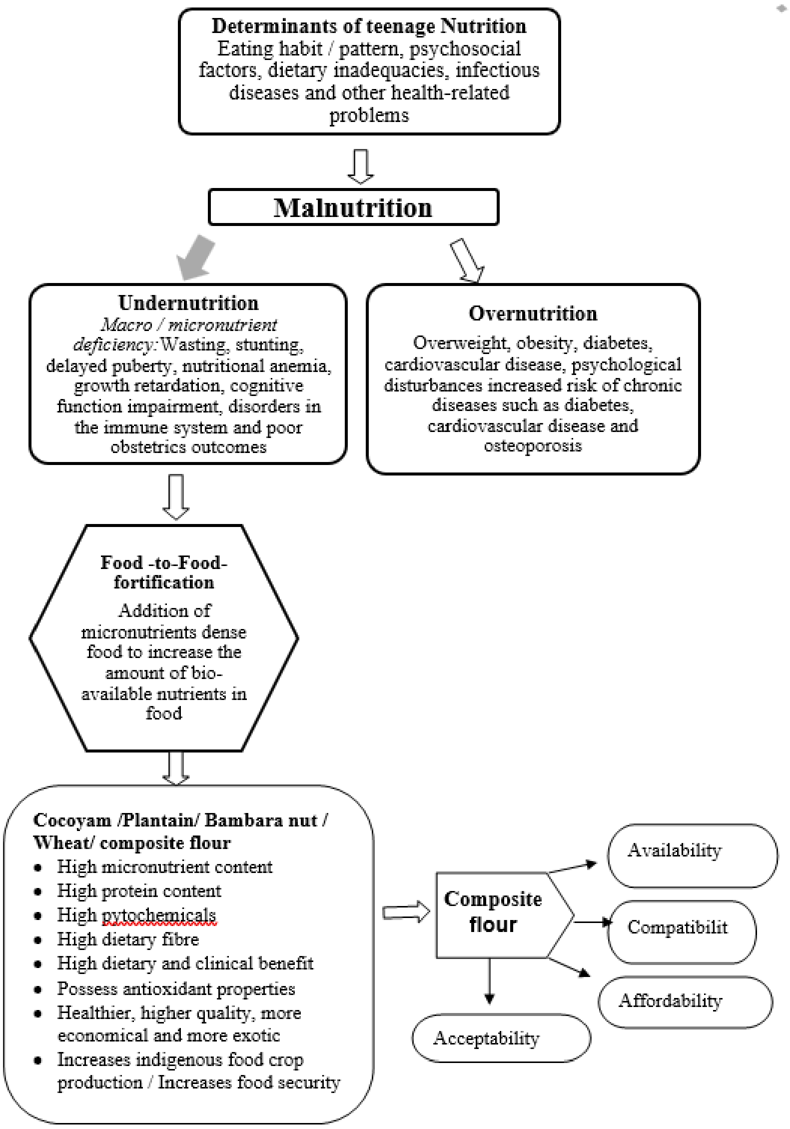

Figure 1. Conceptual Model of Food-to-Food Composite Cake

2. Method

2.1. Area of Study

The study was conducted in the Food and Nutrition Laboratory, Department of Vocational Education (Home Economics Unit), Delta State University, Abraka. The laboratory setting provided controlled conditions for product preparation and convenient access to panelists.

2.2. Research Design

This was an experimental study involving seven cake formulations (six wheat–cocoyam–plantain–Bambara nut composite blends and one 100% wheat control) and repeated sensory and shelf life evaluations over a 20-day storage period. Experimental research design is appropriate for developing and improving food products based on prior scientific and practical knowledge (OECD, 2015). Cakes prepared from 100% wheat flour and composite flours with substitution ratios of 5: 5: 5: 85; 10: 5: 5: 80; 10: 10: 10: 70; 10: 15: 10: 65; 15: 15: 15: 55; and 15: 20: 15: 50 (cocoyam: plantain: Bambara nut: wheat) were evaluated for nutritional composition, sensory attributes, and shelf life.

2.3. Population, Sample and Sampling Technique

The population comprised male and female academic staff and undergraduate students in the Department of Vocational Education, Delta State University, Abraka, and the Department of Home

Economics, University of Delta, Agbor, totalling 185 individuals (16 staff and 142 students in Abraka; 6 staff and 21 students in Agbor; Office of the Heads of Departments, 2024).

From this population, 15 panelists (7 academic staff and 8 undergraduate students) were purposively selected for the sensory evaluation based on willingness to participate, availability during the study period, and familiarity with cake consumption. The panel was designed to include adolescents and young adults, in line with the target consumer group of the product. In addition, 5 semi-trained panelists were purposively selected from undergraduate students of Home Economics, Department of Vocational Education, Delta State University, Abraka for the shelf life evaluation.

2.4. Research Instruments

Two instruments were used for data collection. The first was a sensory evaluation questionnaire ("Sensory Evaluation Questionnaire for WCPB Cakes"), based on a 9-point hedonic scale, which assessed consumer acceptability of the cake samples. The scale ranged from 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, and 1 = dislike extremely. This instrument was used to collect data on appearance, colour, flavour, texture, taste, mouthfeel, and overall acceptability for all seven formulations. The second instrument was a shelf life evaluation questionnaire, which used a 5-point rating scale to monitor changes in general appearance, colour, flavour, texture, taste, and overall acceptability during storage. The scale consisted of 5 = excellent, 4 = very good, 3 = good, 2 = fair, and 1 = poor.

2.5. Validity of the Instruments

Face and content validity were established by three experts: one lecturer in Home Economics, one in Measurement and Evaluation, and one in Biochemistry, all from Delta State University, Abraka. The experts assessed the clarity, relevance, and coverage of the items. Their corrections and suggestions were incorporated before the instruments were used in a pilot test.

2.6. Reliability of the Instruments

A pilot test was conducted to determine the reliability of both instruments. Ten undergraduate students of Home Economics (Department of Vocational Education, Delta State University, Abraka) were purposively selected as a test panel. Cakes fortified with cocoyam, plantain, and Bambara nut and a 100% wheat control cake were evaluated using the 9-point hedonic questionnaire. Data were analyzed using Cronbach's alpha, yielding a reliability coefficient of 0.81, indicating good internal consistency.

For the shelf life instrument, five copies of the 5-point questionnaire were administered to five purposively selected subjects from the Home Economics unit. They evaluated two sets of wheat–cocoyam–plantain–Bambara nut composite cakes. Cronbach's alpha for this instrument was 0.88, indicating high reliability.

2.7. Data Collection Procedure

Fifteen copies of the sensory evaluation questionnaire were administered to the 15 panelists with the help of two trained research assistants. Each panelist tasted all cake samples and rated general appearance, colour, flavour, texture, crispiness, taste, mouthfeel, and overall acceptability using the 9-point hedonic scale. A bottle of clean water was provided to each panelist to rinse the mouth between samples in order to prevent carry-over effects.

For shelf life evaluation, five copies of the 5-point structured questionnaire were given to the five shelf life panelists. They monitored and rated each cake sample on general appearance, colour, flavour, texture, taste, and overall acceptability every four days over a 20-day period.

2.8. Materials

Cocoyam, matured unripe plantain (Musa paradisiaca), Bambara nut, wheat flour, margarine, eggs, baking powder, sugar, and other cake ingredients were purchased from local markets in Ughelli, Delta State. Reagents for laboratory analyses were supplied by the laboratory analyst. Standard baking equipment (oven, cake pans, kitchen scale, measuring cups and spoons, mixer, mixing bowls, sieve, egg whisk and spatulas) was used for cake preparation.

2.9. Sample Preparation

2.9.1. Flour Production

Two instruments were used for data collection. A sensory evaluation questionnaire ("Sensory Evaluation Questionnaire for WCPB Cakes"), based on a 9-point hedonic scale, was used to assess consumer acceptability of the cake samples. The scale was defined as: 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, and 1 = dislike extremely. This instrument was used to collect data on appearance, colour, flavour, texture, taste, mouthfeel, and overall acceptability for all seven formulations. In addition, a shelf life evaluation questionnaire using a 5-point rating scale was employed to monitor changes in general appearance, colour, flavour, texture, taste, and overall acceptability during storage. The scale for this instrument was: 5 = excellent, 4 = very good, 3 = good, 2 = fair, and 1 = poor.

2.9.2. Formulation of Composite Flours and Cake Recipes

Composite flours containing wheat (W), cocoyam (C), plantain (P), and Bambara nut (B) were formulated by partially substituting wheat flour with cocoyam, plantain, and Bambara nut at different ratios. Six composite blends were prepared with the following W:C:P:B proportions: WCPB1 (85:5:5:5), WCPB2 (80:10:5:5), WCPB3 (70:10:10:10), WCPB4 (65:15:15:10), WCPB5 (55:15:15:15), and WCPB6 (50:15:20:15). A 100% wheat flour sample (WF) served as the control, giving a total of seven cake formulations. The detailed mass of each flour component per formulation, along with the complete cake recipe (wheat/composite flour, margarine, sugar, eggs, lemon zest, nutmeg, vanilla, baking powder, and salt), is presented in Table 1.

Table 1. Formulations of Wheat–Cocoyam–Plantain–Bambara Nut Composite Flours Used for Cake Preparation

Formulation code	Wheat (W) (%)	Cocoyam (C) (%)	Plantain (P) (%)	Bambara nut (B) (%)
WF (control)	100	0	0	0
WCPB1	85	5	5	5
WCPB2	80	10	5	5
WCPB3	70	10	10	10
WCPB4	65	15	15	10
WCPB5	55	15	15	15
WCPB6	50	15	20	15

2.9.3. Cake Preparation

Cakes were prepared from each flour formulation using the creaming method, following all Nigerian recipes (2022) with slight modifications to ingredient levels and formulations. Margarine and sugar were first creamed together until light and fluffy, after which baking pans were greased and lightly dusted with flour. The eggs were beaten to a uniform consistency and gradually incorporated into the creamed mixture. The oven was preheated to 220 °C while the dry ingredients, including the flour blends, baking powder, salt, and spices, were sifted together. Vanilla extract and lemon zest were then added to the batter, followed by the gradual folding in of the sifted dry ingredients until a uniform mixture was achieved. The batter was poured into the prepared pans and baked in the preheated oven for approximately 40 minutes or until golden brown and fully cooked. After baking, the cakes were cooled on a rack for about one hour before being used for sensory evaluation and later stored for shelf life assessment.

2.9.4. Shelf Life Evaluation

All composite cake samples and the 100% wheat control were subjected to sensory-based shelf life evaluation. Six attributes (general appearance, colour, flavour, taste, texture, and overall acceptability) were monitored using the 5-point rating scale. Evaluations were conducted by the five semi-trained panelists at 4-day intervals over 20 days of ambient storage. The cut-off point for acceptability was set at a mean score of 3.0. Samples with mean scores between 3.0 and 5.0 were considered acceptable, while scores below 3.0 were considered indicative of unacceptable quality.

2.9.5. Data Analysis

Data from nutritional composition, sensory evaluation, and shelf life assessment were summarized using means ($\bar{x}$) and standard deviations (SD). To test the hypotheses, analysis of variance (ANOVA) was used to determine significant differences among cake formulations. When

ANOVA indicated significant effects, Duncan's Multiple Range Test (DMRT) was applied for post-hoc separation of means. Statistical analyses were performed using SPSS version 27, and differences were considered statistically significant at $p \leq 0.05$.

3. Results and Discussion

The shelf lives of cakes made from different blends of wheat, cocoyam, plantain, and Bambara nut composite flours (WCPB1, WCPB2, WCPB3, WCPB4, WCPB5, and WCPB6) were evaluated in comparison with a 100% wheat cake (WF). From day 1 to 4 of storage, all cake samples received a score of 5 (excellent) for all evaluated parameters, namely appearance, colour, flavour, texture, and overall acceptability, indicating that the cakes were still very fresh at this stage. As shown in Table 2, during days 8 to 12 of the shelf life evaluation, the mean scores for appearance ranged from 4.80 ± 0.45 to 4.00 ± 0.00, with the control sample WF recording the highest score (4.80 ± 0.45) and WCPB5 the lowest. For colour, the mean scores were between 4.80 ± 0.45 and 4.00 ± 0.00, while flavour scores ranged from 4.80 ± 0.45 to 4.20 ± 0.45. Taste scores were between 4.80 ± 0.45 and 4.20 ± 0.45, texture ratings ranged from 4.40 ± 0.55 to 4.00 ± 0.00, and overall acceptability scores were between 4.60 ± 0.55 and 4.00 ± 0.00.

Between days 12 and 16, a gradual decline in quality was observed. The mean appearance scores ranged from 4.00 ± 0.00 to 3.60 ± 0.55, while colour scores were between 4.00 ± 0.00 and 3.60 ± 0.55. Flavour ratings decreased to between 3.40 ± 0.55 and 3.20 ± 0.45, and taste scores ranged from 3.00 ± 0.00 to 2.40 ± 0.45. Texture scores were between 3.40 ± 0.55 and 3.20 ± 0.45, and overall acceptability decreased to between 3.40 ± 0.55 and 3.20 ± 0.45. By day 20 of storage, further deterioration was evident: appearance scores had dropped to between 3.00 ± 0.00 and 1.60 ± 0.55, colour scores ranged from 3.80 ± 0.45 to 3.20 ± 0.45, and flavour scores were between 3.00 ± 0.00 and 2.80 ± 0.45. Taste was not evaluated on day 20 due to visible mold growth on some samples. Texture scores declined to between 2.80 ± 0.45 and 2.00 ± 0.00, and overall acceptability ranged from 3.20 ± 0.45 to 1.60 ± 0.55. These results, summarized in Table 2, indicate a progressive decline in sensory quality and acceptability of all cake samples over the 20-day storage period.

Tabel 2. Shelf Life Evaluation of All Cake Samples

Day	Sample	Appearance	Colour	Flavour	Taste	Texture	Overall Acceptability
4 to 8	WCPB1	4.60 ±0.46a	4.60 ±0.55a	4.40 ±0.55b	4.20 ±0.45a	4.00 ±0.00a	4.00 ±0.00a
	WCPB2	4.40 ±0.55a	4.40 ±0.55a	4.60 ±0.55a	4.60 ±0.55a	4.60 ±0.55a	4.60 ±0.55a
	WCPB3	4.40 ±0.55a	4.40 ±0.55a	4.20 ±0.45a	4.00 ±0.00a	4.00 ±0.00a	4.00 ±0.00a
	WCPB4	4.20 ±0.45a	4.20 ±0.45a	4.60 ±0.55a	4.40 ±0.55a	4.40 ±0.55a	4.40 ±0.55a
	WCPB5	4.00 ±0.00a	4.00 ±0.00a	4.20 ±0.45a	4.20 ±0.45a	4.20 ±0.45a	4.20 ±0.45a
	WCPB6	4.20 ±0.45a	4.20 ±0.45a	4.40 ±0.55a	4.20 ±0.45a	4.20 ±0.45a	4.20 ±0.45a
	WF	4.80 ±0.45a	4.80 ±0.45a	4.80 ±0.55a	4.80 ±0.55a	4.60 ±0.55a	4.60 ±0.55a
	Total	4.37 ±0.49	4.37 ±0.49	4.46 ±0.51	4.43 ±0.50	4.29 ±0.46	4.29 ±0.58
12 to 16	WCPB1	3.80 ±0.45a	3.80 ±0.45a	3.20 ±0.45a	3.00 ±0.00ab	3.20 ±0.45a	3.00 ±0.00a
	WCPB2	3.80 ±0.45a	3.80 ±0.45a	3.40 ±0.55a	3.20 ±0.45a	3.40 ±0.55a	3.40 ±0.55a
	WCPB3	3.60 ±0.55a	3.60 ±0.55a	3.00 ±0.00ab	3.20 ±0.45a	3.20 ±0.45a	3.00 ±0.71a
	WCPB4	4.00 ±0.00a	4.00 ±0.00a	3.40 ±0.55a	3.00 ±0.00ab	3.40 ±0.55a	3.20 ±0.45a
	WCPB5	4.00 ±0.00a	4.00 ±0.00a	3.20 ±0.44a	2.80 ±0.45b	3.20 ±0.45a	3.20 ±0.45a
	WCPB6	4.00 ±0.00a	4.00 ±0.00a	2.60 ±0.55b	3.40 ±0.55a	3.20 ±0.45a	3.20 ±0.45a
	WF	3.60 ±0.55a	3.60 ±0.55a	2.40 ±0.55b	3.40 ±0.55a	3.40 ±0.55a	2.80 ±0.46a
	Total	3.83 ±0.38	3.83 ±0.38	3.29 ±0.458	2.86 ±0.43	3.31 ±0.47	3.11 ±0.47
20	WCPB1	2.60 ±0.55a	3.40 ±0.55a	3.00 ±0.00a	-	2.40 ±0.55a	2.00 ±0.71b
	WCPB2	3.00 ±0.00a	3.80 ±0.45a	3.20 ±0.45a	-	2.60 ±0.55a	3.40 ±0.55a
	WCPB3	2.00 ±1.00ab	3.40 ±0.55a	3.00 ±0.00a	-	2.00 ±0.00a	2.00 ±0.00b
	WCPB4	2.40 ±0.55a	3.80 ±0.45a	3.20 ±0.45a	-	2.60 ±0.55a	3.20 ±0.45a
	WCPB5	2.00 ±0.45ab	3.80 ±0.45a	3.00 ±0.00a	-	2.80 ±0.45a	3.00 ±0.71a
	WCPB6	2.00 ±0.00ab	3.20 ±0.45a	3.20 ±0.45a	-	2.60 ±0.55a	2.80 ±0.45b
	WF	1.60 ±0.55b	3.20 ±0.45a	2.80 ±0.45a	-	2.20 ±0.45a	1.60 ±0.55b
	Total	2.26 ±0.66	3.51 ±0.51	3.06 ±0.34	-	2.46 ±0.51a	2.57 ±0.82

Samples with different superscripts within same roll differ significantly by Duncan's multiple test ($P < 0.05$). The hypothesis of this study states that there is no significant difference in the shelf life of cakes made from various composite flour blends (WCPB1, WCPB2, WCPB3, WCPB4, WCPB5, and WCPB6) compared to cakes made from one hundred percent (100%) wheat flour (WF).

The result in Table 3 shows that the F value for appearance of shelf life of all the cake samples was 0.630 and the significant value was 0.705 at $P \leq 0.05$ level. This shows that there was no significant difference among in the appearance of all the cake samples, including the control at P > 0.05 level in day 4 to 8. Therefore, the null hypothesis was accepted.

Table 3. ANOVA for Appearance of Shelf Life of All the Cake Samples (Day 4 to 8)

Appearance	Sum of Squares	df	Mean ($\bar{x}$) Square	F	Sig.	Decision
Between Groups	0.971	6	0.162	0.630	0.705	Accept
Within Groups	7.200	28	0.257			
Total	8.171	34				

The result in Table 4 indicated that the F value for colour within 4 to 8 days of all the cake samples was 2.667 and the significant value was 0.036 at P ≤ 0.05 level. This shows that significant difference colour exists in the colour of all the cake samples at P > 0.05 level. Therefore the null hypothesis was rejected at P > 0.05 level. The Duncan multiple comparison test showed that sample WF (control) was significantly different with WCPB4, WCPB5 and WCPB6 but does not differ with WCPB1, WCPB2 and WCPB3, therefore, the hypothesis was rejected. Samples WCPB1 and WCPB2 were not significantly different from WCPB3, WCPB4 and WF (control), but differ from WCPB5 and WCPB6 in colour attribute at P ≤ 0.05 level within days 4 to 8 of self life evaluation. Therefore, the hypothesis was also rejected. The sample WCPB3 was not significantly different from all the samples including the control. Sample WCPB4 was not significantly different from the rest of the samples except the control, while cake sample WCPB5 does not differ significantly from WCPB4 and WCPB6 but differ significantly from the rest of the samples; thus the hypothesis was rejected at P ≤ 0.05 level.

Table 4: ANOVA for Colour of Shelf Life of All the Cake Samples (Day 4 to 8)

Colour	Sum of Squares	df	Mean ($\bar{x}$) Square	F	Sig.	Decision
Between Groups	2.971	6	0.495	2.667	0.036	Reject
Within Groups	5.200	28	0.186			
Total	8.171	34				

The ANOVA Table 5 revealed that the F value for flavour within 4 to 8 days of all the cake samples was 0.333 and the significant value was 0.914 at P ≤ 0.05 level. This shows that there is no significant difference in flavour among all the cake samples including the control at P>0.05 level day 4 to 8. Hence, the null hypothesis was accepted. The null hypothesis of no significant difference in flavour of shelf life of cake samples was accepted at P ≤ 0.05.

Table 5. ANOVA for Flavour of Shelf Life of All the Cake Samples (Day 4 to 8)

Flavour	Sum of Squares	df	Mean ($\bar{x}$) Square	F	Sig.	Decision
Between Groups	0.571	6	0.095	0.333	0.914	Accept
Within Groups	8.000	28	0.286			
Total	8.571	34				

The result in Table 6 depict the F value for taste within 4 to 8 days of all the cake samples was 0.833 and the significant value was 0.554 at P ≤ 0.05 level. This shows that the taste of all the cake samples including the control does not differ at P > 0.05 level in day 4 to 8 of evaluation. Therefore, the null hypothesis was accepted. The null hypothesis of no significant difference in taste of shelf life of cake samples was accepted at P ≤ 0.05.

Table 6. ANOVA for Taste of Shelf Life of All the Cake Samples (Day 4 to 8)

Taste	Sum of Squares	df	Mean ($\bar{x}$) Square	F	Sig.	Decision
Between Groups	1.143	6	0.190	0.833	0.554	Accept
Within Groups	6.4 00	28	0.229			
Total	7.543	34				

The result in Table 7 indicated that the F value for texture within 4 to 8 days of evaluation of all the cake samples was 0.222 and the significant value was 0.996 at P ≤ 0.05 level. This shows the texture of all the cake samples does not differ significantly at P > 0.05 level in day 4 to 8 of evaluation. Therefore the null hypothesis was accepted at P > 0.05.

Table 7. ANOVA for Texture of Shelf Life of All the Cake Samples (Day 4 to 8)

Texture	Sum of Squares	df	Mean ($\bar{x}$) Square	F	Sig.	Decision
Between Groups	0.343	6	0.057	0.222	0.966	Accept
Within Groups	7.200	28	0.257			
Total	7.543	34				

The result in Table 8 shows that the F value for overall acceptability within 4 to 8 days of evaluation of all the cake samples was 1.774 with significant value of 0.146 at P ≤ 0.05 level. This indicated that the overall acceptability of all the cake samples does not differ significantly within day 4 to 8 of evaluation. Therefore, the null hypothesis of no significant difference in acceptability of shelf life of cake samples was accepted at P ≤ 0.05.

Table 8. ANOVA for Overall Acceptability of Shelf Life of All the Cake Samples (Day 4 to 8)

Acceptability	Sum of Squares	df	Mean ($\bar{x}$) Square	F	Sig.	Decision
Between Groups	1.943	6	0.324	1.744	0.148	Accept
Within Groups	5.200	28	0.186			
Total	7.143	34				

The result in Table 9 shows that the F value for appearance within day 12 to 16 of evaluation of all the cake samples was 1.133 with significant value of 0.369 at P ≤ 0.05 level. This indicated that the appearance of all the cake samples had no significant difference within day 12 to 16 of evaluation. Therefore, the null hypothesis of no significant difference in appearance of shelf life of cake samples was accepted at P ≤ 0.05.

Table 9. ANOVA for Appearance of Shelf Life of All the Cake Samples (Day 12 to 16)

Appearance	Sum of Squares	df	Mean ($\bar{x}$) Square	F	Sig.	Decision
Between Groups	0.971	6	0.162	1.133	0.369	Accept
Within Groups	4.000	28	0.143			
Total	4.971	34				

The result in Table 10 shows that the F value for colour within day 12 to 16 of cake samples evaluation was 1.133 and the significant value was 0.369 at P ≤ 0.05 level. This shows that the samples do not differ significantly in colour attributes within day 12 to 16 of evaluation at P > 0.05 level. Therefore, the null hypothesis of no significant difference in colour of the shelf life of cake samples was accepted at P ≤ 0.05.

Table 10. ANOVA for Colour of Shelf Life of All the Cake Samples (Day 12 to 16)

Colour	Sum of Squares	df	Mean ($\bar{x}$) Square	F	Sig.	Decision
Between Groups	0.971	6	0.162	1.133	0.369	Accept
Within Groups	4.000	28	0.143			
Total	4.971	34				

The result in Table 11 revealed that the F value for flavour within day 12 to 16 of shelf life evaluation of all the cake samples was 0.778 with significant value of 0.594 at P ≤ 0.05 level. This indicated that the flavour of all the cake samples does not differ significantly within day 12 to 16 of evaluation. Therefore, the null hypothesis of no significant difference in flavour of shelf life of cake samples was accepted at P ≤ 0.05.

Table 11. ANOVA for Flavour of Shelf Life of All the Cake Samples (Day 12 to 16)

Flavour	Sum of Squares	df	Mean ($\bar{x}$) Square	F	Sig.	Decision
Between Groups	1.200	6	0.200	0.778	0.594	Accept
Within Groups	7.200	28	0.257			
Total	8.400	34				

The result in Table 12 indicated that the F value for taste within day 12 to 16 of cake samples evaluation was 2.667 and the significant value was 0.036 at P ≤ 0.05 level. This shows significant difference in taste among all the cake samples including the control at P > 0.05 level in day 12 to 16 Therefore the null hypothesis was rejected. The Duncan multiple range test analysis showed that WF (control) was significantly difference with all the samples except WCPB5 and WCPB6; hence, the hypothesis was rejected at P ≤ 0.05 level.

Table 12. ANOVA for Taste of Shelf Life of All the Cake Samples (Day 12 to 16)

Flavour	Sum of Squares	df	Mean ($\bar{x}$) Square	F	Sig.	Decision
Between Groups	2.286	6	0.381	2.667	0.036	Reject
Within Groups	4.000	28	0.143			
Total	6.286	34				

The result in Table 13 shows that the F value for texture within day 12 to 16 of shelf life evaluation of all the cake samples was 0.222 with significant value of 0.966 at P ≤ 0.05 level. This indicated that there was no significant difference in texture of all the cake samples within day 12 to 16 of shelf life evaluation. Therefore, the null hypothesis of no significant difference in texture of shelf life of cake samples was accepted at P ≤ 0.05.

Table 13. ANOVA for Texture of Shelf Life of All the Cake Samples (Day 12 to 16)

Texture	Sum of Squares	df	Mean ($\bar{x}$) Square	F	Sig.	Decision
Between Groups	0.343	6	0.057	0.222	0.966	Accept
Within Groups	7,200	28	0.257			
Total	7.543	34				

The result in Table 14 depict the F value for overall acceptability within day 12 to 16 of shelf life evaluation of cake samples was 0.549 with significant value of 0.766 at P ≤ 0.05 level. This shows that the overall acceptability of all the cake samples does not differ significantly within day 12 to 16 of evaluation. Therefore, the null hypothesis was accepted at P > 0.05 level.

Table 14. ANOVA for Acceptability of Shelf Life of All the Cake Samples (Day 12 to 16)

Texture	Sum of Squares	df	Mean ($\bar{x}$) Square	F	Sig.	Decision
Between Groups	0.800	6	0.133	0.549	0.766	Accept
Within Groups	6.800	28	0.243			
Total	7.600	34				

The result in Table 15 shows that the F value for appearance on day 20 of shelf life evaluation of all the cake samples was 3.492 with significant value of 0.11 at P ≤ 0.05 level. This indicated that there was significant difference in appearance of all the cake samples in the 20th day of shelf life evaluation. Therefore, the null hypothesis was rejected at P > 0.05 level.

Table 15. ANOVA for Appearance of Shelf Life of All the Cake Samples (Day 20)

Texture	Sum of Squares	df	Mean ($\bar{x}$) Square	F	Sig.	Decision
Between Groups	6.286	6	1.048	3.492	0.11	Reject
Within Groups	8.400	28	0.300			
Total	14.686	34				

The result in Table 16 shows that the F value for colour on day 20 of shelf life evaluation of all the cake samples was 1.708 with significant value of 0.156 at P ≤ 0.05 level. This indicated that there was no significant difference in colour among all the cake samples in the 20th day of shelf life evaluation. Therefore, the null hypothesis was accepted at P > 0.05 level.

Table 16. ANOVA for Colour of Shelf Life of All the Cake Samples (Day 20)

Texture	Sum of Squares	df	Mean ($\bar{x}$) Square	F	Sig.	Decision
Between Groups	2.343	6	0.390	1.708	0.156	Accept
Within Groups	6.400	28	0.229			
Total	8.743	34				

The result in Table 17 indicated that the F value for flavour on the 20th day of shelf life evaluation of cake samples was 1.000 with significant value of 0.445 at P ≤ 0.05 level. This shows that there was no significant difference in flavour attribute among all the cake samples. Therefore, the null hypothesis was accepted at P > 0.05 level.

Table 17. ANOVA for Flavour of Shelf Life of All the Cake Samples (Day 20)

Texture	Sum of Squares	df	Mean ($\bar{x}$) Square	F	Sig.	Decision
Between Groups	0.686	6	0.114	1.000	0.445	Accept
Within Groups	3.200	28	0.114			
Total	3.686	34				

The result in Table 18 revealed that the F value for texture on the 20th day of shelf life evaluation of cake samples was 1.667 with significant value of 0.166 at P ≤ 0.05 level. This indicated that there was no significant difference in texture attribute of all the cake samples. Therefore, the null hypothesis was accepted at P > 0.05 level.

Table 18. ANOVA for Texture of Shelf Life of All the Cake Samples (Day 20)

Texture	Sum of Squares	df	Mean ($\bar{x}$) Square	F	Sig.	Decision
Between Groups	2.286	6	0.381	1.667	0.166	Accept
Within Groups	6.400	28	0.229			
Total	8.686	34				

The result in Table 19 indicated that the F value for overall acceptability on the 20th day of shelf life evaluation of cake samples was 0.833 with significant value of 0.554 at P ≤ 0.05 level. This indicated that the samples were not significantly different in overall acceptability of all the cake samples. Therefore, the null hypothesis was accepted at P > 0.05 level.

Table 19. ANOVA for Overall Acceptability of Shelf Life of All the Cake Samples (Day 20)

Texture	Sum of Squares	df	Mean ($\bar{x}$) Square	F	Sig.	Decision
Between Groups	1.143	6	0.190	0.833	0.554	Accept
Within Groups	6.400	28	0.229			
Total	7.543	34				

A good cake should possess good keeping quality, remaining fresh and moist for as long as possible under typical storage conditions. In this study, all composite cakes and the wheat control were stored at ambient temperature in clean containers and monitored for 20 days. Shelf life stability was assessed by a semi-trained panel using appearance, colour, flavour, taste, texture, and overall acceptability as indicators of quality. Overall, the sensory scores followed a typical shelf-life pattern: high acceptability at the beginning of storage, gradual decline in quality during intermediate storage, and clear signs of spoilage at the end of the 20-day period.

During the early storage days, all formulations, including the control, were rated in the "excellent" to "very good" range, indicating that partial substitution of wheat with cocoyam, plantain, and Bambara nut did not compromise initial consumer acceptability. As storage progressed, panelists reported progressive drying and firmness of the crumb, alongside reduced flavour intensity and overall acceptability. These changes are consistent with moisture loss, starch retrogradation, and fat oxidation, which are well-known mechanisms driving staling in cakes and other bakery products. As water migrates from the crumb and starch molecules reassociate, the texture becomes harder and less pleasant, while volatile flavour compounds dissipate, leading to lower scores for flavour and overall acceptability even when visible spoilage is not yet apparent.

By the intermediate storage period, most samples were still rated "good" and considered fit for consumption, but texture and flavour scores had declined relative to day 1. Panelists specifically noted that all cakes felt drier, suggesting that moisture loss was a key driver of sensory deterioration. Interestingly, the control (100% wheat) showed a faster decline in taste than most composite samples, which may reflect its higher susceptibility to starch retrogradation and its lack of additional fibre and protein from the non-wheat flours. Formulations with the highest levels of cocoyam, plantain, and Bambara nut (WCPB5 and WCPB6) also showed reduced taste scores at this stage, likely due to their denser crumb and higher fibre content, which can intensify the perception of dryness and reduce sweetness perception.

By day 20, visible mould growth was observed on most samples, particularly on the wheat control, and the panel therefore did not taste the cakes at this point for safety reasons. Appearance scores dropped to “fair” for nearly all formulations, and textures were also rated “fair”, reflecting both microbial spoilage and advanced staling. The control was the least accepted in overall acceptability at this stage, reinforcing the observation that 100% wheat cake was less shelf-stable than several composite formulations under the same conditions.

Within this overall pattern, composite cake WCPB2 (10% cocoyam, 5% plantain, 5% Bambara nut) consistently showed the best shelf-life performance, maintaining “good” appearance and relatively higher sensory scores up to day 20. Several mechanisms may explain this behaviour. First, the moderate level of substitution in WCPB2 appears to provide a balance between structural integrity and moisture management: the inclusion of cocoyam, plantain, and Bambara nut adds dietary fibre and protein, which are known to influence water-binding capacity and crumb structure. Adequate water binding can help slow down moisture loss and staling, while a well-structured crumb reduces crumbling and surface area exposed to air, thereby preserving texture and appearance for longer.

Second, the non-wheat flours used in WCPB2 likely contributed bioactive compounds such as phenolics and natural antioxidants from plantain and Bambara nut. These compounds may help to delay oxidative changes and, to a limited extent, microbial proliferation, especially at moderate inclusion levels where they do not overly disrupt cake structure or palatability. In contrast, higher substitution levels (as in WCPB5 and WCPB6) may introduce more fibre and stronger flavours, which can accelerate perceived dryness and reduce acceptability despite any potential antioxidant benefits.

Third, the better performance of WCPB2 compared with the control suggests that the composite formulation may have slightly modified water activity and substrate availability for moulds. Wheat-only cakes tend to have a relatively open crumb and readily available starch, which can support faster microbial growth once spores germinate. The presence of alternative starches and proteins, together with altered crumb structure in WCPB2, may have made the environment marginally less conducive to rapid mould development, at least in sensory terms.

The finding that WCPB2 maintained acceptable quality the longest is in line with previous work showing that moderate levels of composite flour substitution can enhance the functional and keeping qualities of baked products, while excessive substitution may compromise sensory properties. Amer (2018), for example, reported delayed onset of visible mould growth in composite cakes fortified with citrus essential oils, highlighting how formulation and ingredient choice can extend shelf life. Similarly, studies on composite cakes and cookies using root, tuber, and legume flours have reported that formulations combining modest substitution levels and fibre- or antioxidant-rich ingredients tend to show slower declines in sensory scores during storage, particularly in appearance and flavour, compared with 100% wheat controls.

Taken together, these results indicate that composite cakes containing cocoyam, plantain, and Bambara nut can match or even exceed the shelf-life performance of conventional wheat cakes, provided that substitution levels are optimized. In this study, WCPB2 emerged as a promising formulation, balancing acceptable sensory quality with improved storage stability under ambient conditions. For adolescent consumers, who often snack on cakes stored at room temperature without refrigeration, such formulations may offer safer, more stable, and nutritionally enhanced products, supporting both product quality and the broader goal of leveraging indigenous crops in snack development.

4. Conclusion

In relation to the first objective, the study showed that cakes produced from composite flours of wheat, cocoyam, plantain, and Bambara nut were as acceptable as the 100% wheat flour control at the beginning of storage, with all seven formulations receiving “excellent” sensory ratings during the first four days, indicating that partial substitution did not compromise initial consumer liking. With respect to the second objective, the results revealed a gradual decline in appearance, flavour, texture, and overall acceptability after day 8 for all samples, with significant differences emerging mainly in taste and appearance as storage progressed; mould growth became evident by day 20, particularly in the 100% wheat cake, and reduced consumer acceptability across samples, while among the composite formulations WCPB2 (10% cocoyam, 5% plantain, 5% Bambara nut) showed the most favourable shelf-life profile, maintaining better scores for appearance and overall acceptability at later storage times. Overall, these findings indicate that incorporating cocoyam, plantain, and Bambara nut into wheat flour can yield nutritionally enriched cakes with acceptable initial sensory qualities and reasonable shelf stability under ambient conditions, thereby supporting the use of underutilized indigenous crops as partial wheat substitutes in bakery applications and contributing to reduced wheat dependency and improved local food and nutrition security.

Data Availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Conflicts of Interest

All authors in this publication declare no conflict of interest regarding the title, data, location, and results of the research.

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Supplementary Materials

This study does not include any supplementary materials.

Declaration on AI Use

The authors declare that no artificial intelligence (AI) or AI-assisted tools were used in the preparation of this manuscript. AI were used only to improve readability and language under strict human oversight; no content, ideas, analyses, or conclusions were generated by AI.

References

Adegunwa, M. O., Oloyede, I. O., Adebanjo, L. A., & Alamu, E. O. (2019). Quality attribute of plantain (Musa paradisiaca) sponge-cake supplemented with watermelon (Citrullus lanatus) rind flour. *Cogent Food & Agriculture*, *5*(1), 1631582.

Akinjayeju, O., Ijarotimi, O. S., Awolu, O. O., & Fagbemi, T. N. (2020). Nutritional composition, glycaemic properties and anti-diabetic potentials of cereal-based soy-fortified flours for functional dough meal in diabetic induced rats. *Journal of Food Science and Nutrition Research, 3*(2), 102–120. https://doi.org/10.26502/jfsnr.2642-11000042

Akusu, O. M., Kiin-Kabari, D. B. & Ebere, C. O. (2016). Effect of substituting levels on the physicochemical and sensory properties of cake and chin-chin made from wheat/cocoyam flour blends. *International Journal of Food and Nutrition Science, 5*(4), 2320–7876.

Amer, T. A. M. (2018). Effect of lemon and orange oils on shelf life of cake. *Middle East Journal of Applied Sciences, 8*(4), 1364–1374.

Abraham, A. (2015). *Public health nutrition intervention to delay the progression of HIV to AIDS among people living with HIV (PLWHIV) in Abuja, Nigeria* (Doctoral dissertation, University of Westminster).

Arubayi, D., & Ogbonyomi, O. B. (2019). Recipe development and organoleptic evaluation of meat pies made from plantain composite flour for wealth creation. *Food Science & Nutrition Research*, *2*(2), 1–7.

Ayanwale, A. B., Fatunbi, A. O., & Ojo, M. (2016). Innovation opportunities in plantain production in Nigeria. In *Guide Book 1. Forum for Agricultural Research in Africa (FARA), Accra, Ghana*.

Bader, U. l., Ain, H., Saeed, F., Ahmad ,N., Imran, A., & Niaz, B. (2018) Functional and health-endorsing properties of wheat and barley cell wall's non-starch polysaccharides. *International Journal of Food Properties, 21*(1), 1463–1480.

Chadare, F. J., Idohou, R., Nago, E., Affonfere, M., Agossadou, J., Fassinou, T. K., Kénou, C., Honfo, S., Azokpota, P., Linnemann, A. R., & Hounhouigan, D. J. (2019). Conventional and food-to-food fortification: An appraisal of past practices and lessons learned. *Food Science & Nutrition*, *7*(9), 2781–2795.

Chawla, R., Sivakumar, S., Mishra, S. K., Kaur, H., & Anurag, R. K. (2021). Modified atmosphere packaging for milk cake: Assessment of ideal gas composition for extending shelf life. *British Food Journal*, *123*(8), 2893–2906.

D'Souza, A. A., Kumari, D., & Banerjee, R. (2017). 15 - Nanocomposite biosensors for point-of-care—evaluation of food quality and safety. *Nanobiosensors*, 629–676. https://doi.org/10.1016/B978-0-12-804301-1.00015-1

Damfami, A., & Namo, O. A. T. (2020). Bambara groundnut (Vigna subterranea (L.) Verd.): A review of its past, present and future role in human nutrition. *Journal of Agricultural Meteorology, 3*(1), 274–281.

D'Auria, E., Borsani, B., Pendezza, E., Bosetti, A., Paradiso, L., & Verduci, E. (2020). Complementary feeding: Pitfalls for health outcomes. *International Journal of Environmental Research and Public Health, 17*(21), 7931. https://doi.org/10.3390/-ijerph17217931

Dwyer, J. T., Wiemer, K. L., Dary, O., Keen, C. L., & King, J. C. (2015). Fortification and health: Challenges and opportunities. *Advances in Nutrition, 6*(1), 124–131.

Ebewore, S. O. (2020). Rural folks perception of suicide drivers in rural communities of delta state, Nigeria: Implications for Societal and Agricultural Security. *Open Agriculture*, *5*(1), 50–62.

Enwereji, N. A., Ohamobi, G. N., & Nwokeji, E. (2022). Assessing the relationship between utilization of computer and academic achievement of postgraduate students in degree awarding institutions in Anambra State. *European Journal of Research and Reflection in Educational Sciences, 10*(1), 2–15.

FAO. (2012). *FAO Statistical year book. World food and agriculture*. Rome, Italy.

Haouet, M. N., Tommasino, M., Mercuri, M. L., Benedetti, F., Di Bella, S., Framboas, M., Pelli, S., & Altissimi, M. S. (2019). Experimental accelerated shelf life determination of a ready-to-eat processed food. *Italian journal of food safety, 7*(4), 6919.

Idigo, B. C. (2022). Terrorism and national security in Nigeria: A case of Boko-Haram, 2009–2019. *International Journal of General Studies, 2*(1), 86–105.

Idigo, B. C. (2024). Cross border migration and human security in Nigeria. *Journal of Education, Humanities, Management & Social Sciences (JEHMSS), 1*(1), 37–60.

Kalu, C. L. O., Emegha, N., Bosah, P. C., & Idigo, B. C. (2025). The effects of climate change on food security in Nigeria: A review. *International Journal of Research and Scientific Innovation, 12*(4), 1–12.

Kiin-Kabari, D. B., & Banigo, E. B. (2015). Quality characteristics of cakes prepared from wheat and unripe plantain flour blends enriched with Bambara groundnut protein concentrate. *European Journal of Food Science and Technology, 3*(3), 1–10.

Kruger, J., Taylor, J. R., Ferruzzi, M. G., & Debelo, H. (2020). What is food-to-food fortification? A working definition and framework for evaluation of efficiency and implementation of best practices. *Comprehensive Reviews in Food Science and Food Safety*, *19*(6), 3618–3658.

Lebot, V., & Lawac, F. (2017). Quantitative comparison of individual sugars in cultivars and hybrids of taro [Colocasia esculenta (L.) Schott]: Implications for breeding programs. *Euphytica*, *213*(7), 147.

Mashau, M. E., Mabodze, T., Tshiakhatho, O. J., Silungwe, H., & Ramashia, S. E. (2020). Evaluation of the content of polyphenols, antioxidant activity and physicochemical properties of tortillas added with Bambara groundnut flour. *Molecules*, *25*(13), 3035.

Neufeld, L. M., Baker, S., Garrett, G. S., & Haddad, L. (2017). Coverage and utilization in food fortification programs: critical and neglected areas of evaluation. *The Journal of nutrition*, *147*(5), 1015S–1019S.

OECD. (2015). *Education at a glance 2015*. https://www.oecd.org/en/publications/2015/11/education-at-a-glance-2015_g1g59741.html

Ogbonyomi, O. B., Diana, O. A., & Azonuche, J. E. (2023). Nutritional composition and sensory evaluation of cakes fortified with plantain, soybeans and sesame seed for sustainable economic development. *Konfrontasi: Jurnal Kultural, Ekonomi dan Perubahan Sosial*, *10*(4), 204–222.

Ohamobi, I. N., Manafa, I. F., & Osegbue, G. C. (2020). Curriculum implementation in secondary school on national cohesion and global competitiveness. *Journal of Contemporary Education Research, 20*(8), 30–40.

Okafor, N. C., Ohamobi, I., & Manafa, I. (2021). Strategies for promoting sustainable development and quality assurance in secondary schools in Anambra State. *Journal of Educational Research and Development, 4*(2), 62–71.

Okonkwo, A. E., & Idigo, B. C. (2025). Erosion of institutional efficacy: The nexus between governance failures and escalating insecurity in Nigeria. *International Journal of Academic Multidisciplinary Research, 8*(10), 122–127

Orhevba, B. A., & Ndanaimi, Y. (2021). Proximate and sensory properties of wheat-cocoyam (colocasia esculenta) composite bread. *European Journal of Agriculture and Food Sciences, 3*(2), 86–90.

Osegbue, G. C., Ohamobi, I. N., Ekwe, N. I., & Alordiah, C. O. (2025). AI-enhanced crisis management in schools. *Nigerian Journal of Social Psychology, 8*(1), 3–15.

Pellegrino, R., & Luckett, C. R. (2020). Aversive textures and their role in food rejection. *Journal of Texture Studies, 51*(5), 733–741. https://doi.org/10.1111/jtxs.12543

Phimolsiripol, Y., & Suppakul, P. (2016). Techniques in shelf life evaluation of food products in reference module in food science. *Reference Module in Food Science*, 1-8. https://doi.org/10.1016/B978-0-08-100596-5.03293-5

World Food Programme. (2022). *Food fortification: An effective and safe way to fight micronutrient malnutrition and its consequences*. https://www.wfp.org