

FORMULATION AND QUALITY EVALUATION OF INSTANT BEVERAGE PRODUCED FROM SORGHUM INCORPORATED WITH SOAKED AND COOKED BAMBARANUT FLOUR

¹Onwuchekwa Amarachi Ihedinachi, ^{2*}Odi Amarachi Jane, ¹Anayo-Ezeamama Kelechi Lorreta

¹Department of Food Science and Technology, University of Nigeria, Nsukka, Enugu State, Nigeria

²Department of Human Nutrition and Dietetics, David Umahi Federal University of Health Sciences, Uburu, Ebonyi State, Nigeria

*Corresponding Author Email Address: odiiaj@dufuhs.edu.ng

ABSTRACT

Sorghum and Bambara nut are underutilized crops with potential to improve dietary diversity. This study developed instant beverages from their flours and evaluated nutritional, functional, and sensory properties. Sorghum grains were soaked, dried, and milled, while Bambara nuts were either cooked or soaked before milling. Blends were formulated at 90:10 and 80:20 ratios, alongside controls. Proximate composition, functional properties, micronutrients, and phytochemicals were analyzed using standard methods. Sensory evaluation employed a 9-point hedonic scale with 20 semi-trained panelists. Data were subjected to one-way ANOVA and Duncan's Multiple Range Test ($p < 0.05$). Significant differences ($p < 0.05$) were observed in moisture, protein, fat, carbohydrate, and micronutrients. Calcium ranged from 12.00–19.40 mg/100g, iron 5.90–12.85 mg/100g, zinc 25.43–31.50 mg/100g, vitamin B1 0.12–0.21 mg/100g, vitamin B2 0.04–0.06 mg/100g, and vitamin A 0.11–0.26 mg/100g. Sensory scores (5.25–7.40) indicated general acceptability across attributes. Incorporating soaked and cooked Bambara nut flour into sorghum-based beverages enhanced nutritional quality without compromising sensory acceptability. These instant beverages show promise as convenient, nutrient-dense products to promote dietary diversity and utilization of local crops.

Keywords: Sorghum, Bambara nut, instant beverage, Nutritional composition and sensory evaluation.

INTRODUCTION

Instant beverages are food products formulated as powders or granules that readily dissolve or disperse in water or other suitable carrier liquids, producing a beverage that is ready for consumption within a short period. This ease of reconstitution makes them a convenient option for consumers seeking quick and efficient beverage preparation (Ren *et al.*, 2024; Jiang *et al.*, 2025). The increasing demand for convenient, nutritious, and functional food products has led to the development of various instant beverages. They are particularly valued for their ease of preparation, longer shelf life, portability and potential to deliver functional health benefits. Instant powdered beverage drinks require minimal preparation, as they can be readily reconstituted with hot or cold water, making them particularly suitable for modern lifestyles characterized by limited preparation time (Affendi *et al.*, 2015). Instant beverages can also be served as a vehicle for nutritional enhancement. When properly formulated, they can contain bioactive compounds such as antioxidants, vitamins, and dietary fiber. The primary advantages of instant beverages include their convenience and rapid preparation, making them well suited to

modern, fast-paced lifestyles. In addition, their reduced bulk and weight facilitate packaging, storage, and transportation, while their low moisture content contributes to an extended shelf life compared with ready-to-drink liquid beverages (Chaturvedi & Chakraborty, 2024).

Sorghum (*Sorghum bicolor* (L.) Moench) is a healthy and underutilized cereal whose potential to develop nutritious ready-to-drink beverages remains unrealized, despite its nutritional benefits and functional properties. Many populations in Africa and Asia rely heavily on sorghum for minerals, calories, and protein (Hadebe *et al.*, 2017). It is a staple crop for many low-income households and ranks third behind wheat and maize. Sorghum contains a variety of bioactive compounds, including phenolic acids, tannins, anthocyanins, phytosterols and policosanols (Awika & Rooney, 2004). This grain is considered the fifth most-produced cereal in the world after wheat, rice, maize, and barley (Mabelebele *et al.*, 2015). It is a crop of great importance because it can grow in tropical and subtropical arid regions of the world where rainfall is deficient and high temperatures predominate, making other cereals challenging to grow. Whole sorghum grains have key health benefits, such as free radical scavenging activity, which is associated with antimicrobial properties, reduced oxidative stress and anti-inflammatory and anti-cancer activity (Rao *et al.*, 2018). Bambara Groundnut (*Vigna subterranea*) is an African legume known for its high protein content, essential amino acids and significant levels of minerals such as iron, magnesium and zinc. It is the third most important legume after groundnut (*Arachis hypogaea*) and cowpea (*Vigna unguiculata*) in Africa (Gbenyi *et al.*, 2016). It is classified in the family Fabaceae and the genus *Vigna* (Olanrewaju *et al.*, 2022). Bambara groundnut is also a good source of dietary fibre and contains appreciable amounts of fat, contributing to its nutrient-dense composition. Its relatively high contents of dietary fibre, resistant starch and complex carbohydrates can slow carbohydrate digestion and reduce the postprandial glycaemic response, making Bambara groundnut a promising low-glycaemic food with potential benefits for blood glucose regulation and weight management (Udeh, 2020). Its strong nutritional qualities may improve human nutrition, particularly in rural areas. In regions with limited availability of animal protein, Bambara nuts provide a significant source of essential nutrients (Boye *et al.*, 2015).

The nutritional composition of Bambara groundnut (*Vigna subterranea* (L.) Verdc.) has earned it a reputation as a "complete food" due to its appreciable levels of protein, carbohydrates, dietary fibre, healthy fats, vitamins, minerals, and other bioactive

compounds (Halimi *et al.*, 2019; Udeh *et al.*, 2020). Despite its nutritional potential, the use of Bambara groundnut (BG) in food formulations, particularly in beverage products, remains relatively limited, partly due to inadequate research, processing technologies, and applications for incorporating it into convenient foods (Murevanhema & Jideani, 2013; Udeh *et al.*, 2020). Therefore, there is a need to improve the nutritional quality of cereal-based beverages by incorporating underutilized legumes such as Bambara groundnut. Although sorghum and Bambara groundnut are nutritionally valuable crops, limited attention has been paid to their combined use in developing convenient instant beverage products. Previous studies have largely focused on the nutritional composition, processing, and utilization of Bambara groundnut and sorghum independently. In contrast, information on the effects of incorporating soaked and cooked Bambara groundnut flour into sorghum-based instant beverages, particularly regarding proximate composition, micronutrient content, functional properties, phytochemical characteristics, and sensory acceptability, remains limited. Furthermore, the influence of different Bambara groundnut processing treatments and incorporation levels on the overall quality and acceptability of sorghum-based instant beverages has not been adequately established. Addressing this gap could provide an opportunity to develop a nutritionally improved, affordable, and convenient plant-based beverage while promoting the utilization of locally available crops. Therefore, this study aimed to formulate and evaluate instant beverages produced from blends of sorghum and soaked and cooked Bambara groundnut flours, with particular emphasis on their proximate composition, functional properties, micronutrient and phytochemical contents, and sensory characteristics.

MATERIALS AND METHODS

Materials Procurement

Sorghum grain and Bambara nut used for instant beverage production were purchased from Oria Orba market in Udenu Local Government Area, Nsukka, Enugu State, Nigeria.

Material Preparation

Preparation of Sorghum grain flour

Sorghum flour was prepared as described by Omah *et al.* (2021). The sorghum was sorted and carefully washed to remove contaminants and non-grain particles. Freshly washed sorghum was soaked for 8 h, then drained and milled into a slurry. The slurry was dried in a hot-air oven at 50 °C for 24 h. The flour was re-milled and sieved to fine flour using a 500 µm mesh sieve. The sorghum was properly packaged for further use.

Preparation of Bambara groundnut Flour

The processing procedures were adapted from Barimalaa (2005) and Adeleke *et al.* (2017) and modified. Bambara nuts were sorted to remove extraneous materials. The Bambara groundnuts were divided into two portions corresponding to the different treatments. Two treatment methods — soaking and boiling—were employed. For soaking, the prepared sample was soaked for 8 hrs, then drained, milled and oven-dried at 50 °C for 24 h. The Bambara groundnut flour was re-milled and sieved using a 500 µm mesh sieve. For boiling, the sample was heated at 1000 °C for 15 min, then cooled and milled. Bambara nut flour was dried in an oven at 50 °C for 24 h, remilled and sieved to a fine flour using a 500 µm

mesh sieve. The soaked and boiled Bambara nut flour was properly packaged separately for further use.

Table 1: Formulation of Instant Beverage from Blends of Sorghum/Soaked and Cooked Bambara nut flour.

Treatment	Samples	Sorghum (%)	Bambara groundnut (%)
Soaked (SBD)	SSBD1	90	10
	SSBD2	80	20
Cooked (CBD)	CSBD1	90	10
	CSBD2	80	20
Control	SBD	100	0

KEY: The blend proportions were expressed on a weight-by-weight (w/w) basis, with the total flour blend representing 100%. Thus, SSBD1 consisted of 90% sorghum flour and 10% soaked Bambara nut flour; SSBD2 consisted of 80% sorghum flour and 20% soaked Bambara nut flour; CSBD1 consisted of 90% sorghum flour and 10% cooked Bambara nut flour, while CSBD2 consisted of 80% sorghum flour and 20% cooked Bambara nut flour. The control sample (SBD) consisted of 100% sorghum flour without Bambara nut flour.



SSBD1



SSBD2



CSBD1



CSBD2



SBD

Proximate composition

The proximate composition of the samples was determined using the standard methods described by AOAC (2010), while carbohydrate content was determined by difference.

Micronutrients Determination

Determination of Mineral Content

Determination of Iron

Iron content was determined by the phenanthroline method (AOAC, 2010).

Determination of Calcium

Calcium content was determined by titration, as described by Kirk and Sawyer (1998).

Determination of Zinc Content

Zinc content was analysed using an Atomic Absorption Spectrophotometer after dry digestion of about 5.0g samples, with air-acetylene as the energy source for atomization (American Association of Cereal Chemists, Citation 2000).

Determination of Vitamin

Vitamin A Determination

The AOAC (2010) calorimeter method was used to determine the vitamin A content of the sample.

Vitamin B2 (Riboflavin) Determination

Riboflavin content was determined according to the method as described by Onewuka (2005).

Vitamin B1 (Thiamine)

Vitamin B1 was determined using the colorimetric method as described by Pearson (1976).

Functional Properties Determination

Bulk Density Determination

The bulk density and water absorption were determined using the method by AOAC (2010)

Water Absorption Capacity Determination

One gram of the flour sample (W) was weighed and transferred into a clean centrifuge tube of known weight (W1). Distilled water was mixed with the flour to prepare a dispersion of up to 10 mL. This will be centrifuged at 3500 rpm for 15 min. The supernatant will be decanted, and its contents will be reweighed (W2). The gain in mass due to the water absorption of flour will be calculated using the formula.

$$WAC = \frac{W3 - W1}{W2 - W1}$$

RESULTS

Table 2: Proximate Composition of Instant Beverage Flour Produced from Sorghum Incorporated with Soaked and Cooked Bambara Groundnut Flour

Samples	Moisture %	Ash %	Fiber %	Fat %	Protein %	Carbohydrate %
SSBD1	10.70 ^b ± 0.28	1.65 ^a ± 0.21	0.35 ^a ± 0.25	0.36 ^a ± 0.21	4.18 ^e ± 0.28	82.68 ^a ± 0.82
SSBD2	10.40 ^{bc} ± 0.56	1.25 ^a ± 0.35	0.40 ^a ± 0.14	0.31 ^{ab} ± 0.21	7.21 ^b ± 0.28	80.42 ^{bc} ± 1.11
CSBD1	10.65 ^b ± 0.21	1.70 ^a ± 0.28	0.17 ^a ± 0.03	0.30 ^{ab} ± 0.21	5.48 ^c ± 0.21	81.68 ^{ab} ± 0.53
CSBD2	11.70 ^c ± 0.28	1.65 ^a ± 0.21	0.11 ^a ± 0.21	0.28 ^{bc} ± 0.28	4.40 ^d ± 0.28	81.85 ^{ab} ± 0.57
SBD	9.70 ^c ± 0.28	1.25 ^a ± 0.35	0.13 ^a ± 0.01	0.24 ^c ± 0.28	3.65 ^a ± 0.35	79.02 ^c ± 0.71

W = Weight of sample

W1 = Weight of empty tube

W2 = Weight of tube + Water absorbed

Determination of swelling capacity

The swelling capacity of the composite flour blends was determined following the technique described by Onwuka (2018).

Determination of Gelatinization temperature and time

The Gelatinization temperature and time were determined following the technique described by Onwuka (2018).

Phytochemical Analysis

Determination of total flavonoid content

The total flavonoid content of the instant beverage was determined colorimetrically using an aluminum chloride (AlCl₃·6H₂O) solution (Nanasombat et al., 2015).

Determination of total phenol content

The total phenolic content of the instant beverage was analyzed according to the colorimetric technique of Folin-Ciocalteu with some modifications, as stated by Chlopicka *et al.* (2012).

Sensory Evaluation

The sensory evaluation of the samples was conducted by 20 semi-trained panelists from the Department of Food Science and Technology, University of Nigeria, Nsukka, Enugu State, Nigeria. The 20 semi-trained panelists were familiarized with the sensory evaluation procedure and instructed to independently evaluate the samples for appearance, colour, taste, aroma, consistency, mouthfeel and overall acceptability. Each sample was assigned a randomly generated three-digit code to prevent identification of the formulation and minimize potential bias. The coded samples were presented to the panelists in a randomized serving order. Panelists evaluated the samples independently in individual evaluation sessions and were instructed not to discuss their responses with one another. Drinking water was provided for palate cleansing between samples, and panelists were allowed sufficient time between evaluations to minimize sensory carry-over effects. Each sensory attribute was rated on a 9-point hedonic scale (1 = dislike extremely and 9 = like extremely) (Ihekoronye & Ngoddy, 1985).

Experimental Design and Statistical Analysis

SPSS version 20 was used to analyze the data obtained from the study statistically. The study adopted a completely randomized design (CRD). All data generated were subjected to analysis of variance (ANOVA), and means were separated using the Duncan Multiple Range Test; significance was accepted at P<0.05.

Table 3: Functional Properties of Instant Blend Produced from Sorghum Incorporated Soaked and Cooked Bambara Groundnut Flour

Sample	Water absorption g/ml	Bulk density g/ml	Gelation %	Swelling capacity g/g
SSBD1	9.20 ^b ± 0.28	0.50 ^{ab} ± 0.21	43.50 ^{bc} ± 2.12	13.04 ^b ± 2.12
SSBD2	9.25 ^d ± 0.35	0.49 ^{ab} ± 0.21	66.50 ^a ± 2.12	12.23 ^c ± 0.28
CSBD1	10.20 ^a ± 0.28	0.55 ^a ± 0.28	37.00 ^c ± 2.83	10.34 ^e ± 0.02
CSBD2	10.25 ^b ± 0.35	0.48 ^b ± 0.28	48.00 ^b ± 2.83	11.24 ^d ± 0.03
SBD	8.30 ^c ± 0.42	0.41 ^c ± 0.52	40.50 ^c ± 3.53	14.63 ^a ± 0.02

Note: Values with different superscript letters within the same column are significantly different ($p < 0.05$), while values with the same superscript letters are not significantly different.

Key: SSBD1= 90% sorghum, 10% soaked Bambara nut; SSBD2 = 80% sorghum, 20% soaked Bambara nut flour; CSBD1 = 90% sorghum 10% cooked Bambara nut, CSBD2= 80% sorghum 20% cooked Bambara nut flour SBD= 100% sorghum,

Table 4: Phytochemical Composition of Instant Beverage Flour Produced from Sorghum Incorporated with Soaked and Cooked Bambara nut Flour

Sample	Flavonoid (mg/g)	Phenolic (mg/g)
SSBD1	8.23 ^a ± 0.02	3.33 ^e ± 0.02
SSBD2	6.15 ^a ± 0.04	6.20 ^d ± 0.02
CSBD1	7.34 ^c ± 0.02	7.30 ^b ± 0.03
CSBD2	7.75 ^b ± 0.04	8.16 ^a ± 0.03
SBD	6.36 ^d ± 0.02	6.53 ^c ± 0.03

Note: Values with different superscript letters within the same column are significantly different ($p < 0.05$), while values with the same superscript letters are not significantly different. Key: SSBD1= 90% sorghum, 10% soaked Bambara nut; SSBD2 = 80% sorghum, 20% soaked Bambara nut flour; CSBD1 = 90% sorghum, 10% cooked Bambara nut; CSBD2 = 80% sorghum, 20% cooked Bambara nut flour; SBD = 100% sorghum.

Table 5: Micronutrient Composition of Instant Beverage Blends Produced from Sorghum Incorporated with Soaked and Cooked Bambara nut Flour (mg/100g)

Sample	Vitamin B1	Vitamin B2	Vitamin A	Calcium	Iron	Zinc
SSBD1	0.21 ^a ± 0.03	0.05 ^{bc} ± 0.00	0.11 ^c ± 0.00	14.60 ^a ± 0.28	12.85 ^a ± 0.35	29.05 ^b ± 0.35
SSBD2	0.12 ^d ± 0.04	0.04 ^c ± 0.00	0.12 ^c ± 0.00	15.75 ^a ± 0.21	5.90 ^e ± 0.42	25.45 ^c ± 0.35
CSBD1	0.14 ^c ± 0.03	0.06 ^a ± 0.00	0.12 ^c ± 0.00	14.55 ^a ± 0.21	7.30 ^d ± 0.42	28.50 ^b ± 0.42
CSBD2	0.15 ^b ± 0.04	0.05 ^{abc} ± 0.00	0.18 ^b ± 0.00	19.40 ^a ± 0.28	8.60 ^c ± 0.28	31.50 ^a ± 0.42
SBD	0.13 ^c ± 0.03	0.06 ^{ab} ± 0.00	0.26 ^a ± 0.00	12.00 ^a ± 6.79	10.05 ^b ± 0.35	31.40 ^a ± 0.28

Note: Values with different superscript letters within the same column are significantly different ($p < 0.05$), while values with the same superscript letters are not significantly different. Key: SSBD1= 90% sorghum, 10% soaked Bambara nut; SSBD2 = 80% sorghum, 20% soaked Bambara nut flour; CSBD1 = 90% sorghum, 10% cooked Bambara nut; CSBD2 = 80% sorghum, 20% cooked Bambara nut flour; SBD = 100% sorghum.

Table 6: Sensory Evaluation of Instant Beverage Drinks Produced from Sorghum and Bambara Nut Flour

Sample	Appearance	Colour	Taste	Aroma	Consistency	Mouth feel	Overall Acceptability
SSBD1	6.85 ^a ± 0.87	7.00 ^a ± 1.26	5.25 ^b ± 1.16	5.95 ^a ± 1.80	5.90 ^a ± 1.37	5.40 ^a ± 1.70	5.65 ^b ± 1.42
SSBD2	6.65 ^a ± 1.23	6.80 ^a ± 1.47	5.35 ^b ± 1.35	6.05 ^a ± 1.19	6.00 ^a ± 1.41	5.65 ^a ± 1.50	5.75 ^{ab} ± 1.30
CSBD1	7.35 ^a ± 1.14	6.95 ^a ± 1.32	6.35 ^a ± 1.14	6.45 ^a ± 1.43	5.90 ^a ± 1.48	6.25 ^a ± 1.62	6.35 ^{ab} ± 1.39
CSBD2	7.20 ^a ± 1.15	7.25 ^a ± 1.29	5.80 ^{ab} ± 1.24	6.25 ^a ± 1.57	6.15 ^a ± 1.60	5.85 ^a ± 1.39	6.65 ^{ab} ± 1.35
SBD	7.40 ^a ± 1.14	7.00 ^a ± 1.30	6.20 ^a ± 1.40	6.60 ^a ± 1.39	6.50 ^a ± 1.32	6.10 ^a ± 1.41	6.18 ^{ab} ± 1.44

Note: Values are presented as mean ± standard deviation of sensory scores from 20 semi-trained panelists. Means bearing different superscripts within the same column differ significantly ($p < 0.05$), while means bearing the same superscript are not significantly different ($p > 0.05$). Key: SSBD1 = 90% sorghum + 10% soaked Bambara nut; SSBD2 = 80% sorghum + 20% soaked Bambara nut; CSBD1 = 90% sorghum + 10% cooked Bambara nut; CSBD2 = 80% sorghum + 20% cooked Bambara nut; SBD = 100% sorghum. Sensory attributes were evaluated using a 9-point hedonic scale (1 = dislike extremely; 9 = like extremely).

DISCUSSION

Proximate Composition of Instant Beverage Produce from Blends of Sorghum Incorporated Soaked and Cooked Bambara nut Flour

Moisture content

The moisture content of the instant beverage blends ranged from 9.70 to 11.70%, with significant differences ($p < 0.05$) among the formulations. The higher moisture content observed in CSBD2 (80:20% sorghum-Bambara nut) than in the 100% sorghum control may be due to the effects of cooking on the structural

characteristics of the Bambara nut. Cooking promotes starch gelatinization and structural disruption, thereby increasing the capacity of flour components to associate with and retain water. The progressive increase in moisture with Bambara nut incorporation also suggests that the legume component contributed to the blends' water-binding characteristics. Akintola and Anifowose (2025) similarly reported that increasing Bambara nut incorporation can influence water retention and swelling characteristics of composite flour systems. Although the moisture content was higher in the Bambara nut-containing samples, all

values were relatively low for an instant beverage flour. This is technologically important because low moisture content generally reduces the amount of free water available for microbial growth and chemical deterioration, thereby contributing to the storage stability of dry food products.

Ash content

The ash content ranged from 1.25 to 1.70%, with no significant difference ($p > 0.05$) among the samples. The relatively small variation indicates that incorporating Bambara nut and different pretreatments did not substantially alter the total mineral residue of the beverage flour. The highest value was observed in CSBD1, while the lowest was observed in SSBD2. The relatively low ash content observed in the soaked Bambara nut formulation may be due to the leaching of water-soluble minerals during soaking. Soaking involves prolonged contact with water, which may facilitate the migration of soluble mineral components from the seed into the soaking medium. Soaking can reduce the retention of certain minerals in Bambara groundnut by leaching them into the soaking water, particularly water-soluble mineral constituents (Mashau *et al.*, 2025; Tan *et al.*, 2020).

Fiber content

The fiber content of instant beverage from blends of sorghum incorporated with soaked and cooked Bambara nut showed no significant ($p > 0.05$) difference and ranged from 0.11-0.40 %. Sample SSBD2 containing (80:20% sorghum : soaked Bambara nut) recorded the highest fiber content (0.40%), while CSBD2 (80:20% sorghum: cooked Bambara nut flour) had the least fiber content (0.11%). A decrease in the fiber content of flour blends was observed; this could be attributed to mineral loss during preprocessing (soaking), which could cause minerals to leach into processing water and soften the grain (Kebakile, 2009).

Fat content

The fat content increased with Bambara nut incorporation, ranging from approximately 0.24 to 0.36%. SSBD1 containing 10% soaked Bambara nut recorded the highest value, whereas the 100% sorghum control had the lowest value. This trend is expected because Bambara nut contains appreciable amounts of lipid compared with sorghum. Consequently, increasing the proportion of Bambara nut can increase the contribution of lipid to the composite flour. The relatively low fat content of the control sample is consistent with sorghum's generally low lipid contribution compared with oil-rich food ingredients. The slightly higher fat content observed in the Bambara nut-containing formulations may be attributed to the contribution of Bambara groundnut, which contains appreciable amounts of dietary lipid (Tan *et al.*, 2020). From a nutritional perspective, the increase in fat following Bambara nut incorporation may increase the beverage's energy density and improve its essential fatty acid contribution.

Protein content

The protein content increased significantly ($p < 0.05$) with Bambara nut incorporation, ranging from 3.65 to 7.21%. SSBD2 containing 20% soaked Bambara nut had the highest protein content, whereas SBD had the lowest. The marked increase demonstrates the nutritional advantage of combining sorghum with a protein-rich legume. The improvement can be attributed to the greater protein contribution of Bambara nut than that of sorghum. Bambara nut is a leguminous crop with substantial protein content; therefore,

replacing part of the cereal flour with Bambara nut increases the protein concentration of the resulting blend. Ameh *et al.* (2023) similarly reported that increasing Bambara nut incorporation can improve the protein content of composite food products. This finding is particularly important for the development of cereal-legume beverages, as sorghum-based products may benefit nutritionally from the addition of legume protein.

Carbohydrate content (CHO)

The carbohydrate content ranged from 79.02 to 82.68% and differed significantly ($p < 0.05$) among the formulations. The relatively high carbohydrate content across all samples reflects the beverage's cereal-based nature, as sorghum is predominantly carbohydrate, particularly starch. The highest carbohydrate value was observed in SSBD1, while the control recorded the lowest value. The variation does not necessarily indicate that Bambara nut is a richer carbohydrate source than sorghum; rather, it may reflect differences in the relative contribution of protein, fat, ash, fiber, and moisture among the formulations, particularly where carbohydrate was obtained by difference.

Functional Properties of Instant Beverages Produced from Sorghum Incorporated Soaked and Cooked Bambara groundnut flour.

Water absorption capacity (WAC)

The water absorption capacity (WAC) ranged from 8.30 to 10.25 g/ml, with CSBD2 recording the highest value and SBD the lowest. The significant increase in WAC with Bambara nut incorporation indicates that the legume altered the hydration characteristics of the flour blends. The higher WAC observed in CSBD2 may be associated with structural changes induced during cooking. Heat treatment can alter the starch-protein matrix and expose hydrophilic sites that bind water, thereby increasing the water-absorption capacity of the flour (Mashau *et al.*, 2025). In addition, Bambara nut proteins can contribute to water binding through interactions between polar groups and water molecules. Awuchi *et al.* (2019) reported that the functional properties of flours are influenced by their major components, particularly carbohydrates and proteins, as well as the structural characteristics of these components. These interactions can influence the water absorption capacity of flour systems.

Bulk Density (BD)

Bulk density ranged from 0.41 to 0.55 g/ml and differed significantly ($p < 0.05$) among the formulations. CSBD1 recorded the highest bulk density, while SBD had the lowest. The increase in bulk density following Bambara nut incorporation indicates that the composite formulations occupied a greater mass per unit volume than the sorghum-only flour. The higher bulk density may be associated with differences in particle characteristics, milling behaviour, and the structural changes resulting from cooking. Gbenyi *et al.* (2016) reported that incorporation of Bambara groundnut flour influenced the physical properties, including bulk density, of sorghum-based extrudates, demonstrating that Bambara groundnut inclusion and processing conditions can modify the structural characteristics of composite food products. From a processing perspective, bulk density is important because it affects packaging requirements, transportation, storage volume, and the amount of flour that can be accommodated in a given package.

Gelation capacity

Gelation capacity ranged from 37.00 to 66.50%. SSBD2 recorded the highest gelation capacity, whereas CSBD1 recorded the lowest. There was no significant difference ($p > 0.05$) between the CSBD1 and SBD samples. The high gelation capacity of SSBD2 may be attributed to the combined contributions of starch and protein to the formation of a continuous gel network upon hydration and heating. Protein molecules can interact with starch and with one another during heating, while starch contributes to viscosity and structural development. The lower gelation capacity observed in the cooked Bambara nut formulation may indicate that the prior cooking treatment modified the starch and protein structures, reducing their subsequent ability to form a strong gel. Akubor *et al.* (2013) reported that the gelation properties of flour are influenced by the ability of starch and proteins to form a continuous network and that flour with suitable gelation characteristics may function effectively as a thickening ingredient. Therefore, the differences in gelation capacity among the formulations could influence the thickness and mouthfeel of the reconstituted beverage.

Swelling capacity

Swelling capacity ranged from 10.35 to 14.63 g/g and differed significantly ($p < 0.05$) among the samples. The highest swelling capacity was recorded in SBD, while CSBD1 had the lowest. The higher swelling capacity of the 100% sorghum formulation may be associated with its higher starch content relative to the Bambara nut-containing blends. Sorghum starch contributes substantially to water-induced swelling, whereas replacing part of the sorghum with Bambara nut reduces the relative proportion of starch available for swelling. The observed reduction in swelling capacity with Bambara nut incorporation therefore reflects a dilution of the starch-rich cereal component. Kaur *et al.* (2013) similarly associated flour swelling behaviour with starch characteristics and composition.

Phytochemical Composition of Instant Beverage Blend Produced from Sorghum Incorporated Soaked and Cooked Bambara groundnut flour

Phenolic content

The phenolic content of the blend flour values ranged from 3.33 to 8.16 mg/g. Sample CSBD2, containing (80:20% sorghum: cooked Bambara nut), shows the highest percentage of phenolics (8.16 mg/g), while sample SSBD1, containing (90:10% sorghum: soaked Bambara nut), had the least phenolic content (3.33 mg/g). There were significant differences ($p < 0.05$) between the samples, indicating that sorghum and Bambara nut contain a large fraction of phenolic content in bound form. Therefore, heat generated during cooking destroys cell walls and releases bound phenolic content. This finding aligns with Ozkaya *et al.* (2017), who reported that cooking could effectively increase the free phenolic content of cereal; this may be attributed to differences in binding, release and degradation of phenolic content during thermal processing. The relatively higher phenolic concentration of CSBD2 is therefore nutritionally relevant because phenolic compounds contribute to the antioxidant potential of plant-based foods.

Flavonoid content

The flavonoid content ranged from 6.15 to 8.23 mg/g, with significant differences ($p < 0.05$) among the formulations. SSBD1 recorded the highest flavonoid value, while SSBD2 had the lowest.

This could be due to the soaking treatment used; water penetrates the grain, which can lead to swelling, disruption of cell walls and the release of flavonoids. The relatively high value in SSBD1 may be related to the interaction between the 90:10 formulation and soaking treatment. Soaking hydrates the seed and may cause structural disruption, facilitating the release or extraction of certain phytochemicals. The significant differences among the formulations demonstrate that the choice of Bambara nut pretreatment can influence the phytochemical profile of the resulting beverage.

Micronutrient contents of instant beverage blend produced from sorghum incorporated with soaked and cooked Bambara groundnut.

Vitamin B1

Vitamin B1 content ranged from 0.12 to 0.21 mg/100 g and differed significantly ($p < 0.05$) among the samples. The variation indicates that processing method and formulation influenced thiamine retention. The lower value observed in SSBD2 may be due to soaking, as thiamine is water-soluble and can be lost during prolonged exposure to water. This finding is consistent with Kliu (2019), who reported that washing caused a significant loss of vitamin B and mineral content, whereas soaking only decreased the thiamine content. This finding highlights an important processing consideration. Although soaking can improve certain technological properties of Bambara nut and facilitate subsequent processing, it may also reduce the levels of water-soluble micronutrients. Consequently, optimizing soaking conditions is necessary to achieve desirable processing characteristics while minimizing nutrient losses.

Vitamin B₂ (Riboflavin)

The vitamin B₂ content ranged from 0.04 to 0.06 mg/100 g. The highest value was observed in CSBD1, while SSBD2 recorded the lowest. The relatively higher riboflavin concentration in CSBD1 may partly reflect its higher sorghum content compared with the 20% Bambara nut formulation. The increase in vitamin B₂ is due to the higher Percentage of sorghum in sample CSBD1. Arukwe and Nwanekezi (2022) stated that Sorghum grain is a good source of vitamin B₂, so the increase in sorghum increased the vitamin B₂ content. The relatively narrow range among the samples suggests that the formulation changes had only a modest effect on vitamin B₂ concentration. Nevertheless, the finding indicates that maintaining a relatively high proportion of sorghum may help preserve the beverage's contribution of this micronutrient.

Vitamin A

Vitamin A content ranged from 0.11 to 0.26 mg/100 g, with SBD recording the highest value and SSBD1 the lowest. The higher value in the 100% sorghum sample suggests that dilution of the sorghum component with Bambara nut reduced the measured vitamin A concentration. Samples SSBD1, SSBD2 and CSBD1 were not significantly ($p > 0.05$) different from each other. Jaisimha Reddy *et al.* (2022) reported that sorghum contains carotenoid pigments, including β -carotene, lutein, and zeaxanthin. The result suggests that increasing Bambara nut incorporation does not necessarily improve every micronutrient. Rather, the nutritional effect of composite formulation depends on the nutrient contribution of each raw material.

Calcium

The calcium content ranged from 12.00 mg/100g in SBD (100% sorghum) to 19.40 mg/100g in CSBD2 (80:20 sorghum: cooked Bambara nut). There were no significant differences ($p > 0.05$) among the samples. Sample CSBD2 (90:10 sorghum: cooked Bambara nut) had the highest calcium content (19.40mg/100g), while sample SBD (100% sorghum) had the lowest (12.00mg/100g). The increase in calcium content might be due to the 20% increase in Bambara nut. Bambara nut is rich in calcium, so the increase in Bambara nut helped in increasing the calcium content of the sample.

Iron

Iron content ranged from 5.90 to 12.85 mg/100 g and differed significantly ($p < 0.05$) among the formulations. SSBD1 had the highest iron concentration, while SSBD2 had the lowest. The difference between the two soaked Bambara nut formulations indicates that increasing Bambara nut from 10 to 20% did not consistently increase iron content. This could be attributed to the treatment method (soaking) used.

Zinc

The zinc content ranged from 25.45 to 31.50 mg/100 g. CSBD2 recorded the highest value, 31.50 mg/100 g, followed closely by SBD at 31.40 mg/100 g. However, the absence of a significant difference between these two samples indicates that the small difference should not be regarded as a statistically confirmed improvement. The relatively high zinc value observed in CSBD2 may be associated with the contribution of Bambara nut and the cooking treatment. Thermal processing may modify the food matrix and reduce antinutritional factors such as phytate, thereby potentially increasing the availability of mineral elements for absorption. In Bambara groundnut, cooking has been reported to reduce phytate levels, potentially improving nutrient utilization (Ndidi *et al.*, 2014; Gwala *et al.*, 2020). The finding is consistent with the broader principle that processing can influence mineral availability by modifying mineral anti-nutrient interactions.

Sensory Score of Instant Beverages Produced from Sorghum Incorporated Soaked and Cooked Bambara Groundnut Drink

Appearance

The appearance scores of the instant beverage samples ranged from 6.65 to 7.40, with sample CSBD1 (90% sorghum: 10% cooked Bambara groundnut) recording the highest score (7.40), while SSBD2 (80% sorghum: 20% soaked Bambara groundnut) recorded the lowest score (6.65). However, there was no significant difference ($p > 0.05$) among the samples across all formulations. Although CSBD1 had the highest appearance score, this difference was not statistically significant, indicating that incorporating soaked or cooked Bambara groundnut flour at the levels investigated did not significantly affect the perceived appearance of the instant beverages. The relatively high scores recorded for all samples suggest that the beverages had generally acceptable visual characteristics to the panelists.

Colour

The colour of the instant beverage ranged from 6.80 to 7.25 and did not differ significantly ($p > 0.05$). The relatively close scores suggest that neither the incorporation of Bambara nut nor the processing method produced a sufficiently pronounced colour

change to affect consumer perception negatively. This is important for product development because visual acceptability is often an initial determinant of consumer willingness to consume a food product.

Taste

The taste scores of the instant beverage samples ranged from 5.25 to 6.35. Sample CSBD1 (90% sorghum: 10% cooked Bambara groundnut) recorded the highest score (6.35), followed by SBD (100% sorghum) with a score of 6.20, while SSBD1 (90% sorghum: 10% soaked Bambara groundnut) recorded the lowest score (5.25). There was a significant difference ($p < 0.05$) among the samples. Based on the Duncan Multiple Range Test, CSBD1 was significantly different from SSBD1 and SSBD2, while CSBD2 did not differ significantly from the other samples. The higher taste score obtained for CSBD1 indicates greater preference for the beverage containing 10% cooked Bambara groundnut. In contrast, the lower score recorded for SSBD1 suggests that the soaking treatment may have produced a less preferred taste characteristic compared with the cooked treatment at the same incorporation level. The observed differences in taste may be associated with the processing method and level of Bambara groundnut incorporation, which can influence the flavor characteristics of the resulting beverage.

Aroma

The aroma scores of the instant beverage samples ranged from 5.95 to 6.60, with sample SBD (100% sorghum) recording the highest score (6.60), while SSBD1 (90% sorghum: 10% soaked Bambara groundnut) had the lowest score (5.95). However, there was no significant difference among the samples ($p > 0.05$). The higher aroma score recorded for SBD indicates greater preference for the aroma of the 100% sorghum beverage. In contrast, the relatively low SSBD1 score suggests that incorporating soaked Bambara groundnut may have altered the characteristic aroma of the sorghum beverage. Differences in aroma may be associated with the inherent volatile compounds of Bambara groundnut and changes in flavor characteristics resulting from soaking and subsequent processing.

Consistency

Consistency scores ranged from 5.90 to 6.50, with no significant difference ($p > 0.05$) among the samples. SBD had the highest numerical score, whereas SSBD1 had the lowest. The lack of a significant difference indicates that incorporating Bambara nut at the levels investigated did not substantially alter the perceived consistency of the beverages.

Mouth Feel

Mouth feel scores ranged from 5.40 to 6.25, with no significant difference ($p > 0.05$) among the formulations. CSBD1 recorded the highest numerical value, while SSBD1 recorded the lowest. The relatively favourable mouthfeel of CSBD1 may be associated with the effects of cooking on the Bambara nut matrix and its interaction with sorghum starch during reconstitution. The absence of a significant difference, however, indicates that the observed numerical variation was not sufficiently large to demonstrate a statistically meaningful effect. This suggests that both soaked and cooked Bambara nuts could be incorporated at the investigated levels without producing a significant deterioration in perceived mouthfeel.

Overall Acceptability

There was a significant ($p < 0.05$) difference in the overall acceptability of instant beverage drinks, with values ranging from 5.65 to 6.65. The sample CSBD2 (80% sorghum: 20% cooked Bambara groundnut) had the highest value (6.65) and was the most preferred sample, while SSBD1 (90:10% sorghum: soaked Bambara nut) had the lowest value (5.65) and was the least preferred sample.

Conclusion

The study demonstrated that nutritionally improved and sensorially acceptable instant beverages can be produced from sorghum flour incorporated with soaked and cooked Bambara groundnut flour. Incorporation of Bambara groundnut resulted in significant variations in the proximate composition and micronutrient contents of the beverages, indicating that Bambara groundnut can complement sorghum in improving the nutritional quality of cereal-based instant beverages. The formulated beverages were generally acceptable to the panelists, although sensory scores varied with the level and processing treatment of Bambara groundnut flour. Among the formulations, CSBD2 (80% sorghum:20% cooked Bambara groundnut) showed the highest consumer preference for key sensory attributes, particularly appearance, taste, and aroma, suggesting that moderate incorporation of cooked Bambara groundnut provides a favourable balance between nutritional enhancement and sensory quality. Overall, the findings demonstrate the potential of combining sorghum and Bambara groundnut flours to develop convenient, affordable, and nutritionally enhanced plant-based instant beverages, while also promoting the use of these locally available crops. Further studies should investigate optimization of Bambara groundnut incorporation levels, processing conditions and shelf stability on a larger scale to support commercial application.

REFERENCES

- Adeleke, O. R., Adiamo, O. Q., Fawale, O. S., & Olamiti, G. (2017). Effect of soaking and boiling on anti-nutritional factors, oligosaccharide contents and protein digestibility of newly developed Bambara groundnut cultivars. *Turkish Journal of Agriculture—Food Science and Technology*, 5(9), 1006–1014
- Affandi, N., Wahidu, Z., Tajul, A. Y. & Azhar, M. E (2017). Production of Nigella sativa beverage powder under Foam mat drying using egg Albumen as a Foaming agent, *Beverages*. 3(9). 1-5
- Akintola, A. & Anifowose, M. T. (2025). Evaluation of Functional Characteristics of cassava and Bambara nut Flour blends for Baking and Extruded product. *African Journal of Agriculture Science and Food Research*, 19(1), 139-147
- Ameh, C. O., Abu, J. C. & Bundle-Tsegba, C. M. (2023). Chemical and sensory Properties of Maize ogi enriched with flour and Protein Isolate from Bambara nut and Soyabean. *Applied Science Research periodical* 1(9), 39- 60
- AOAC (2010). Official Methods of Analysis. 18th Edition, Revision 2010. Association of Official Analytical Chemists, Washington, DC, USA.
- Arukwe, D. C. & Nwanekezi, E. C (2022). Assessment of the Mineral composition and Vitamin A content of blended sorghum (*Sorghum bicolor*) and pigeon pea (*Cajanus cajan* L) Flour. *World Journal of Advanced Research and Reviews*. 14(01), 534–540.
- Awika, J. M. & Rooney, L. W. (2004). Sorghum phytochemicals and their Potential Impact on Human health. *Photochemistry*, 65(9), 1199-12221
- Awuchi, C. G (2019). Proximate Composition and Functional Properties of Different Grain Flour Composites for Industrial Applications. *International Journal of Food Sciences* 2520-4637 (online) vol 2, Issue 1, No. 4: 43 – 64
- Awuchi, C. G., Igwe, V. S., & Echeta, C. K. (2019). The functional properties of foods and flours. *International Journal of Advanced Academic Research*, 5(11), 139–160.
- Barimalaa, I. S. (2005). Studies on the performance of Bambara groundnut flour in Okpa preparation. *Journal of the Science of Food and Agriculture*, 85(3), 413–417
- Boye, J., Zare, F. & Pletch, A. (2015). Pulse proteins: processing, characterization, functional properties and applications in food and feed. *Food Research International*, 43(2), 414–431.
- Chaturvedi S, & Chakraborty S. (2024). Effect of temperature and packaging materials on the shelf-life stability and in vitro properties of microencapsulated and spray-dried synbiotic legume-based instant beverage powder. *Sustainable Food Technology* 2(1): 62–74
- Chlopicka, J., Pawel, P., Shela, G., Aneta, J. & Pawel, Z. (2012). Total phenolic and total flavonoid content, antioxidant activity and sensory evaluation of pseudocereal breads. *Journal of Food Science and Technology*, 46: 548–555.
- Gbenyi, D. I., N. I., & Badau, M. (2016). Optimizing physical and functional properties of sorghum-Bambara groundnut Extrudates. *Journal of Food Research*, 5(2), 81–93.
- Gwala, S., Kyomugasho, C., Wainaina, I., Rousseau, S., Hendrickx, M., & Grauwet, T. (2020). Ageing, dehulling and cooking of Bambara groundnuts: Consequences for mineral retention and in vitro bioaccessibility. *Food & Function*, 11, 5816–5831.
- Hadebe, S.T., Modi, A. & S. M. Abhaudhi, T. (2017). Drought Tolerance and Water Use of Cereal Crops: A Focus on Sorghum as a Food Security Crop in Sub-Saharan Africa. *Journal of Agronomy and Crop Science*, 203(3), 177–191.
- Halimi, R. A., Barkla, B. J., Mayes, S., & King, G. J. (2019). The potential of the underutilized pulse Bambara groundnut (*Vigna subterranea* (L.) Verdc.) for nutritional food security. *Journal of Food Composition and Analysis*, 77, 47–59
- Ihekoronye, A.I. & Ngoddy, P. O. (1985). *Integrated Food Science and Technology for the tropics*. Macmillan Publishers Limited, London, pp. 345-360
- Jiang, H, Zhang, N, Xie, L, Li, G, Chen, L, & Liao, Z. (2025). A comprehensive review of the rehydration of instant powders: mechanisms, influencing factors, and improvement strategies. *Foods*. 14(16):2883
- Kaur, M., Asthiri, B and Mahajan, G (2017). Variation in Antioxidants, Bioactive Compounds and Antioxidant Capacity in Germinated and Underminated Grains of Ten Rice Cultivars. *Rice Science*, 24(6): 349i359
- Kebekile, M. M. (2009). Sorghum dry-milling processes and their Influence on Meal and Porridge Quality (Doctoral Dissertation, University of Pretoria)
- Mabelebele, M., M. Siwela, R. M. & Gous, P. A. (2015). Chemical Composition and Nutritive value of South African Sorghum varieties as feed for Broiler chickens. *South African Journal of Animal Sciences* 45 (2):206–13
- Mashau, M. E., Ramatsetse, K. E., Takalani, T., Bamidele, O. P., & Ramashia, S. E. (2025). Effect of bioprocessing on the

- nutritional composition, antinutrients, functional properties, and metabolites of Bambara groundnut and its prospective food applications: A review. *Molecules*, 30(11), 2356.
- Mashau, M. E., Ramatsetse, K. E., Takalani, T., Bamidele, O. P., & Ramashia, S. E. (2025). Effect of bioprocessing on the nutritional composition, antinutrients, functional properties, and metabolites of Bambara groundnut and its prospective food applications: A review. *Molecules*, 30(11), 2356.
- Murevanhema, Y. Y., & Jideani, V. A. (2013). Potential of Bambara groundnut (*Vigna subterranea* (L.) Verdc.). Milk as a probiotic beverage—A review. *Critical Reviews in Food Science and Nutrition*, 53(9), 954–967.
- Nanasombat, S., Thonglong, J., & Jitlakha, J. (2015). Formulation and characterization of novel functional beverages with antioxidant and anti-acetylcholinesterase activities. *Functional Foods in Health and Disease*, 5: 1–16.
- Ndidi, U. S., Ndidi, C. U., Aimola, I. A., Olagunju, A., & Muhammad, A. (2014). Effects of processing (boiling and roasting) on the nutritional and antinutritional properties of Bambara groundnuts (*Vigna subterranea* (L.) Verdc.) from Southern Kaduna, Nigeria—*Journal of Food Processing*, 2014, Article 472129.
- Omah, E. C., Nwaudah, E. I., Asogwa, I. S., & Eze, C. R. (2021). Quality evaluation of powdered ogi produced from maize-sorghum and soybean flour blends in Nigeria. *African Journal of Food, Agriculture, Nutrition and Development*, 21(10), 18839–18854.
- Onwuka, G. I. (2005). Food Analysis and Instrumentation: The theory and practice. Lagos: Naphthali Print. P. 1–219.
- Ozkaya, B., Turksoy, S., Ozkaya, H. & Duman, B. (2017). Dehydration of wheat and rice brans by hydrothermal autoclaving Process and the Evaluation of Consequences for dietary Fiber content, Antioxidant activity and phenolic content. *Innovative Food Science and Emerging Technologies*, 39, 209–215.
- Rao, S., Santhakumar, K. A., Chinkwo, G., Johnson, S. K. & Blanchard, C. L. (2018). Characterization of phenolic compounds and antioxidant activity in sorghum grains. *Journal of Cereal Science*, 84:103–11.
- Reddy, K. Jaisimha, Bindu, G. S. M., Hussain, S. A., Devi, M. U., & Maheshwaramma, S. (2022). Nutritional composition of yellow pericarp sorghum (*Sorghum bicolor* L. Moench): A review. *International Journal of Environment and Climate Change*, 12(12), 1732–1738.
- Ren Y, Jia F, & Li D. (2024). Ingredients, structure and reconstitution properties of instant powder foods and the potential for healthy product development: a comprehensive review. *Food Function*, 15(1):37–61.
- Tan, X. L., Azam-Ali, S., Goh, E. V., Mustafa, M., Chai, H. H., Ho, W. K., Mayes, S., Mabhaudhi, T., Azam-Ali, S., & Massawe, F. (2020). Bambara groundnut: An underutilized leguminous crop for global food security and nutrition. *Frontiers in Nutrition*, 7, 601496.
- Udeh, E. L., Nyila, M. A., & Kanu, S. A. (2020). Nutraceutical and antimicrobial potentials of Bambara groundnut (*Vigna subterranea*): A review. *Heliyon*, 6(10).