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QUANTIFYING THE INFLUENCE OF *HIBISCUS SABDARIFFA* (ROSELLE) ON COMPOSITIONAL STABILITY AND SENSORIAL ATTRIBUTES OF LOCALLY FOOD FORMULATIONS FOR WEANING AGE

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Abstract

Utilization of nutrient-dense plant-based ingredients in essential in targeting adequate infant and child nutrition. This study explored the effect of Hibiscus sabdariffa (roselle) fortification on the nutrient stability and sensory acceptability of locally formulated foods. Two formulations were developed: WFF-2R (2% roselle-fortified) and WFF-0R (0% roselle, control), using pearl millet, pigeon pea, sesame seeds, and carrot. The formulations were stored under refrigerated (5 °C), room (27 °C), and accelerated (40 °C) conditions for 0, 6, and 12 weeks. Nutrient stability analyses including carbohydrate, protein, fat, vitamins A and E, and selected minerals (iron, zinc, and calcium) as well as sensory attributes were determined using standard procedures. Storage temperature and duration significantly ($p < 0.05$) affected compositional stability and sensory quality in both formulations. At baseline, carbohydrate content was higher in WFF-0R d (73.518%) than WFF-2R (54.179%), while protein content was higher in WFF-2R (12.146%). After 12 weeks of storage at 5°C, WFF-2R showed higher retention of protein: 7.54%, vitamin A: 0.3426, vitamin E: 0.6211, and calcium: 5.122 as compared with WFF-0R: 6.55%, 0.3321, 0.5634, and 4.968, respectively. Iron and zinc showed fluctuations across storage conditions, with relatively higher stability at lower temperatures. Sensory evaluation indicated that WFF-2R consistently had higher acceptability scores than WFF-0R, with better aroma (3.70), taste (3.35), and overall acceptability (3.85) at 5°C after 12 weeks. Refrigerated storage (5°C) better preserved nutrient composition and sensory quality, while accelerated storage (40°C) led to greater deterioration. The inclusion of Hibiscus sabdariffa improved nutrient stability and sensory acceptability, suggesting its potential as a functional fortifier in enhancing the nutritional stability and consumer acceptability of complementary foods during storage.

1- Introduction

"Hidden Hunger" refers to micronutrient deficiencies that are not necessarily shown in anthropometric measurements and thus remain hidden. It affects 2 billion people globally, and occurs among infants and young children on a "healthy diet," as perceived by family members (Elizabeth & Koshy, 2024). Hidden hunger is recognizable with a high index of suspicion and hence the term "micronutrient hunger" has been proposed. Maternal deficiencies, changing breastfeeding trends, suboptimum infant and young child feeding practices, and universal availability and popularization of junk food result in emerging and re-emerging nutritional disorders that need to be addressed urgently (Iqbal et al., 2026).

Global and regional malnutrition estimates for the indicators stunting, severe wasting, wasting and overweight describe the magnitude and patterns of under- and overnutrition (Arif et al., 2026a). Good nutrition is the bedrock of child survival and development, but today, many children are not getting the nutrients they need to survive and thrive (Urooj et al., 2026a). 1 young child in 4 globally has a diet so restricted it is likely to harm their growth, brain development and chances of survival (Lay, 2024). The first report from Unicef, to assess the diets of under-fives, found about 181 million from almost 100 countries were consuming, at most, only 2 food groups on a daily basis typically milk with a starchy food such as rice, maize or wheat. are up to 50% more likely to experience severe forms of malnutrition (Mazzocchi et al., 2026; Butt et al., 2026).

Complementary feeding is a critical window for child growth and long-term health (Lutter et al., 2021). Traditional complementary foods (TCFs) are usually produced from local staple sources with traditional techniques such as fermentation, malting, and germination, which can improve nutrition and food safety outcomes (Arif et al., 2026b; Adeoye et al., 2024). To enhance the food and nutrition security of weaning children, a climate-resilient and cost-effective strategy is needed that combines local processing technologies and food to food fortification (Bai et al., 2021; Urooj et al., 2026b). Most people around the world still tracing historical and projected changes in global food systems toward alignment with the new Healthy Diet Basket (HDB) used by UN agencies and the World Bank to monitor the cost and affordability of healthy diets worldwide to measure adequacy of national, regional and global supply-demand balances (Izuakor et al., 2024; Naqvi et al., 2025). A minority of households can afford the nutrient-adequate diet at either bound, with 20% of households able to afford the (upper bound) shared diets and 38% the individualized (lower bound) diets. Individualized diets are more frequently feasible with locally available foods (90% vs. 60% of the time) and show more moderate seasonal fluctuation (Schneider et al., 2022; Oladiran & Emmambux, 2022).

Plants have played an important role in the life of human being as they provide the basic need of mankind, that is food, clothing, shelter, and medicines (Singh et al., 2017; Shabbir et al., 2026). In recent years, focus on plant research has increased globally to find out the immense potential of plants used in various traditional formulations; one among them is *Hibiscus sabdariffa,* known for its delicacy and medicinal properties which has several health benefits (Riaz & Chopra, 2018; Fazal et al., 2026).

Hibiscus sabdariffa, commonly known as Roselle, jamaica (in Spanish), red sorrel (in English), or karkadeh (in Arabic), is a tropical species extensively cultivated in tropical and subtropical regions worldwide (Izquierdo-Vega et al., 2020; Almajid et al., 2023). It has a long history of uses, mainly focused on culinary, botanical, floral, and medicinal uses (Pimentel-Moral et al., 2024; Hernández-Hernández et al., 2024). Latter being of great therapeutic properties, has been attributed being rich in phytochemicals, mainly phenolic acids, flavonoids, anthocyanins, and organic acids (citric, hydroxycitric, hibiscus, tartaric, malic, and ascorbic) (Urooj et al., 2026c; Li et al., 2024).

Pigeon pea (*Cajanus cajan (L) Millsp*), belongs to the family leguminoseae, contains 20 to 22% protein, 1.2% fat, 65% carbohydrate, and 3.8% ash. Its utilization is generally low because of its tough testa which makes its cooking time long and increase fuel, and processing time (Soloon et al.,

2017; Rani et al., 2024). All products obtained from soya beans can be produced from pigeon pea. Pearl Millet (*Penninsetum americanum*) is not toxic at any stage, and it contains higher protein content (8-19%) than most cereals (Oyarekua et al., 2022; Yang et al., 2024a). Millet is rich in minerals, vitamins, and methionine. Carrots (*Daucus carota*) of Apiaceae family have high levels of betacarotene, which is converted to vitamin A within the body (Ortenzi & Beal, 2021; Bianchi & Venturi, 2025).

In the face of increasing global demand, shifting consumer, shelf life is not merely a label datum: it encapsulates complex interactions among microbial ecology, physicochemical stability, packaging systems, supply chain logistics, and consumer behavior (Zakaria et al., 2025; Yusuf et al., 2022). In recent decades, synthetic preservatives and high-intensity treatments toward milder, integrative, and sustainable strategies that better preserve nutritional and sensory attributes while reducing waste and aligning with the "clean label" movement (Martínez & Carballo, 2024; Akdemir Evrendilek, 2026). Despite these advances, the selected quality indicators are monitored as a function of time under storage conditions that mimic foreseeable conditions which enhance deteriorative reactions (Ameye et al., 2025; Yang et al., 2024b).

Therefore, the present study aimed to formulate roselle-fortified weaning foods using locally available ingredients and to evaluate the effect of roselle incorporation on compositional stability and sensory attributes during storage under refrigerated, room, and accelerated conditions. The findings from this study are expected to contribute to the development of affordable, nutrient-dense and shelf stable complementary foods suitable for infant feeding. This research supports food-based strategies aimed at reducing childhood malnutrition and Improving food security.

2- Materials and Methods

Selection of raw materials

Pearl millet (*Pennisetum glaucum*), pigeon pea (*Cajanus cajan*), sesame seeds (*Sesamum indicum*), carrots (*Daucus carota*), and roselle (*Hibiscus sabdariffa*) were sourced from a local central market in Faisalabad, Punjab, Pakistan, a major regional agricultural hub. High quality raw materials were manually selected based on physical uniformity, freshness, and absence of visual infestation, damage, or mold. All processing, sample formulation, and analytical procedures were conducted under aseptic conditions in a food testing laboratory to minimize contamination risk. All chemicals, solvents, and analytical reagents were of analytical grade and procured from certified scientific suppliers in Faisalabad, Pakistan.

Preparation of pearl millet, pigeon pea, and sesame seeds

Pearl millet, pigeon pea, and sesame seeds were manually sorted, washed, and toasted separately before milling. Pigeon pea was toasted at 135°C for 25 min to reduce beany flavour and improve protein digestibility, pearl millet at 125°C for 15 min to enhance flavour (Kumari et al., 2024), and sesame seeds at 115°C for 10 min to improve aroma and reduce moisture. Before milling, the laboratory blender was sterilized by running it for 2 min to minimize microbial contamination (Obinna-Echem et al., 2021). Each sample was milled separately into fine flour, with pigeon pea flour additionally sieved through muslin cloth. The flours were stored in airtight polyethylene bags until formulation.

Preparation of carrot and roselle powders

Fresh carrot and roselle calyces were thoroughly washed under running water to remove adhering soil particles and impurities. The carrot samples were sliced using a stainless-steel knife into thin pieces, while roselle calyces were cleaned and sorted manually. The carrot slices and roselle calyces were oven dried at 60°C for 6 hours. They were separately blended into fine powders using a previously sterilized blender. The powders were stored in separate airtight polyethylene bags before food formulation.

Food formulations

Two food formulations designated as WFF-2R and WFF-0R were formulated using different

proportions of processed raw materials. The formulation was carried out using the NutriSurvey 2007, a commercial German software (EBISpro) developed by Dr. Juergen Erhardt for nutrient composition analysis. The software was used to estimate the nutrient composition of the formulated weaning foods and to ensure that the ingredient combinations met the nutritional requirements for complementary feeding. The ingredients for each formulation were accurately weighed using a digital weighing balance and mixed thoroughly in a clean, dry stainless-steel bowl to ensure homogeneity of the flours and powders. Formulated food samples were packaged in airtight plastic containers, and the composition is presented in Table 1.

Table 1. Composition of Weaning Food Formulations Fortified with Roselle Powder

Ingredients (%)	**Weaning Food Formulations (WFF)**	
	Roselle powder fortification (%)	
	2%	0%
Pearl millet (*Pennisetum glaucum*) flour	45	45
Pigeon pea (*Cajanus cajan*) flour	30	30
Carrot (*Daucus carota*) powder	15	15
Sesame (*Sesamum indicum*) seed flour	8	10
Roselle (*Hibiscus sabdariffa*) powder	2	0
Sample code	**WFF-2R**	**WFF-0R (Control-type)**



Figure 1: Pictorial representation of two formulations

Nutritional and sensory analyses were performed before storage. WFF-2R and WFF-0R were then packaged in plastic containers and stored at 5°C, 27°C, and 40°C. Nutrient stability and sensory acceptability were evaluated at 0, 6, and 12 weeks. Proper labeling and handling were maintained

throughout storage to prevent cross-contamination.

Table 2. Storage Design for Roselle-Fortified Weaning Food Formulations (WFF) under Different Storage Conditions

Factors	Experimental Levels	Descriptions
Formulations	2 levels	WFF-3R (2% roselle fortification), WFF-0R (0% roselle fortification)
Storage conditions	3 levels	Refrigerated (5°C), Room (27°C), Accelerated (40°C)
Analysis intervals	3 levels	0, 6, and 12 weeks

Nutritional Composition Analysis

Total carbohydrate, crude protein, and crude fat contents of the formulated weaning food samples were determined using standard analytical methods with minor modifications. Total carbohydrate was quantified by the Anthrone method following Tivkaa et al. (2025). Acid-hydrolyzed samples were reacted with freshly prepared anthrone reagent, and absorbance was measured at 630 nm using a UV-Vis spectrophotometer. Carbohydrate content was calculated and expressed as a percentage (%). Crude protein was determined using the Kjeldahl method (Shtylla et al., 2024; Atique et al., 2026). Samples were digested with concentrated H_2SO_4 in the presence of a $CuSO_4$-Na_2SO_4 catalyst, followed by alkaline distillation and titration with 0.01 M HCl. Nitrogen content was calculated from the titration values, and crude protein was obtained using a conversion factor of 6.25. Crude fat content was determined by petroleum ether solvent extraction according to Bhardwaj et al. (2023). 2 g of each sample was extracted with petroleum ether, and the solvent was evaporated. The remaining fat residue was dried to constant weight at 105°C, and crude fat was calculated and expressed as percentage (%).

Quantification of Vitamin A by Spectrophotometric Method

Vitamin A content in WFF-2R and WFF-0R samples was determined by alkaline saponification, solvent extraction, and UV-Vis spectrophotometry following modified methods (Słowik-Borowiec et al., 2023; Moxness Reksten et al., 2020). 1 g of sample was refluxed with absolute ethanol and 50% KOH at 80°C for 30 min, followed by extraction with diethyl ether, isopropyl alcohol, and *n*-hexane. The hexane layer containing vitamin A was collected, and absorbance was measured at 420 nm against *n*-hexane as the blank. Vitamin A concentration was calculated from a standard calibration curve and expressed as mg/100 g.

Quantification of Vitamin E by Spectrophotometric Method

Vitamin E was determined according to Azadovna et al. (2026) and Asif et al. (2025a) with slight modifications. 1 g of sample was refluxed with 12% ethanolic sulfuric acid at 80°C for 30 min, extracted with diethyl ether, evaporated to dryness, and reconstituted in absolute ethanol. After reaction with concentrated nitric acid for 5 min, absorbance was measured at 410 nm using ethanol as the blank. Vitamin E content was quantified using a standard calibration curve.

Quantification of Mineral Elements by Atomic Absorption Spectrophotometry (AAS)

Mineral contents (Fe, Zn, and Ca) were determined by wet acid digestion followed by atomic absorption spectrophotometry (Benabid et al., 2024). 2 g of sample was digested with a HNO_3:$HClO_4$:H_2SO_4 (10:4:1, v/v/v) acid mixture at 200°C, diluted to 50 mL with deionized water, filtered, and analyzed using an Agilent FS240AA Atomic Absorption Spectrophotometer. Mineral concentrations were quantified using external calibration standards.

Sensorial Attributes

Sensory evaluation was carried out through the method adopted by Obinna-Echem et al. (2021) and Kumari et al. (2024). Sensory assessment was done through a panel of 20 members, including mothers and caregivers recruited from the Faisalabad community. Before the assessment, panelists were briefed about the procedure and sensory scorecard used for evaluation. Slurry foods were made from WFF-2R and WFF-0R by dissolving measured quantities of formulated flour blends in warm potable water and cooked gently under mild heat until a smooth consistency was achieved. Prepared samples were coded with random 3-digit numbers and served in identical containers to minimize bias during evaluation. Drinking water was provided to panelists before each sample evaluation to rinse the mouth in between. Attributes evaluated include appearance, aroma, taste, mouthfeel, and overall acceptability using a 5-point hedonic scale where 1 = dislike extremely and 5 = like extremely, as mentioned by Asif et al. (2025b) and Fatima et al. (2026). Sensory evaluation was conducted at 0-, 6-, and 12-weeks during refrigerated (5°C), room (27°C), and accelerated (40°C). Evaluation was done in a well-lit and well-ventilated environment.

Statistical Analysis

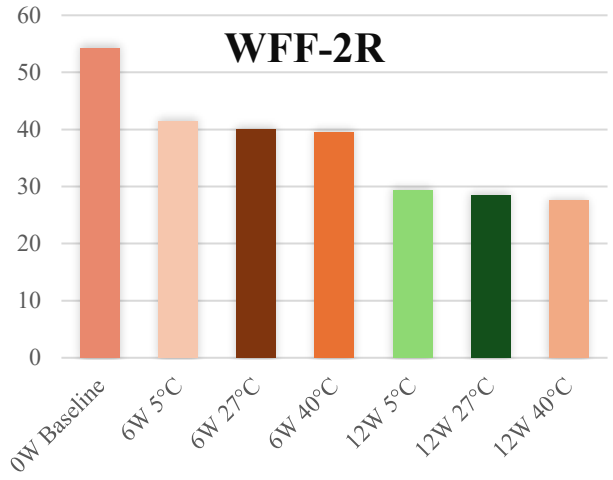
Nutrient analyses were conducted as a one-off procedure, and the results obtained were carried out in triplicate, and results were expressed as mean ± standard deviation (Asif et al., 2023; Fatima et al., 2025; Zahid et al., 2025). The Tukey test was used for separating means that had a significant difference at $p < 0.05$.

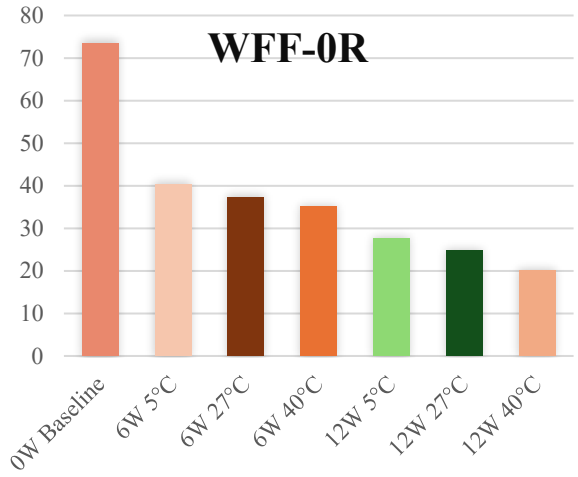
3- Results and Discussions

Nutritional Composition

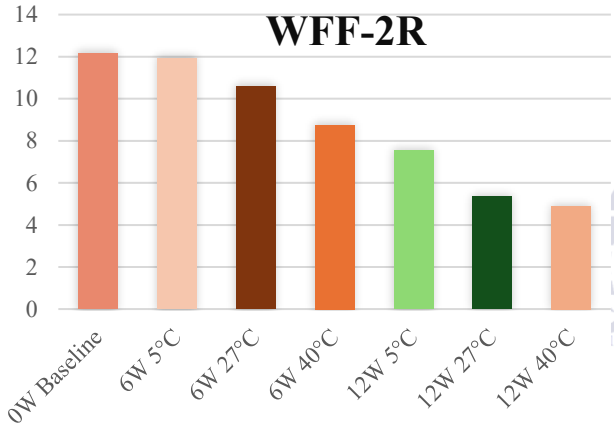
Carbohydrate concentration in both formulations (WFF-2R and WFF-0R) exhibited a progressive decline as storage duration and temperature increased ($p < 0.05$) as shown in Figure 2. Baseline values were higher in WFF-0R (73.52%) than in WFF-2R (54.18%), showing the absence of roselle and a higher proportion of sesame seeds. Following 12 weeks of storage, carbohydrate losses peaked under accelerated conditions (40°C), dropping to 27.51% in WFF-2R and 20.18% in WFF-0R. Across all intervals and temperatures, WFF-2R demonstrated superior carbohydrate retention, aligning with previous observations that spice supplementation (Alabi et al., 2025; Dilrukshi, 2022) and roselle incorporation (Adepeju et al., 2024) enhance the storage stability of cereal-based complementary foods. Roselle fortification significantly attenuated thermal and oxidative protein degradation throughout the 12 weeks trial. Baseline protein content was elevated in WFF-2R (12.15%) relative to WFF-0R (10.90%). Although elevated storage temperatures accelerated protein loss in both samples, WFF-2R consistently preserved higher protein levels. By week 12, protein content dropped drastically at 40°C (4.90% in WFF-2R vs. 3.82% in WFF-0R), whereas refrigeration (5°C) best minimized degradation (7.54% vs. 6.55%, respectively). These results confirm the protective role of antioxidant-rich roselle in suppressing oxidative protein loss (Ijarotimi, 2022a; Ijarotimi et al., 2022b). Fat content of WFF-2R declined progressively from a baseline of 15.00% to 5.74% (5°C) and 7.38% (40°C) after 12 weeks, driven by hydrolytic and oxidative lipid breakdown. Notably, samples stored at elevated temperatures (27°C and 40°C) maintained higher apparent fat percentages than those at 5°C. This counterintuitive trend is attributed to thermal moisture loss, which creates a dry-matter concentration effect that masks absolute lipid degradation (Muscolo et al., 2024).

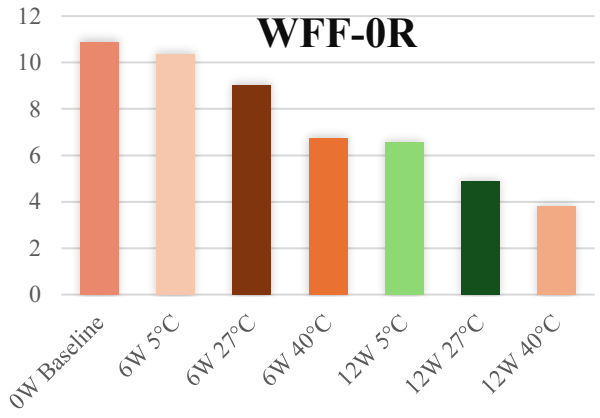
A) Carbohydrate



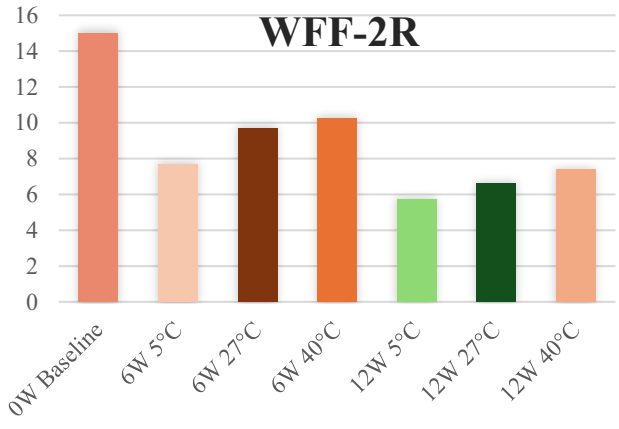


B) Protein





C) Fat



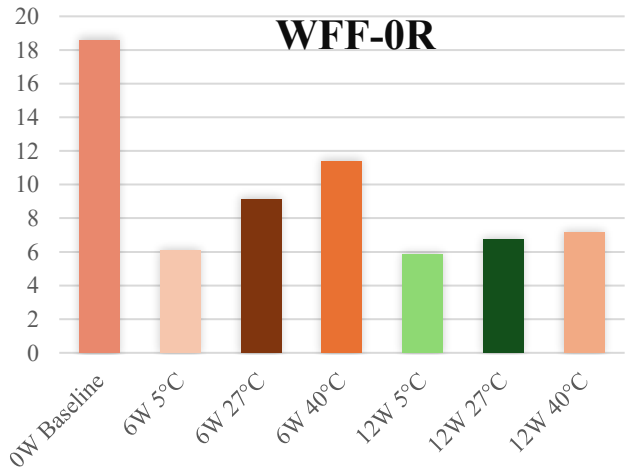


Figure 2. Effect of roselle (Hibiscus sabdariffa) fortification and storage conditions on composition of weaning food formulations (A) carbohydrate content, (B) protein content, and (C) fat content

Vitamin A

At baseline (0 weeks), vitamin A content was higher in WFF-2R (0.4783) compared with WFF-0R (0.4278), indicating that formulation differences influenced initial retention of fat-soluble vitamins. After 6 weeks of storage, vitamin A content declined in both formulations under all storage conditions. In WFF-2R, values decreased to 0.43 at 5°C, 0.4111 at 27°C, and 0.36 at 40°C. A similar decreasing trend was observed in WFF-0R, where vitamin A was reduced to 0.4035 (5°C), 0.3709 (27°C), and 0.26 (40°C). Highest losses occurred under accelerated storage (40°C), indicating that elevated temperature significantly accelerates vitamin A degradation. However, WFF-2R consistently retained higher vitamin A levels than WFF-0R across all storage conditions, suggesting a protective effect of roselle on vitamin stability. At 12 weeks of storage, a further decline in vitamin A content was observed in both formulations. In WFF-2R, vitamin A decreased to 0.3426 at 5°C, 0.2977 at 27°C, and 0.2141 at 40°C. In WFF-0R, values dropped more sharply to 0.3321 (5°C), 0.2755 (27°C), and 0.1238 (40°C). The greatest reductions were observed under accelerated storage conditions, confirming that prolonged exposure to heat intensifies degradation of fat-soluble vitamins. Overall, vitamin A content decreased progressively with increasing storage duration and temperature in both formulations. However, WFF-2R consistently exhibited higher retention of vitamin A compared with WFF-0R at all storage points, indicating that roselle incorporation improved the oxidative stability and preservation of vitamin A during storage. These findings are consistent with previous reports that fat-soluble vitamins are highly sensitive to heat- and oxygen-induced oxidation during storage Hassan et al. (2025) and Edkaidek et al. (2026), while natural antioxidants in plant-based ingredients can enhance vitamin stability in formulated foods.

Vitamin E

Vitamin E content was higher in WFF-2R than in WFF-0R at pre-storage, indicating that roselle enhanced the retention of fat-soluble vitamins in the formulation. At baseline (0 weeks), vitamin E content in WFF-2R was 0.7676. A general decline in vitamin E content was observed after storage under all conditions, indicating progressive degradation during storage. After 6 weeks of storage, vitamin E content decreased to 0.6868 at 5°C, 0.6533 at 27°C, and 0.584 at 40°C. This trend shows that higher storage temperature accelerated vitamin E loss, with the greatest reduction observed under accelerated storage (40°C). Despite this decline, the rate of loss was relatively moderate, suggesting partial protection of vitamin E within the formulation matrix. At 12 weeks of storage, vitamin E content further declined to 0.6211 at 5°C, 0.5975 at 27°C, and 0.524 at 40°C. The continued reduction across all storage conditions indicates ongoing degradation over time, likely due to oxidative reactions, since vitamin E is highly sensitive to oxygen, heat, and light exposure. Overall, vitamin E content decreased progressively with increasing storage duration and temperature in WFF-2R. The highest retention was consistently observed under refrigerated storage (5°C), while the lowest values occurred under accelerated conditions (40°C), confirming the strong influence of temperature on vitamin E stability. The observed decline aligns with established findings that fat-soluble vitamins undergo oxidation during prolonged storage, particularly at elevated temperatures Irshad et al. (2023).

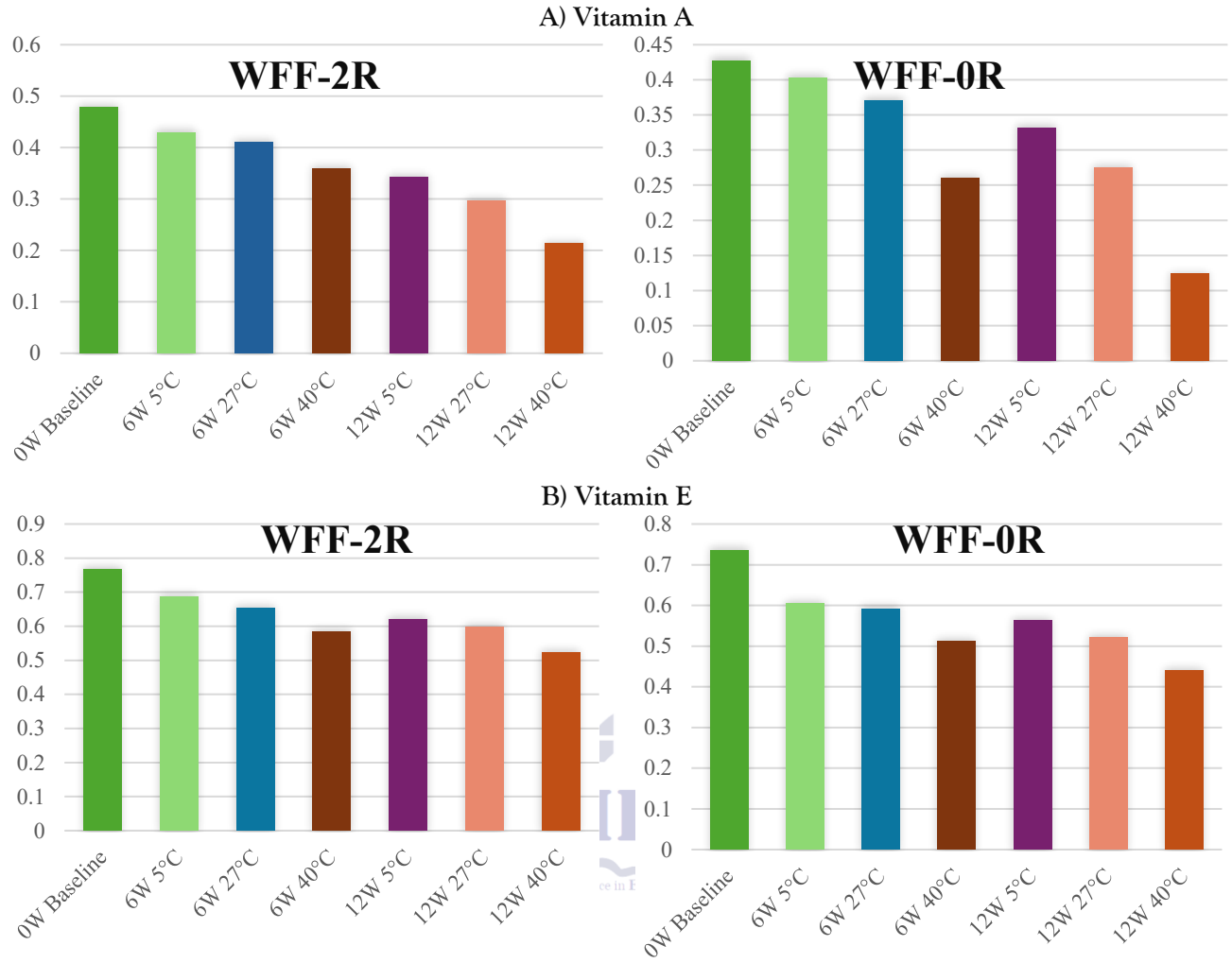


Figure 3. Effect of roselle (Hibiscus sabdariffa) fortification and storage conditions on vitamins of weaning food formulations (A) Vitamin A, and (B) Vitamin B

Iron

Figure 4 shows the iron composition of food formulations at baseline (0 weeks), iron content ranged from 0.9421 to 1.1319, with WFF-0R showing a comparatively higher iron level than WFF-2R because of the higher contribution of sesame seed and other mineral-rich ingredients in WFF-0R Holinesti et al. (2025). After 6 weeks of storage, iron content in WFF-2R increased to 1.4964 at 5°C, while lower values were recorded at 27°C (1.1371) and 40°C (1.1076). Similarly, WFF-0R recorded iron values of 1.2566, 1.1681, and 1.1728 under the respective storage conditions. At 12 weeks of storage, WFF-2R recorded iron contents of 0.963, 1.043, and 0.733 at 5°C, 27°C, and 40°C, respectively, while WFF-0R showed values of 1.258, 1.322, and 0.890. due to physicochemical changes and redistribution of minerals within the stored products. Iron is an essential micronutrient required for oxygen transport, hemoglobin synthesis, and energy metabolism in children. Therefore, the presence of iron in the formulated weaning foods may contribute positively to the nutritional quality of complementary feeding products.

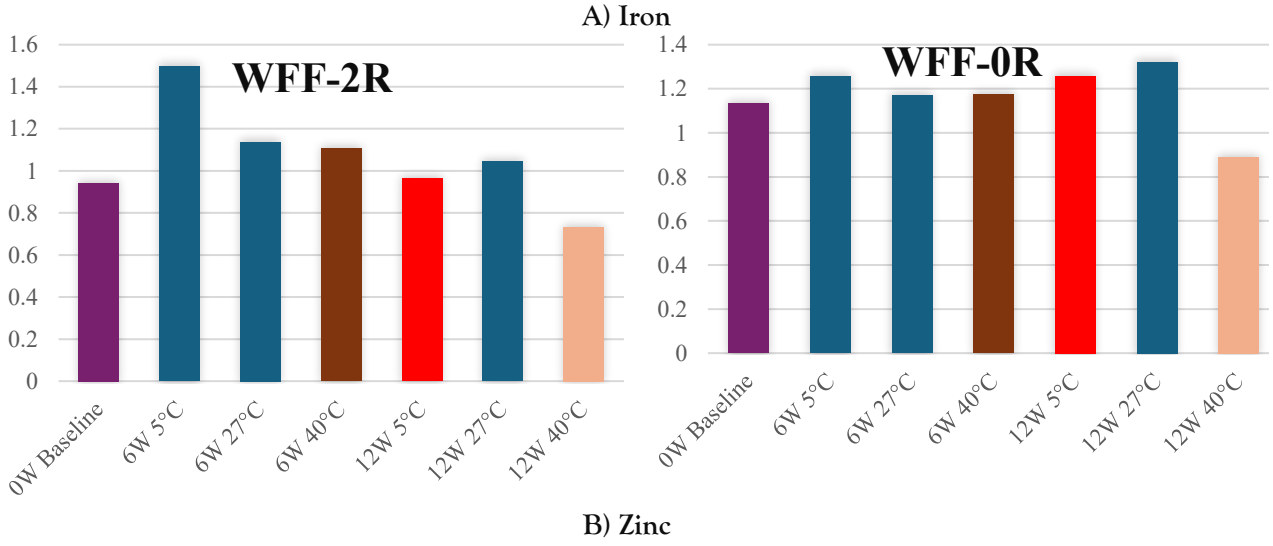
Zinc

Figure 4 shows the zinc composition of roselle-fortified and non-fortified weaning food formulations stored under different storage conditions. At baseline (0 weeks), zinc content ranged from 0.6857 to 0.9061, with WFF-0R

showing a higher initial zinc concentration than WFF-2R. This variation may be linked to differences in ingredient composition, particularly the mineral contribution from sesame seed Holinesti et al. (2025). After 6 weeks of storage, WFF-2R recorded zinc values of 1.2665, 1.2341, and 1.0962 at 5°C, 27°C, and 40°C, respectively, while WFF-0R recorded 1.1047, 1.1690, and 1.1536 under the corresponding conditions. The increase in zinc concentration during storage may be attributed to moisture loss. At 12 weeks of storage, WFF-2R recorded zinc values of 0.457, 0.500, and 0.377 at 5°C, 27°C, and 40°C, respectively, whereas WFF-0R showed values of 0.533, 0.8964, and 0.620 under corresponding storage conditions. The reductions observed during prolonged storage may be associated with mineral redistribution and physicochemical changes occurring within the products during storage. Zinc is an important micronutrient; its presence in formulated weaning foods may improve the nutritional quality of the products.

Calcium

Calcium, in particular, is a key structural and functional mineral are presented in Figure 4, and its deficiency has been associated with impaired bone development and growth disorders in early life stages Adepeju et al. (2024). Calcium content at baseline (0 weeks), ranged between 6.257 and 7.467, with WFF-0R exhibiting a comparatively higher calcium content than WFF-2R. Due to higher proportion of sesame seed in WFF-0R, which is known to be a rich source of calcium Muscolo et al. (2024). After 6 weeks of storage, a noticeable decline in calcium content was observed from 5.488, 5.109, and 3.787 under refrigerated, room, and accelerated storage conditions, respectively. Similarly, WFF-0R showed reductions to 4.975, 4.103, and 3.320 under the corresponding conditions. At 12 weeks of storage, an overall tendency toward partial recovery or apparent increase in some conditions. In WFF-2R, calcium values were recorded as 5.122, 5.827, and 6.216 at 5°C, 27°C, and 40°C, respectively, while WFF-0R showed values of 4.968, 7.155, and 7.109 under the same conditions. These increases may be associated with moisture loss during storage, leading to concentration effects within the dry matter, or may reflect analytical variations in mineral estimation under storage-induced matrix changes. Adequate presence of calcium in complementary foods is therefore crucial for supporting healthy growth and development. The observed variations between WFF-2R and WFF-0R indicate that both formulation composition and storage conditions significantly influenced calcium stability and retention.



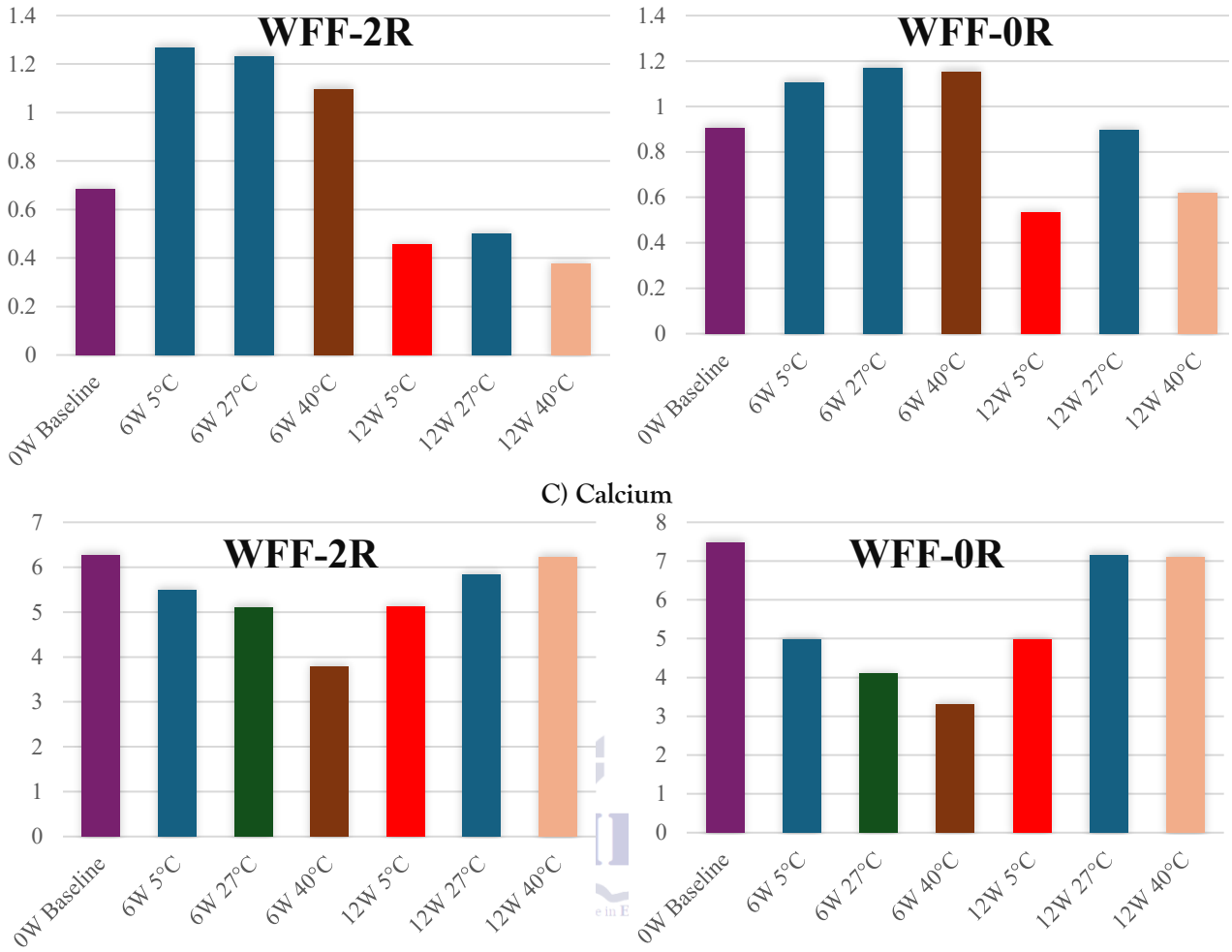
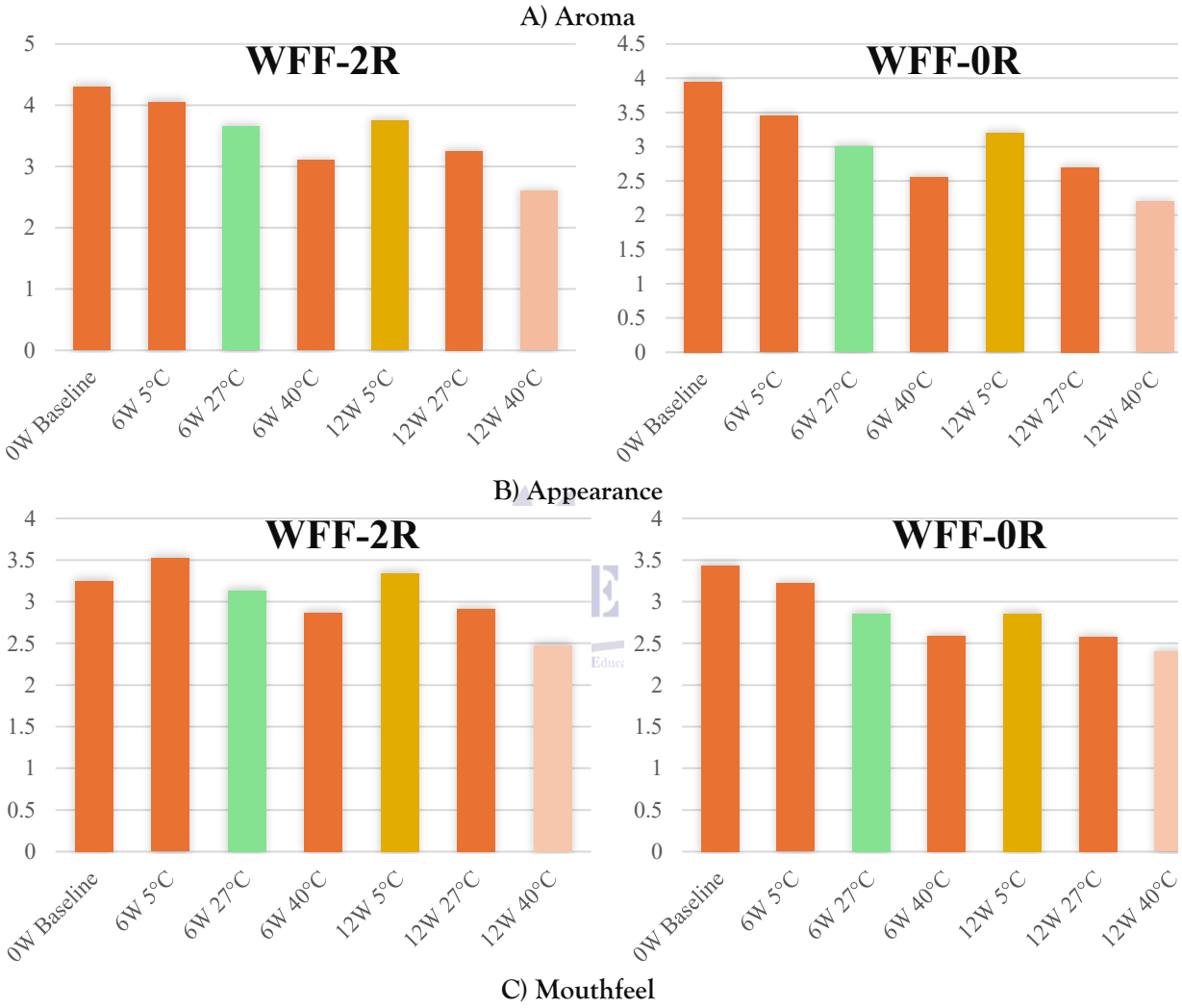


Figure 4. Effect of roselle (Hibiscus sabdariffa) fortification and storage conditions on minerals of weaning food formulations (A) Iron, (B) Zinc, and (C) Calcium

Sensorial Attributes

Formulation composition significantly ($p < 0.05$) influenced sensory acceptability, with panelists clearly distinguishing between WFF-2R and WFF-0R as presented in Figure 5. This aligns with findings by Wirtu (2023), who demonstrated that formulation variations significantly govern sensory perceptions in complementary foods. Across evaluated parameters (aroma, appearance, mouthfeel, taste, and overall acceptability), aroma received the highest overall scores for WFF-2R, confirming its key role as a driver of consumer preference (Holinesti et al., 2025). A significant sample attribute interaction ($p < 0.05$) indicated that formulation differences were attribute-dependent, while a significant three-way interaction ($p < 0.05$) confirmed that storage conditions influenced individual sensory attributes disparately across the two formulations. Storage conditions significantly ($p < 0.05$) degraded sensory acceptability over time across all parameters, with the greatest deterioration occurring after 12 weeks at 40°C, whereas low-temperature storage (5°C) best preserved sensory attributes. Specifically, aroma scores decreased from baseline values (4.20 in WFF-2R and 3.85 in WFF-0R) to terminal ratings of 2.56 and 2.23 at 12 weeks (40°C). Visual acceptability showed a similar declining trajectory, with baseline appearance scores (3.25vs. 3.43) dropping to 2.48 (WFF-2R) and 2.4 (WFF-0R) under maximum thermal stress. Mouthfeel ratings decayed from initial scores of 3.51 and 3.79 to 2.52 and 2.10, respectively. Taste acceptability declined sharply at

40°C over 12 weeks, declining from baseline values (3.59 vs. 3.45) to 2.63 in WFF-2R and 2.02 in WFF-0R. Consequently, WFF-2R consistently maintained superior overall acceptability scores compared to WFF-0R throughout storage, though both formulations exhibited progressive deterioration over 12 weeks, declining from baseline scores of 3.64 and 3.63 to 2.55 and 2.19 at 40°C. This storage-induced loss of consumer acceptability corroborates similar shelf-life observations in complementary flour blends (Ngume et al., 2022).



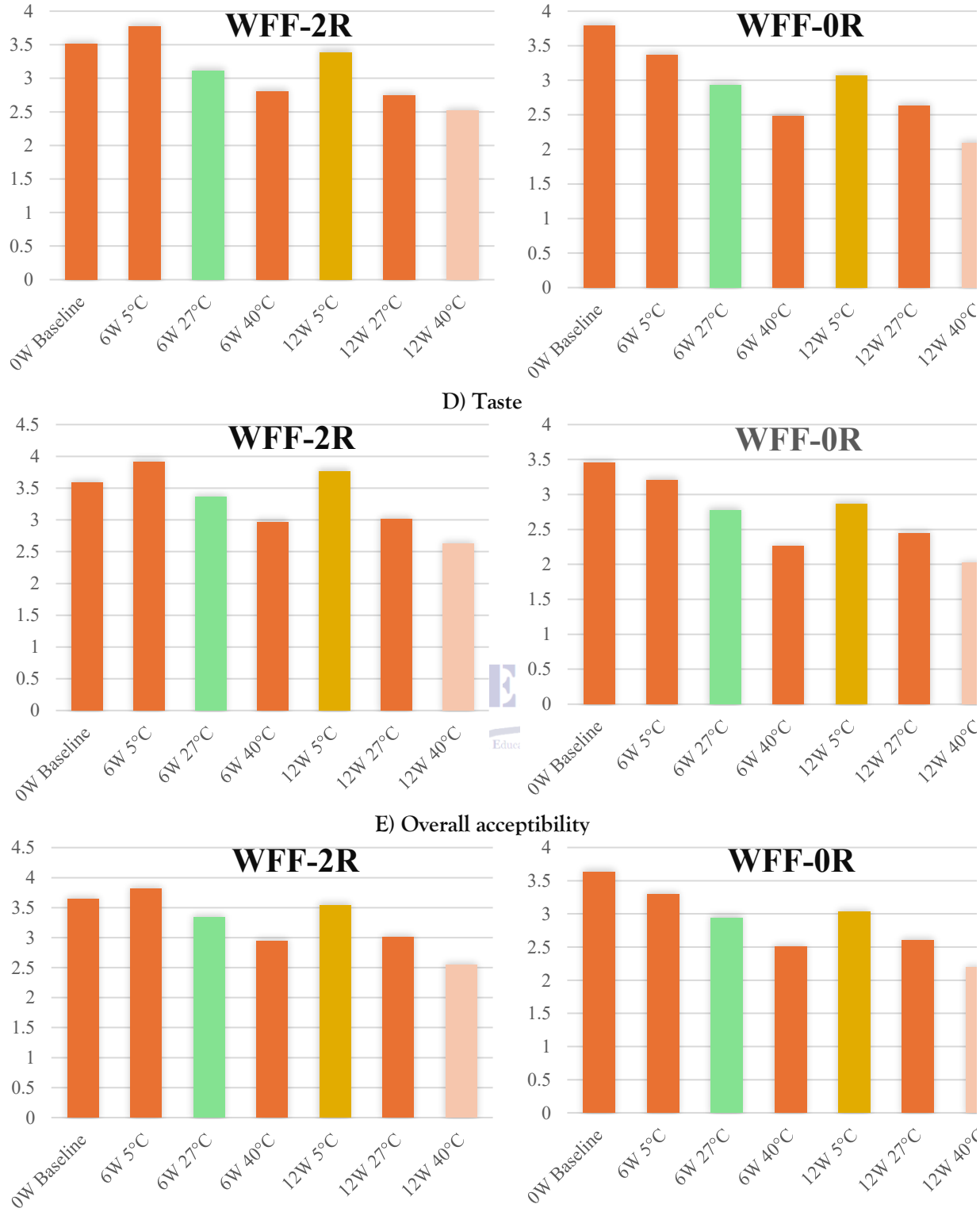


Figure 5. Effect of roselle (Hibiscus sabdariffa) fortification and storage conditions on sensory attributes of weaning food formulations (A) Aroma, (B) Appearance, (C) Mouthfeel, and (D) Taste

4- Conclusion

This study demonstrated that roselle (*Hibiscus sabdariffa*) fortification significantly influenced the compositional stability and sensory acceptability of locally formulated weaning foods during storage. Two formulations, WFF-2R (2% roselle fortification) and WFF-0R (0% roselle fortification), were evaluated under refrigerated (5°C), room (27°C), and accelerated (40°C) storage conditions for 12 weeks. The results showed progressive reductions in carbohydrate, protein, fat, vitamins A and E, and selected minerals with increasing storage duration and temperature. However, WFF-2R consistently demonstrated better retention of protein, vitamins A and E, calcium, and overall sensory quality compared with WFF-0R, indicating the protective effect of roselle against oxidative and storage-related deterioration. Refrigerated storage (5°C) provided the best preservation of nutrient composition and sensory attributes, whereas accelerated storage (40°C) resulted in the greatest nutrient degradation and decline in consumer acceptability. Sensory evaluation further revealed that roselle-fortified samples were more acceptable to panelists, particularly in terms of aroma, taste, and overall acceptability. Although sensory scores declined during prolonged storage, WFF-2R maintained comparatively higher acceptability than the control formulation throughout the storage period. The findings suggest that roselle can serve as a functional fortifying ingredient capable of improving nutrient stability, shelf life, and organoleptic quality of complementary foods formulated from locally available ingredients.

Conflict of Interest

The authors stated that no actual or potential conflicts of interest.

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5- REFERENCES

Elizabeth, G. J., & Koshy, G. (2024). Micronutrient Hunger or Hidden Hunger Among Infants and Young Children on Healthy Diets. *Nestle Nutrition Institute Workshop Series*, 100, 111-124. https://doi.org/10.1159/000540141

Adeoye, A. O., M. A. Ogunjemilusi, and J. C. Akanfe. (2024). Formulation and Assessment of Nutritious Infant Complementary Foods from Co-Fermented Maize, Millet and Pigeon Pea Blends. *European Journal of Nutrition & Food Safety*, 16(10), 227-239. https://doi.org/10.9734/ejnfs/2024/v16i101571

Adepeju, A. B., Aladesiun, O. A., Oyinloye, A. M., Olugbuyi, A. O., & Oni, K. (2024). Spice Fortification of "Ogi" from Maize, Millet and Sorghum Blend. *FUOYE Journal of Pure and Applied Sciences (FJPAS)*, 9(2), 93-110.

Akdemir Evrendilek, G. (2026). Designing functional foods beyond bioactivity: Integrating processing, safety, and regulatory readiness. *Applied Sciences*, 16(6), 2999. https://doi.org/10.3390/app16062999

Alabi, S. O., Okeji, M. A., Ajewole, D. S., Foluso, O. E., & Enujiugha, V. N. (2025). Enhancing the techno-functional properties of sorghum ogi via starter culture fermentation and mixed-spice incorporation. *IPS Journal of Nutrition and Food Science*, 4(2), 444-455.

Almajid, A., Bazroon, A., AlAhmed, A., & Bakhurji, O. (2023). Exploring the health benefits and therapeutic potential of roselle (*Hibiscus sabdariffa*) in human studies: A comprehensive review. *Cureus*, 15(11), e49309. https://doi.org/10.7759/cureus.49309

Ameye, L., de Brouwer, S., Gilliland, D. L., Heckmann, J., Janakiraman, K., Kirwan, B.-A., Lavigne, X., Moya, F., & Zammit, V. (2025). Stability of nutrients in complex liquid and powder food matrices: Learnings from shelf-life studies in foods for special medical purposes. *Current Research in Food Science*, 10, 101055. https://doi.org/10.1016/j.crfs.2025.101055

Arif, T., Urooj, A., & Shafqat, A. (2026b). Development, characterization, and therapeutic evaluation of functional cocofee gummies for type 2 diabetes management in Wistar albino rats. *Policy Research Journal*, 4(6), 77–78. https://doi.org/10.5281/zenodo.20605895

Arif, T., Saddiqa, A., Butt, M. S., Asghar, A., Iqbal, M., Urooj, A., Butt, H. D., & Ahmad, M. (2026a). Formulation, nutritional, and phytochemical characterization of functional tomato condiment fortified with *Mentha piperita* (Peppermint) and *Piper nigrum* (Black Pepper). *Indus Journal of Bioscience Research*, 4(5), 365–366. https://doi.org/10.70749/ijbr.v4i5.3171

Asif, M., M.K.I. Khan, M.I. Khan, A.A. Maan, H.Helmick and J.L. Kokini. (2023). Effects of citrus pomace on mechanical, sensory, phenolic, antioxidant, and gastrointestinal index properties of corn extrudates. *Food Bioscience*, 55:103012.

Asif, M., M. Abbas, K. Fatima, N. Ahmad, S.Ahmed, P. Meghwar, E. Hosseini, A.Nasir and S.A. Hassan. (2025a). Innovative corn extrudates incorporating barley-oat flour blends: Nutritional, functional, and sensory evaluation. *Applied Food Research*, 100812.

Asif, M., A.A. Maan, A. Nazir, M.I.M. Khan and M.K.I. Khan. (2025b). Effect of chickpea on the physicochemical, nutritional, antioxidant, and organoleptic characterization of corn extrudates. *Journal of the Science of Food and Agriculture*, 105:2059-2067.

Atique, Z., M. Aftab, A. Usman, S. Ahmed, A. Faryad, M. Sultan, B. Almas, K. Fatima and M. Asif. 2026. Fabrication and characterization of granola bar supplemented with flaxseed and banana peel powder for compositional, biofunctional, and sensorial attributes. Policy Research Journal. 4:233-242.

Azadovna, K. M., O'G'Li, A. S. A., & Kuchkorovna, M. D. (2026). Determination of vitamins in melon and its powder using spectrophotometery. *Universum: технические науки*, 8(3 (144)), 14-20.

Bai, Y., Huybregts, L., Iannotti, L., Chapnick, M., Jones, A., Headey, D., & Masters, W. (2021). The economics of feeding infants: Least-cost nutrient adequate diets from 6 to 23 months of age using breastmilk and locally available foods in 31 low-income countries. *Current Developments in Nutrition*, 5(Supplement_2), 623. https://doi.org/10.1093/cdn/nzab045_005

Benabid, H., Bouveresse, D. J. R., Valderrama, P., & Rutledge, D. N. (2024). Chemometrical methods applied to chemical data of raw and cooked spinach (*Chenopodium vulvaria*) and purslane (*Portulaca oleracea*). *African Journal of Food, Agriculture, Nutrition and Development*, 24(5), 26253–26276. https://doi.org/10.18697/ajfand.130.24030

Bhardwaj, A. K., Kashyap, N. K., Bera, S. K., Hait, M., & Dewangan, H. (2023). Proximate composition and mineral content analysis of *Curcuma caesia* rhizome. *Biochemical Systematics and Ecology*, 109, 104661.

Bianchi, A., & Venturi, F. (2025). Enhancing the shelf life of food products: Strategies, challenges, and innovations. *Foods*, 14(23), 4034. https://doi.org/10.3390/foods14234034

Butt, H. D., Gill, P., Kubra, K. T., Ahmad, B., Urooj, A., & Arif, M. R. (2026). Development and characterization of nutrient-dense oat-based energy crackers for combating malnutrition. *Policy Research Journal*, 4(4), 530–546. https://doi.org/10.5281/zenodo.19730779

Dilrukshi, H. N. (2022). The effect of extrusion on the nutritional, functional and structural properties of gluten-free extruded snacks fortified with whey protein concentrate and cowpea flour (Doctoral dissertation, Lincoln University).

Edkaidek, H., Dahiya, D., & Nigam, P. S. (2026). Prospects of Bioactive Compounds in Designing Functional Foods: Challenges and Solutions. *Foods*, 15(8), 1291.

Elizabeth, G. J., & Koshy, G. (2024). Micronutrient Hunger or Hidden Hunger Among Infants and Young Children on Healthy Diets. *Nestle Nutrition Institute Workshop Series*, 100, 111-124. https://doi.org/10.1159/000540141

Fazal, A., Butt, H. D., Hira, Z., Mazhar, U., Ashraf, A., Mushtaq, H., & Urooj, A. (2026). Formulation and functional evaluation of protein enriched herbal antidiabetic bar for glycemic control. *Policy Research Journal*, 4(5), 10–11. https://doi.org/10.5281/zenodo.20036016

Fatima, A., A. Fatima, A. Chaudhry, M.U. Ali, M.M. Rasheed, N. Nasir, A. Usman, N. Raza, A. Tahir and M. Asif. 2026. Nutritional and sensorial evaluation of calcium-enriched sesame bars developed with blended flour. The Research of Medical Science Review. 4:1215-1223.

Fatima, K., M. Asif, S.A. Hassan, M. Naveed, T. Alvi and M. Abbas. 2025. Fabrication and Characterization of Protein Fortified Corn Extrudates for Nutritional, Bio-functional, Structural and Organoleptic Properties. Food Biophysics. 20:1-12.

Hassan, A., Ahmed, I., Reshi, Q. M., & Hassan, P. (2025). Role of Fat-Soluble Vitamins in Fish Nutrition. In *Aquaculture: Enhancing Food Security and Nutrition* (pp. 203-224). Cham: Springer Nature Switzerland.

Hernández-Hernández, F. A., Gómez-Aldapa, C. A., Castro-Rosas, J., Vargas-León, E. A., Gutierrez, M. C., Velazquez, G., Jiménez-Regalado, E. J., & Aguirre-Loredo, R. Y. (2024). *Hibiscus sabdariffa* L. extract as a natural additive in food packaging biodegradable films to improve antioxidant, antimicrobial, and physicochemical properties. *Plant Foods for Human Nutrition*, 79(2), 285–291. https://doi.org/10.1007/s11130-024-01189-4

Holinesti, R., Tasrif, N., Rahayu, I., Hasanah, A. N., Hidayanti, H., Naserd, Y. F., & Halipah, S. (2025). Formulation, nutritional profile, and sensory acceptability of cookies incorporating locally sourced ingredients as complementary foods for toddlers: A strategy for stunting prevention. *Food Chemistry Advances*, 7, 101017.

Ijarotimi, O. S. (2022a). Nutritional quality, functional property and acceptability of maize (*Zea mays*) based complementary foods enriched with defatted groundnut (*Arachis hypogea* L.) and ginger (*Zingiber officinale* Roscoe) powder in Wistar rats. *Food Production, Processing and Nutrition*, 4(1), 13.

Ijarotimi, O. S., Fatiregun, M. R., & Oluwajuyitan, T. D. (2022b). Nutritional, antioxidant and organoleptic properties of therapeutic-complementary-food formulated from locally available food materials for severe acute malnutrition management. *Bulletin of the National Research Centre*, 46(1), 39.

Iqbal, S., Urooj, A., Afzal, M., Bashir, A., Rasheed, M. M., Khan, M., Asif, M., Arshad, N., & Fatima, A. (2026). Nutritional, phytochemical, and sensory characterization of gluten-free cookies developed from rice, chickpea, and banana peel composite flour. *Policy Research Journal*, 4(3), 502–516. https://doi.org/10.5281/zenodo.19061728

Irshad, Z., Aamir, M., Akram, N., Asghar, A., Saeed, F., Ahmed, A., & Teferi Asres, D. (2023). Nutritional profiling and sensory attributes of sesame seed-enriched bars. *International Journal of Food Properties*, 26(2), 2978-2994.

Izquierdo-Vega, J. A., Arteaga-Badillo, D. A., Sánchez-Gutiérrez, M., Morales-González, J. A., Vargas-Mendoza, N., Gómez-Aldapa, C. A., Castro-Rosas, J., Delgado-Olivares, L., Madrigal-Bujaidar, E., & Madrigal-Santillán, E. (2020). Organic acids from roselle (*Hibiscus sabdariffa* L.)-A brief review of its pharmacological effects. *Biomedicines*, 8(5), Article 100. https://doi.org/10.3390/biomedicines8050100

Izuakor, P. N., Okoye, P. A. C., Ekpunobi, U. E., Nnaebue, K. C., & Madubuko, U. A. (2024). Comparative analysis of nutrient and anti-nutrient profiles in complementary foods formulated from yellow maize, sorghum, millet, and soybeans fortified with walnuts, pumpkin seeds, and date palm fruits. *European Journal of Nutrition & Food Safety*, 16(12), 87-102.

Lay, K. (2024, June 6). One in four young children at risk of 'irreversible' harm due to poor diet-report. *The Guardian*. https://www.theguardian.com/global-development/article/2024/jun/06/one-in-four-young-children-at-risk-of-irreversible-harm-due-to-poor-diet-report

Li, N., Simon, J. E., & Wu, Q. (2024). Determination of anthocyanins, organic acids, and phenolic acids in hibiscus market products using LC/UV/MS. *Journal of Food Science*, 89(2), 1098–1113. https://doi.org/10.1111/1750-3841.16909

Lutter, C. K., Grummer-Strawn, L., & Rogers, L. (2021). Complementary feeding of infants and young children 6 to 23 months of age. *Nutrition Reviews*, 79(8), 825-846.

Martínez, S., & Carballo, J. (2024). Physicochemical, sensory, and nutritional properties of foods affected by processing and storage series II. *Foods*, 13(1), 156. https://doi.org/10.3390/foods13010156

Mazzocchi, A., Sinarinzi, P., Agostoni, C., & Berti, C. (2026). Sustainable complementary feeding in low-resource countries: Bridging global recommendations and local food systems. *Frontiers in Sustainable Food Systems*. Advance online publication.

Moxness Reksten, A., Bøkevoll, A., Frantzen, S., Lundebye, A. K., Kögel, T., Kolås, K., Aakre, I., & Kjellevold, M. (2020). Sampling protocol for the determination of nutrients and contaminants in fish and other seafood the EAF-Nansen Programme. *MethodsX*, 7, 101063. https://doi.org/10.1016/j.mex.2020.101063

Muscolo, A., Mariateresa, O., Giulio, T., & Mariateresa, R. (2024). Oxidative stress: the role of antioxidant phytochemicals in the prevention and treatment of diseases. *International Journal of Molecular Sciences*, 25(6), 3264.

Naqvi, S. N. U. A., Anwar, A., Almas, I., Khalid, I., Muzammal, S. F., Urooj, A., & Arif, A. (2025). Exploring the Storage Effect on the Physicochemical and Microbiological Properties of Peach-Plum Juice. *RADS Journal of Biosciences*, 4(1), 12-19. https://doi.org/10.37962/jfbs.v4i1.49

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Ngume, L. S., Katalambula, L., Munyogwa, M., & Mongi, R. J. (2022). Sensory properties, preference mapping and shelf life stability of linear programmed quelea meat based instant complementary food for children aged 6–23 months in Tanzania. *Journal of Agriculture and Food Research*, 10, 100412.

Obinna-Echem, P. C., Eke-Ejiofor, J., Vito, M. B., & Wordu, G. O. (2021). Proximate composition, mineral and sensory properties of orange-flesh sweet potato starch, soybean and groundnut flour complementary food. *Asian Food Science Journal*, 20(9), 118-130.

Oladiran, D. A., & Emmambux, N. M. (2022). Locally available African complementary foods: Nutritional limitations and processing technologies to improve nutritional quality. A review. *Food Reviews International*, 38(5), 1033–1063. https://doi.org/10.1080/87559129.2020.1762640

Ortenzi, F., & Beal, T. (2021). Priority micronutrient density of foods for complementary feeding of young children (6–23 months) in South and Southeast Asia (Version 1, preprint). *Research Square*. https://doi.org/10.21203/rs.3.rs-947527/v1

Oyarekua, M. A., Adeoye, A. O., & Ojo, O. (2022). Comparable vitamin and mineral contents of co-fermented maize/carrot/pigeon pea and co-fermented millet/sweet potato/pigeon pea as infant complementary food. *Tropical Journal of Natural Product Research*, 6(8), 1331–1335. https://doi.org/10.26538/tjnpr/v6i8.28

Pimentel-Moral, S., Durazzo, A., Lucarini, M. et al. (2024). *Hibiscus sabdariffa*-loaded nanostructured lipid carriers (NLC) for fortified nutraceutical milks. *European Food Research and Technology*, 250, 1999–2010. https://doi.org/10.1007/s00217-024-04509-9

Rani, R., Sabikhi, L., & Kumar, S. M. H. (2024). Storage stability, nutritional profiling and consumer acceptability of a milk-sorghum-based breakfast smoothie. *Sustainable Food Technology*, 2(1), 729–740. https://doi.org/10.1039/d4fb00038b

Riaz, G., & Chopra, R. (2018). A review on phytochemistry and therapeutic uses of *Hibiscus sabdariffa* L. *Biomedicine & Pharmacotherapy*, 102, 575–586. https://doi.org/10.1016/j.biopha.2018.03.023

Schneider, K. R., Christiaensen, L., Webb, P., & Masters, W. A. (2022). Assessing the affordability of nutrient-adequate diets. *arXiv*. https://doi.org/10.48550/arXiv.2207.07240

Shabbir, A., Asif, H., Shakoor, S., Hussain, M., Fatima, A., Fatima, I., Urooj, A., & Asif, M. (2026). Development and characterization of flat bread incorporated with Moringa powder for nutritional, biofunctional, and sensory evaluation. *Policy Research Journal*, 4(4), 233–246. https://doi.org/10.5281/zenodo.19606314

Shobhita Kumari, Neetu Singh, & Prashant Sagar. (2024). Formulation of complementary feeding food using pearl millet and its sensory evaluation. *International Journal of Scientific Research in Science and Technology*, 11(5), 181–186. https://doi.org/10.32628/IJSRST2411436

Shtylla, B., Pikuli, K., Morava, K., Karapanci, N., & Zhidro, N. (2024). Determination of proteins by the Kjeldahl method in cereals of the markets in Korça City. *JASRD Journal of Agriculture and Sustainable Rural Development*, 2(3-4), 26-33.

Singh, P., Khan, M., & Hailemariam, H. (2017). Nutritional and health importance of *Hibiscus sabdariffa*: A review and indication for research needs. *Journal of Nutritional Health & Food Engineering*, 6(5), 125–128.

Słowik-Borowiec, M., Głąb, N., Stach, S., & Szpyrka, E. (2023). A miniaturized sample preparation method for the determination of vitamins A and E in food products. *Molecules*, 28(8), 3449. https://doi.org/10.3390/molecules28083449

Soloon, G. S., Okomoda, V. T., & Oda, S. O. (2017). Nutritional value of toasted pigeon pea (*Cajanus cajan*) seed and its utilization in the diet of *Clarias gariepinus* (Burchell, 1822) fingerlings. *Aquaculture Reports*, 7(C), 34–39.

Tivkaa, J. T., Agada, E. N., & Targema, R. D. (2025). Comparative Determination of Total Carbohydrate Content in Mango, Orange, and Banana Fruits in Ugbokolo, Nigeria Using the Anthrone Method. *BSP Advances in Science, Engineering and Technology (BSPASET)*, 2(1).

Urooj, A., Shabbir, A., Hafeez, R., Rasheed, M. M., Asif, M., Aslam, I., Fatima, T., Shakoor, A., Zaman, K., & Faryad, A. (2026a). Physicochemical, phytochemical, and sensory evaluation of cookies fortified with jujube powder. *Policy Research Journal*, 4(3), 273-280. https://doi.org/10.5281/zenodo.18976208

Urooj, A., Mumtaz, F., Shabbir, A., Sultan, M., Tirmazi, S. M. B., Sarwar, M. S., ... & Asif, M. (2026b). Exploring the ameliorative effects of *Anethum graveolens* and *Foeniculum vulgare* seeds on dyslipidemia: a comparative efficacy in high fat diet-induced model. *Policy Research Journal*, 4(2), 506-527. https://doi.org/10.5281/zenodo.18831840

Urooj, A., Shabbir, A., Shahbaz, A., Ahmed, S., Ul Hassan, H. N., Asif, M., Usman, A., Tofique, M., Abbas, S., & Safdar, A. (2026c). Synergistic effects of *Cinnamomum zeylanicum* and inositol on metabolic and hormonal parameters in women with polycystic ovary syndrome. *Journal of Physical Education, Health and Social Sciences*, 4(1), 637-648. https://doi.org/10.63163/jpehss.v4i1.1176

Wirtu, B. D. (2023). Optimization of nutritional, functional and sensory qualities of complementary food formulated from sorghum, quality protein maize and okra seed in benishangul gumuz region, *Ethiopia*. https://doi.org/10.20372/nadre:14139

Yang, H., Hou, L., Sun, H., & Ye, S. (2024a). Degradation kinetics of vitamins in different enteral feeding formulas during storage at different temperatures. *Heliyon*, 10(8), 29653. https://doi.org/10.1016/j.heliyon.2024.e29653

Yang, L., Fan, C., Gao, Q., Xie, Q., Jiang, C., Wang, S., Jiang, S., & Li, B. (2024b). Physicochemical characterization, sensory quality analysis, and shelf-life prediction during the storage of a total nutrient formula emulsion. *LWT*, 204, 116427. https://doi.org/10.1016/j.lwt.2024.116427

Yusuf, S., Isa, S. A., Baba, J., Aliyu, T. A., & Bashir, Y. A. (2022). Functional properties and storage stability of optimized cereal-based complementary foods. *Croatian Journal of Food Science and Technology*, 14(1), 98-107.

Zakaria, Z., Nursalim, N., & Za, A. T. T. (2025). Accelerated shelf-life assessment of moringa-fortified instant complementary food for infants aged 6-11 months based on microbial parameters. *Italian Journal of Food Safety*, 14(3), 13608.

Zahid, T., S. Nooreen, M. Asif, S. Maqsood, A. Saddiqa, M. Nazar, T. Alvi and M. Rafiq. 2025. Development and characterization of protein-rich cookies fortified with red kidney beans: A nutritional approach to combat malnutrition. Journal of Pure Applied and Agriculture. 10:21-29.

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