International Journal of Food Science and Nutrition
www.foodsciencejournal.com
ISSN: 2455-4898
Received: 02-06-2026, Accepted: 02-07-2026, Published: 17-07-2026
Volume 11, Issue 3, 2026, Page No. 85-90

Effects of malting, fermentation and soybean supplementation on total phenolic content, antioxidant activity and sensory properties of rice–soybean based complementary food

Lawan HK[1*], Bristone C[1], Danjuma S[1], Badau MH[1], Igwegbe AO[1], Maina LD[2]
[1] Department of Food Science and Technology, Faculty of Engineering, University of Maiduguri, Maiduguri, Borno State, Nigeria.
[2] Department of Animal Science, Faculty of Agriculture, University of Maiduguri, Maiduguri, Borno State, Nigeria
Corresponding Author: Lawan HK
DOI: https://doi.org/10.66856/ijfsn.2026.11.3.11122

Abstract
This study investigated the effects of malting, fermentation, and soybean supplementation on total phenolic content (TPC), antioxidant activity, and sensory properties of rice–soybean-based complementary food. The research was motivated by the need to address protein-energy malnutrition and micronutrient deficiencies among infants through the development of nutrient-dense foods from locally available raw materials. Rice (Oryza sativa) and soybean (Glycine max) were processed using malting, fermentation, and combined bi-processing techniques. The resulting flours were analyzed using standard spectrophotometric methods: the Folin–Ciocalteu assay for TPC, and DPPH, FRAP, and reducing power assays for antioxidant activity. Results indicate that the processing significantly enhanced the bioactive properties of the formulations. The fermented rice flour–soybean blend (F3) showed high TPC (122.00 mg GAE/g) and the strongest DPPH radical scavenging activity (up to 87% inhibition), while the combined malted and fermented rice flour sample (S4) recorded the highest total antioxidant activity (0.34 OD). The processing also reduced pH and increased titratable acidity resulting to improved microbial stability. Sensory evaluation scores indicate that all the formulations were generally acceptable. The findings demonstrate that fermentation promotes the release of phenolic compounds, malting enhances enzymatic modification and nutrient availability, and their combined application could produce a nutritionally and functionally improved complementary food. These low-cost processing techniques offer strong potential for improving infant nutrition in resource-limited settings.

Keywords: Antioxidant activity, fermentation, malting, phenolic content, rice, soybean.

Introduction

The first two years of life represent a critical period of rapid growth and development. During this period, adequate nutrition is essential for optimal physical growth, brain development, immune maturation, and long-term health outcomes. Although breast milk provides all the nutrients required by infants during the first six months of life, it becomes insufficient alone thereafter to meet the increasing energy and nutrient needs of the growing child (WHO, 2023).

Complementary feeding refers to the process of introducing solid, semi-solid, and soft foods to an infant while continuing breastfeeding, beginning at six months of age and continuing up to two years or beyond (WHO and UNICEF, 2021). This transition period is one of the most vulnerable stages in child development because poor feeding practices can lead to malnutrition, growth faltering, micronutrient deficiencies, and increased morbidity and mortality (Black *et al*., 2013) [10].

Complementary feeding is one of the most critical interventions in early childhood nutrition and represents a decisive transition in the life of an infant. It bridges the period between exclusive breastfeeding and the eventual adoption of the family diet. This phase typically begins at six months of age, when breast milk alone is no longer sufficient to satisfy the infant's increasing nutritional requirements for energy, protein, essential fatty acids, vitamins, and minerals (WHO, 2023). The successful introduction of complementary foods during this period profoundly influences child survival, growth, cognitive development, immune competence, and long-term health outcomes.

The period from birth to two years of age is often referred to as the "critical window of opportunity" or the "first 1,000 days", encompassing conception through the child's second birthday. During this time, nutrition has a disproportionate impact on physical growth, brain development, metabolic programming, and susceptibility to disease later in life (Victora *et al*., 2021) [30]. Nutritional deficits occurring during this window may lead to irreversible consequences, including stunting, impaired neurodevelopment, reduced school performance, lower adult productivity, and increased risk of chronic diseases such as obesity, diabetes, and cardiovascular disorders (Black *et al*., 2013) [10].

Although breast milk remains the ideal source of nutrition for infants, its nutrient contents alone cannot fully meet the demands of a rapidly growing infant after six months. Specifically, nutrients such as iron, zinc, calcium, and certain fat-soluble vitamins become limited because the infant's body stores acquired during gestation period begin to decline, and physiological needs increase substantially (Dewey, 2013) [16]. Consequently, the introduction of nutrient-dense complementary foods becomes essential to prevent nutritional deficiencies and sustain normal growth trajectories.

Complementary feeding is more than simply offering additional food. It is a dynamic process that involves selecting appropriate foods, ensuring hygienic preparation, determining suitable texture and consistency, establishing adequate and sustainable meal frequency, and responding sensitively to the child's appetite and developmental readiness. The feeding relationship between caregiver and child during this period also plays a significant role in shaping eating behaviors, food preferences, and psychosocial development (Black and Aboud, 2011) [9]. Thus, complementary feeding integrates nutritional science, behavioral psychology, public health, and cultural practices.

Globally, inappropriate complementary feeding practices remain a major contributor to undernutrition and child mortality. Common problems include introducing complementary foods too early or too late, offering foods of low nutrient density, inadequate meal frequency, poor dietary diversity, and unsafe food handling. According to the WHO and UNICEF (2021) [30], only a minority of children aged 6–23 months in many low- and middle-income countries receive diets that meet minimum standards for dietary diversity and meal frequency. These gaps contribute significantly to widespread stunting, wasting, and micronutrient deficiencies, particularly iron deficiency anemia and vitamin A deficiency.

In sub-Saharan Africa, including Nigeria, complementary feeding challenges are compounded by poverty, food insecurity, maternal undernutrition, cultural food taboos, and limited access to health and nutrition education. Traditional complementary foods, such as cereal-based porridges, are often highly diluted and predominantly carbohydrate-based, resulting in low energy and micronutrient density. Without enrichment using legumes, animal-source foods, fruits, and vegetables, such diets may fail to meet infants' nutritional requirements, leading to growth faltering and increased vulnerability to infections.

Complementary feeding also plays a central role in the development of the immune system. Adequate intake of protein, zinc, vitamins A, D, C, and essential fatty acids support mucosal integrity, antibody production, and immune cell function. Conversely, malnutrition weakens immune defenses, increasing susceptibility to recurrent infections. This interaction creates a vicious cycle in which infection worsens nutritional status, and poor nutrition increases infection risk (Bhutta *et al*., 2013) [10].

The impact of complementary feeding extends beyond infancy. Early dietary exposures influence taste preferences, eating habits, and metabolic responses that persist throughout life. Diets rich in fruits, vegetables, legumes, and diverse nutrient sources help establish healthy food patterns, whereas early exposure to sugar-sweetened beverages and ultra-processed foods may predispose children to obesity and noncommunicable diseases (Monteiro *et al*., 2019) [25]. Therefore, complementary feeding serves as a foundation for lifelong nutritional health.

From a public health perspective, improving complementary feeding practices is among the most cost-effective interventions for reducing child morbidity and mortality and enhancing national development. Well-nourished children are more likely to survive, achieve better educational outcomes, and contribute productively to society. Investments in caregiver education, food fortification, breastfeeding support, and community-based nutrition programs will yield substantial social and economic returns (Victora *et al*., 2021) [30].

Complementary feeding is a critical stage in child growth and development, particularly after the period of exclusive breastfeeding (Faturoti *et al*., 2025) [18]. In many low- and middle-income countries, commonly used complementary foods are cereal-based and often low in protein, micronutrients and functional bioactive compounds (Adebayo-Oyetoro *et al*., 2023) [22]. This contributes to protein-energy malnutrition, poor growth and increased vulnerability to disease.

Rice is widely consumed and easily digestible, making it suitable for infant feeding. However, rice alone is nutritionally limited, especially in protein quality and certain micronutrients. Soybean is a valuable legume known for its high protein content and favorable amino acid profile. Blending cereals with legumes has been recommended as an affordable strategy for improving complementary foods.

Traditional processing techniques such as malting and fermentation can further improve food quality. Malting activates endogenous enzymes that enhance digestibility and release nutrients, while fermentation may reduce anti-nutritional factors and increase bioavailability of nutrients and phenolic compounds. In addition, these processes may improve antioxidant capacity, which contributes to protection against oxidative stress.

This study was therefore designed to evaluate the effects of malting, fermentation and soybean supplementation on total phenolic content, antioxidant activity and sensory acceptability of rice–soybean based complementary food. The study aims to examine the effects of malting, fermentation of rice and soybean supplementation on total phenolic contents (TPC), antioxidant activities and sensory properties of complementary food.

Materials and Methods

Materials and Sample Preparation

Paddy rice and soybeans used for this study were purchased from Ngomboru Market, Maiduguri, Borno State, Nigeria. Foreign materials, broken grains, stones, and defective seeds were manually removed, after which the samples were thoroughly cleaned prior to processing.

Five flour formulations were developed using different processing techniques involving rice, soybean supplementation, malting, fermentation, and combined bi-processing methods. Soybean flour was incorporated into the rice-based formulations at predetermined proportions to improve the nutritional quality of the complementary food blends.

Rice samples designated for malting were soaked in clean water, allowed to germinate under controlled conditions, dried, and milled into flour. For fermented samples, cleaned rice grains were steeped in water and subjected to natural solid surface fermentation for an appropriate period, followed by drying and milling. Samples requiring combined processing were subjected to sequential malting and fermentation before flour production. All processed samples were milled, sieved, packaged in airtight containers, and stored under ambient conditions until analysis.

Determination of Total Phenolic Content and Antioxidant Activity

Total phenolic content of the flour samples was determined using the Folin–Ciocalteu spectrophotometric method (Molole *et al*., 2022) [26] and results were expressed as milligrams gallic acid equivalent per gram sample (mg GAE/g).

Antioxidant activity of the samples was evaluated using standard *in vitro* assays, including 2,2-diphenyl-1-

picrylhydrazyl (DPPH) radical scavenging activity, ferric reducing antioxidant power (FRAP), and reducing power assay. The 2,2-Diphenyl-1-picrylhydrazyl (DPPH) is a popular, quick, easy, and affordable approach for the measurement of antioxidant properties that includes the use of the free radicals used for assessing the potential of substances to serve as hydrogen providers or free-radical scavengers (FRS). The technique of DPPH testing is associated with the elimination of DPPH, which would be a stabilized free radical. The free-radical DPPH interacts with an odd electron to yield a strong absorbance at 517nm (Biliyan *et al.*, 2022).

Sensory Evaluation

Complementary food samples prepared from the composite flours were subjected to sensory evaluation by a panel of twenty-five (25) assessors. A multiple comparison test method as described in Arisa *et al.* (2022) [7] was used for the sensory evaluation of coded commentary foods. In this method, a 9-point hedonic scale was used to score the products from 1-9, with 9 being liked extremely, 8 (liked very much), 7 (liked moderately), 6 (liked slightly), 5 (neither liked nor disliked), 4 (disliked slightly), 3 disliked moderately), 2 (liked very much) and 1 (disliked extremely); and the sensory attributes scored included appearance, taste, aroma, texture, and overall acceptability.

Statistical Analysis

All determinations were conducted in triplicate, and results were expressed as mean ± standard deviation. Data obtained were subjected to analysis of variance (ANOVA), and test for significance between treatment means were carried out using Duncan's Multiple Range Test (Dean *et al.*, 2017) [15]. The statistical analyses were performed using Minitab version 21.2, and differences among means were considered significant at 5% level of significance.

Results

Total Phenolic Content and Total Antioxidant Activity

Processing significantly affected ($p < 0.05$) the total phenolic content (TPC) and total antioxidant activity of the rice–soybean complementary food formulations (**Table 1**). The TPC ranged from 26.67 to 130.00mgGAE/g extract. The highest TPC was observed in S2 (malted rice flour), followed by F3 (fermented rice flour + soybean) and S4 (malted and fermented rice flour). The lowest value was recorded in S0 (soybean flour).

On the other, the total antioxidant activity expressed as optical density (OD), ranged from 0.21 to 0.34. The highest antioxidant activity was recorded in S4, followed by F3 and S1/F4 (**Table 1**).

Reducing Power Activity

All the samples formulated showed concentration-dependent increases in reducing power (**Figure 1**). The malted rice flour (S2) exhibited the highest reducing power at higher concentrations, while fermented composite samples (especially F2 and F3) demonstrated strong reducing capacity.

The 2,2-Diphenyl-1-picrylhydrazyl (DPPH) Radical Scavenging Activity

The DPPH radical scavenging activity was observed to increase with increasing concentration across the samples (Figure 2). The highest inhibitory activities were recorded in F3 (Fermented rice flour + soybean), reaching approximately 87%, indicating strong free radical scavenging potential.

Table 1: Total Phenolic Content and Antioxidant Activity of Bi-Process Rice Soybean Based Complementary Food

Sample Code[2]	Parameters[1]	
	TPC (mgGAE/g extract)	Total Antioxidant (optical density OD)
S1	$33.33^{h}\pm1.16$	$0.31^{c}\pm0.00$
S2	$130.00^{a}\pm2.00$	$0.21^{i}\pm0.00$
S3	$80.00^{e}\pm2.00$	$0.22^{h}\pm0.00$
S4	$117.33^{c}\pm2.31$	$0.34^{a}\pm0.00$
S0	$26.67^{i}\pm1.16$	$0.28^{e}\pm0.00$
F1	$68.00^{g}\pm0.00$	$0.28^{f}\pm0.00$
F2	$72.67^{f}\pm1.16$	$0.23^{g}\pm0.00$
F3	$122.00^{b}\pm2.00$	$0.32^{b}\pm0.00$
F4	$87.33^{d}\pm1.16$	$0.31^{d}\pm0.00$

[1]Values are means ± standard deviations of triplicate determinations. In any column, means bearing similar superscripts are not significantly different ($p\geq0.05$).

[2]S1= Not malted not fermented rice flour; S2 = Malted rice flour; S3 = fermented rice flour; S4 = Malted and fermented rice flour; S0 = Soybean; F1= Not malted not fermented rice flour + soybean flour; F2 = Malted rice flour + soybean; F3 = Fermented rice flour + soybean; F4 = Malted and fermented rice flour + soybean.

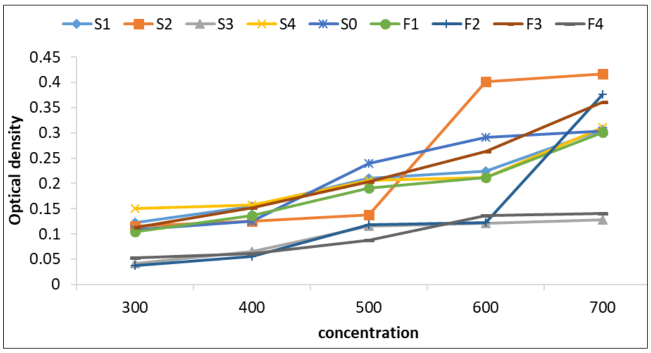

Figure 1: Reducing Power of Bi-Process Rice-Soybean Based Complementary Food[1]

[1]**Key:** S1= Not malted not fermented rice flour; S2 = Malted rice flour; S3 = fermented rice flour; S4 = Malted and fermented rice flour; S0 = Soybean; F1= Not malted not fermented rice flour + soybean flour; F2 = Malted rice flour + soybean; F3 = Fermented rice flour + soybean; F4 = Malted and fermented rice flour + soybean.

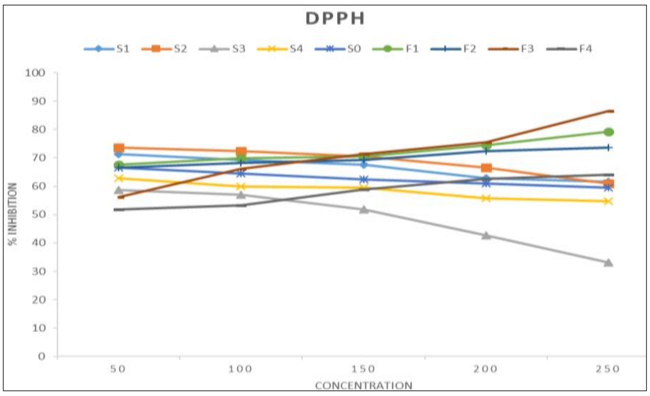

Fig 2: DPPH Of Bi-Process Rice Soybean Based Complementary Food[1]

[1]**Key:** S1= Not malted not fermented rice flour; S2 = Malted rice flour; S3 = fermented rice flour; S4 = Malted and fermented rice flour; S0 = Soybean; F1= Not malted not fermented rice flour + soybean flour; F2 = Malted rice flour + soybean; F3 = Fermented rice flour + soybean; F4 = Malted and fermented rice flour + soybean.

Sensory Evaluation

The results of the organoleptic scorings showed that all the formulations were generally ranked as acceptable by the panelists (Table 2). The scores for colour, aroma, taste, texture, thickness, and overall acceptability were within the ranges of ‘liked very much’ that is 8, and ‘liked moderately’ that is 7 of the hedonic scale, with no serious rejection of any of the formulations was recorded.

Table 2: Sensory Evaluation Scores of Bi-Processed Rice Soybean Based Complementary Food

Sample Code[2]	Sensory Attributes[1]					
	Colour	Aroma	Taste	Thickness	Texture	Overall acceptability
S1	6.40^{a}±1.58	5.40^{a}±1.65	6.30^{a}±1.50	**6.80^{a}±1.62**	**7.00±1.41**	**6.80^{a}±1.14**
S2	7.30^{a}±1.42	6.10^{a}±1.37	6.00^{a}±2.00	**6.60^{a}±1.84**	5.90^{a}±2.69	7.10^{a}±1.73
S3	7.40^{a}±1.17	4.60^{a}±2.01	5.30^{a}±1.42	6.10^{a}±2.03	6.20^{a}±2.09	6.50^{a}±1.84
S4	7.10^{a}±1.29	6.10^{a}±1.60	5.40^{a}±2.50	6.50^{a}±1.51	5.60^{a}±2.50	7.70^{a}±0.95
S0	6.40^{a}±0.97	6.40^{a}±1.17	6.50^{a}±1.35	7.30^{a}±2.21	5.30^{a}±2.80	6.80^{a}±2.20
F1	6.30^{a}±1.89	6.90^{a}±1.20	6.00^{a}±1.83	5.30^{a}±2.36	5.90^{a}±2.33	**5.90^{a}±2.47**
F2	6.70^{a}±1.70	6.50^{a}±2.01	5.50±0.70	5.90^{a}±1.67	7.10^{a}±1.37	6.90^{a}±1.29
F3	6.30^{a}±1.34	6.20^{a}±1.55	4.30^{a}±2.58	5.20^{a}±2.53	5.70^{a}±3.02	**6.40^{a}±2.32**
F4	7.50^{a}±2.12^{a}	6.10^{a}±2.28	6.60^{a}±2.01	**6.10^{a}±1.73**	6.40^{a}±1.96	**5.50^{a}±2.12**

[1]Values are means ± standard deviations of triplicate determinations. In any column, means bearing
similar superscripts are not significantly different ($p \geq 0.05$).
[2]S1= Not malted not fermented rice flour; S2 = Malted rice flour; S3 = fermented rice flour; S4 = Malted and fermented rice flour; S0 = Soybean; F1= Not malted not fermented rice flour + soybean flour; F2 = Malted rice flour + soybean; F3 = Fermented rice flour + soybean; F4 = Malted and fermented rice flour + soybean.

Discussion

Lactic acid fermented foods are traditionally produced in developing countries, both to improve the safety of the food and to improve its digestibility. Starchy porridges are commonly fed to weaning infants in developing countries. The consistency of these gruels, combined with the small capacity of the infant’s stomach, means that it is physically impossible for the child to consume adequate energy to meet its high demands. By acidifying the porridge through lactic acid fermentation, starch is hydrolyzed into shorter chains of glucose and dextrose, which reduce the viscosity of the porridge and increase its energy density. Thus, the child is more able to meet its energy requirements.

In the present study, the significant increase in total phenolic content after processing demonstrates the effectiveness of malting and fermentation in enhancing bioactive compounds in cereal-based foods. The highest TPC recorded, 130.00±2.00 mgGAE/g extract, in malted rice flour (S2) suggests that germination activated hydrolytic enzymes capable of releasing bound phenolics from the grain matrix. Similar increases in phenolic compounds after germination have been reported (Kewuyemi and Adebo, 2024) [24] in cereal-legume systems, where sprouting was observed to improve antioxidant and nutritional quality of the product.

Similarly, the high phenolic values, 122.00^{b}±2.00 mgGAE/g extract, observed in the fermented soybean blend (F3) further indicates that fermentation promotes biochemical transformations that liberate phenolic constituents and generates new antioxidant metabolites. This finding agrees favorably with the reports of Adeoye *et al*. (2024) and Frontiers Editorial Board (2025) [3, 19] who opined that fermentation enhances the functional quality of complementary foods and soybean-based products through microbial enzymatic activities.

The results revealed that S2 (Malted rice flour) had the highest TPC, but its total antioxidant activity was lower than that of S4 (Malted and fermented rice flour). This suggests that antioxidant activity depends not only on the quantity of phenolics present, but also on their structural characteristics, synergistic interactions, and reactivity. Similar findings were reported by Adom and Liu (2002) [4] in grain antioxidant studies, where it was observed that total phenolic contents did not always directly predict antioxidant capacity.

The highest total antioxidant activity observed in S4 indicates a beneficial synergistic effect of combining malting and fermentation. Malting likely improved substrate accessibility through enzymatic softening of grain tissues, while fermentation may have produced smaller bioactive molecules with stronger reducing and radical scavenging properties. Similar findings were also reported by Ikujenlola *et al*. (2025) [21] who emphasized the advantages of combining traditional bioprocessing methods to improve nutrient density and functional value of staple foods.

The strong DPPH radical scavenging activity shown by F3 (up to 87%) revealed that fermented rice–soybean blends possess substantial free radical neutralizing capacity. Results indicates that fermentation might have increased the concentration of peptides, organic acids, and low-molecular-weight phenolics that actively donate hydrogen atoms to stabilize radicals. Comparable improvements in DPPH activity have been reported by Adebayo-Oyetoro *et al.* (2023) and Faturoti *et al*. (2025) [1, 18] in fermented cereal-soy complementary foods.

Sensory acceptability is critical for successful adoption of infant foods. The generally acceptable scores recorded for all samples indicates that nutritional enhancement through malting, fermentation, and soybean fortification did not negatively affect consumer preference. Finding aligns favorably with the reports of Arinola *et al.* (2020) and Ademulegun *et al*. (2024) [2, 6] showing that properly processed cereal-legume blends can achieve both nutritional quality and desirable sensory attributes.

This study revealed that malting, fermentation, and soybean supplementation are practically low-cost strategies for improving the functional and sensory quality of rice-based complementary foods. Among the tested formulations examined, fermented composite blends (F3) and combined processed samples (S4) appeared to be the most promising for infant and young child feeding in resource-limited settings.

Conclusion

This study has demonstrated that malting, fermentation, and soybean supplementation significantly improved the functional and sensory quality of rice–soybean-based complementary foods; and that processing enhanced total phenolic contents and antioxidant activity. The study has also proved the ability of traditional bioprocessing methods to increase the health-promoting potentials of cereal-based infant foods. Among the formulations, the fermented rice flour–soybean blend (F3) exhibited strong phenolic content and radical scavenging capacity, while the combined malted and fermented rice flour sample (S4) showed the highest overall antioxidant activity, indicating the added benefits of integrating both processing techniques.

The generally acceptable sensory scores obtained for all samples studied further confirmed that nutritional improvement did not compromise consumer preference. This is particularly important for successful adoption in infant and young child feeding programs.

The findings establish that locally available rice and soybeans can be transformed through low-cost processing into nutritionally enhanced complementary foods with improved functional properties and good acceptability. These products offer a practical and sustainable strategy for addressing child malnutrition and improving dietary quality in resource-limited communities. It is recommended among others that, fermented and malted fermented rice–soybean formulations should be encouraged as affordable, nutrient-rich complementary foods for infants and young children and nutrition programs targeting malnutrition should adopt these improved processing techniques to enhance the functional properties of complementary foods.

Disclosure of Conflict of Interest

The authors declare that there is no conflict of interest with regards to this study

References

1. Adebayo-Oyetoro AO, Ogundipe OO, Adeeko KN Quality assessment and consumer acceptability of complementary foods produced from fermented maize, soybean and carrot flour blends. Journal of Food Science and Technology,2023:60(4):1452–1463.
2. Ademulegun TI, Akinrinmade R, Alebiosu IA, Adedayo EO Effect of processing method on proximate, mineral and anti-nutrients composition of complementary foods produced from maize, soybean and pumpkin seed. Asian Journal of Food Research and Nutrition,2024:3(2):358–370.
3. Adeoye AO, Ogunjemilusi MA, Akanfe JC Formulation and assessment of nutritious infant complementary foods from co-fermented maize, millet and pigeon pea blends. European Journal of Nutrition & Food Safety,2024:16(10):227–239.
4. Adom KK, Liu RH Antioxidant activity of grains. Journal of Agricultural and Food Chemistry,2002:50:6182–6187.
5. AOAC Official methods of analysis (20th ed.). AOAC International, 2016.
6. Arinola SO, Ojo TP, Akinmolayan JO, Kehinde AO Evaluation of nutritional composition and sensory attributes of breadfruit-soybean flour blends for complementary foods. Asian Food Science Journal,2020:16(2):13–21.
7. Arisa NU, Daramola BE, Fanimokun OS Comparative Evaluation of Some Nutritional Values and acceptability Trifoliate Yam and Potato Products. Nigerian Food Journal,2022:39(2):18 – 32.
8. Baliya S, Mukherjee R, Priyadarshini A, Vibhuti A, Gupta A, Pandey RP, *et al*. Determination of Antioxidants by DPPHRadical Scavenging Activity and Quantitative Phytochemical Analysis of *Ficus religiosa*. Molecules,2022:27:1326. https://doi.org/ 10.3390/molecules27041326.
9. Black MM, Aboud FE Responsive feeding is embedded in a theoretical framework of responsive parenting. The Journal of Nutrition,2011:141(3):490–494.
10. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, de Onis M, *et al*. Maternal and child undernutrition and overweight in low-income and middle-income countries. The Lancet,2013:382(9890):427–451.
11. Bhutta ZA, Das JK, Rizvi A, Gaffey MF, Walker N, Horton S, *et al*. Evidence-based interventions for improvement of maternal and child nutrition. The Lancet,2013:382(9890):452–477.
12. Blandino A, Al-Aseeri ME, Pandiella SS, Cantero D, Webb C Cereal-based fermented foods and beverages. Food Research International,2003:36:527–543.
13. Brand-Williams W, Cuvelier ME, Berset C Use of a free radical method to evaluate antioxidant activity. LWT - Food Science and Technology,1995:28:25–30.
14. Daramola PO Effect of fermentation time on the nutritional composition of soybean-based yoghurt: A review. Asian Journal of Science, Technology, Engineering, and Art, 2025, 1418–1435.
15. Dean A, Voss D, Draguljic D Design and Analysis of Experiments, 2nd Edn. Springer International Publishing, New York, 2017.
16. Dewey KG The challenge of meeting nutrient needs of infants and young children during the period of complementary feeding. The Journal of Nutrition,2013:143(12):2050–2054.
17. FAO Processing of complementary foods. Food and Agriculture Organization of the United Nations, 2013.
18. Faturoti AO, Edob GI, Makiac RS, Oghenewogagad OJ, Oluwabunmi AV, Gaaze TS Qualitative attributes of complementary foods developed from fermented maize, soybean, and breadfruit flour. Journal of Culinary Science & Technology,2025:24(2):325–351.
19. Frontiers Editorial Board Editorial: Enhancing nutrient profile, safety, and sustainability with fermentation technology. Frontiers in Nutrition,2025:12:1571781.
20. Hotz C, Gibson RS Traditional food-processing practices to enhance the bioavailability of micronutrients in plant-based diets. Journal of Nutrition,2007:137(4):1097–1100.

21. Ikujenlola AV, *et al*. Nutritional quality of complementary food made from malted-fermented sorghum and soybean flour blends. Acta Universitatis Cibiniensis. Series E: Food Technology,2025:29(1):29–42.
22. Journal of Functional Foods Editorial Team Research trends and approaches for the nutritional and bio-functionality enhancement of fermented soymilk. Journal of Functional Foods,2023:107:105698.
23. Kalpoutzakis E, Chatzimitakos T, Athanasiadis V, Mitakou S, Aligiannis N, Bozinou E, *et al*. Determination of the Total Phenolics Content and Antioxidant Activity of Extracts from Parts of Plants from the Greek Island of Crete. Plants,2023:12:1092. https:// doi.org/10.3390/plants12051092
24. Kewuyemi YO, Adebo OA Complementary nutritional and health promoting constituents in germinated and probiotic fermented flours from cowpea, sorghum and orange fleshed sweet potato. Scientific Reports,2024:14:1987.
25. Monteiro CA, Cannon G, Levy RB, Moubarac J-C, Louzada MLC, Rauber F, *et al*. Ultra-processed foods: What they are and how to identify them. Public Health Nutrition,2019:22(5):936–941.
26. Molole GJ, Gure A, Abdissa N Determination of total phenolic content and Antioxi- Dant activity of *Commiphora mollis* (Oliv.) Engl. Resin. BMC Chemistry,2022:16:48. https://doi.org/10.1186/s13065-022-00841-x
27. Park YK, Kim J, Ryu MS, Jeong DY, Yang HJ Review of physiological compounds and health benefits of soybean paste (doenjang): Exploring its bioactive components. Journal of Ethnic Foods,2024:11:30.
28. Rahman U, Younas Z, Ahmad I, Yousaf T, Latif R, Rubab U, *et al*. Enhancing health and therapeutic potential: Innovations in the medicinal and pharmaceutical properties of soy bioactive compounds. Frontiers in Pharmacology,2024:15:Article 1397872.
29. Singleton VL, Orthofer R, Lamuela-Raventós RM Analysis of total phenols. Methods in Enzymology,1999:299:152–178.
30. Victora CG, Christian P, Vidaletti LP, Gatica-Domínguez G, Menon P, Black RE Revisiting maternal and child undernutrition in low-income and middle-income countries. The Lancet,2021:397(10282):1388–1399.
31. World Health Organization Complementary feeding. WHO, 2023.
32. World Health Organization, UNICEF Indicators for assessing infant and young child feeding practices. WHO and UNICEF, 2021.