

Analysis and evaluation of Soy milk, Kunu, and Zobo Beverages in Nigeria by atomic absorption spectrophotometry and UV-Vis spectrometry

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ABSTRACT

Soy milk, Kunu, and Zobo are popular soft drinks in Nigeria. Thus, Information about their nutritional composition is crucial for assessing their energy and nutritional relevance. This study utilized standard methods to analyze the proximate composition, physicochemical properties, and mineral content of beverages in Nigeria. The results showed that the percentages (%) of moisture content, ash content, crude fiber, crude protein, crude fat, and carbohydrate content were highest in Zobo (82.89±1.33), Soy milk (1.02±0.05), Kunu (5.40±1.50), Soymilk (12.17±1.25), Soymilk (2.10±0.22) and Zobo (4.54±1.55) respectively. Additionally, the physicochemical properties, such as titratable acidity, pH, apparent colloidal stability, viscosity, total solids, and the mineral composition of the drinks, were determined using the AOAC (2001) standard method. The minerals zinc (Zn), calcium (Ca), magnesium (Mg), potassium(K), and phosphorus(P) were determined by atomic absorption spectrophotometry (F-AAS) and UV-Vis spectrometry. These findings indicate that these locally produced beverages are rich sources of a balanced diet.

1. Introduction

The quest for affordable yet nutritious alternatives to industrially processed protein-rich beverages has sparked interest in locally sourced plant-based options. Soy milk, Zobo (Sorrel Zoborodo), and Kunu (Kunun-zaki) stand out for their considerable protein content. Soy milk is derived from whole soybeans (*Glycine max*). At the same time, Zobo and Kunu are extracts made from Zobo leaves (*Hibiscus sabdariffa*) and either corn (*Zea mays*) or millet (*Panicum miliaceum*), respectively [1].

These beverages are not only popular globally but are particularly favored in developing and underdeveloped regions where access to commercial drinks like Coca-Cola and Malt drinks may be limited due to economic, social, cultural, or religious reasons. Local alternatives have gained traction as health beverages due to their rich nutritional profiles. They are abundant in fatty acids, oils, proteins, B-vitamin complexes, calcium, amino acids, and essential minerals such as magnesium, zinc, iron, phosphorus, and potassium. Furthermore, they boast natural antioxidants like isoflavones and phytoestrogens [2]. Sold commonly in public spaces like markets, motor

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parks, and educational institutions [3], these drinks serve as dairy milk substitutes, being non-caloric, cholesterol-free, and suitable for individuals with lactose intolerance. While extensive literature exists on the proximate and physicochemical analyses of various food items, little attention has been given to locally produced soy milk, Zobo, and Kunu drinks. Despite their high consumption in developing countries like Nigeria, the nutritional composition of these beverages remains underexplored. Therefore, this investigation aims to elucidate the nutritional profile of these drinks, enhancing consumer awareness of the quality parameters inherent in these products. Moreover, recent nanotechnology advancements have provided new mineral analysis methodologies that could significantly enhance the accuracy and sensitivity of nutritional profiling. For instance, nano-palladium embedded on mesoporous silica nanoparticles has been effectively used for mercury vapor removal from air, showcasing the potential of nanotechnology in environmental and health sciences [4]. Similarly, dispersive ionic liquid-liquid microextraction has been employed for air exposure assessment and biological monitoring of mercury, demonstrating the utility of nanotechnology in precise chemical analysis [5]. Single-walled carbon nanotubes (SWCNTs) have also been explored as novel sorbents for determining mercury in air, indicating the versatility of nanomaterials in analytical applications [6]. Additionally, comparative studies on multi-walled and single-walled carbon nanotubes for mercury vapor adsorption and desorption further emphasize the advanced capabilities of nanotechnology in analytical processes [7]. Various advanced analytical techniques have also been employed to evaluate and analyze traditional beverages such as soy milk, Kunu, and Zobo. For instance, speciation and determination of manganese ions in these beverages have been effectively carried out using N-acetylcysteine immobilized on multi-walled carbon nanotubes (MWCNTs), demonstrating the capability of these nanotubes in enhancing detection sensitivity and selectivity in complex matrices [8]. Similarly, the separation of essential trace elements

in soy milk and Zobo using a novel biostructure sorbent based on cysteine and methionine functionalized MWCNTs has been achieved with high efficiency [9]. Moreover, ultrasound-assisted dispersive-modification solid-phase extraction with ionic liquids immobilized on MWCNTs has shown promising results in the speciation and determination of heavy metals in Kunu samples [10]. Additionally, the preconcentration and separation of nickel in traditional beverage samples using functionalized MWCNTs via ultrasound-assisted solid-liquid trap phase extraction highlight the versatility of these nanotubes in food sample analysis [11]. Furthermore, the rapid speciation of contaminants in these beverages using MWCNTs combined with dispersive ionic liquid-suspension-micro-solid phase extraction underscores the potential of this method for food safety and quality assessments [12]. These advanced nanotechnological and analytical methods based on F-AAS and UV-vis spectrometry applied to the analysis of soy milk, Zobo, and Kunu provide more detailed and accurate insights into their mineral content, ultimately enhancing the understanding of their nutritional benefits and supporting their promotion as valuable dietary components.

2. Materials and methods

2.1. Materials and Apparatus

Soy Milk, Kunu, and Zobo Samples prepared from Nigeria (Soy Milk: Locally sourced from a local soy milk producer in Nigeria, Kunu is obtained from traditional Kunu brewers in Nigeria, and Zobo is purchased in Nigeria, made from dried *Hibiscus sabdariffa* calyces). Other materials and apparatus such as Weighing Balance (Model: Sartorius Praxium 213-1S, Germany); Filter paper (Whatman Filter Paper Grade 1, United Kingdom); Beakers (Pyrex Beaker, Corning Inc., USA); Kjeldahl flask (Model: Kjeldahl Digestion Flask, 500 mL, DWK Life Sciences, Kimble, Germany); Distillation Chamber (Model: Kjeltac™ 8400, Foss, Denmark); Digester (Model: Gerhardt Kjeldahl Digestion Unit, C. Gerhardt GmbH & Co. KG, Germany); Oven (Model: Air Clean Oven

YPO-720, China); Furnace (Model: Carbolite ELF 11/6B Furnace, Carbolite Gero, UK); Stirrer (Model: IKA RCT Basic Magnetic Stirrer, IKA Works, Inc., Germany); Test Tubes (Model: Borosilicate Glass Test Tubes, DWK Life Sciences, Kimble, Germany); Crucibles (Model: Porcelain Crucibles with Lid, CoorsTek, USA); Funnels (Model: Polypropylene Funnels, Dynalon Labware, USA); Desiccator (Model: Standard Vacuum Desiccator, Thermo Fisher Scientific, USA); Soxhlet Apparatus (Model: Soxhlet Extraction Unit, BUCHI Labortechnik AG, Switzerland); Measuring Cylinder (Model: Graduated Measuring Cylinder, 1000 ml, VITLAB, Germany); Retort Stand (Model: Standard Laboratory Retort Stand with Clamps, Philip Harris, UK); pH Meter (Model: Hanna Instruments HI 2211 pH/ORP Meter, Romania); Standard Brookfield Viscometer (Model: Brookfield DV-E Viscometer, AMETEK Brookfield, USA); Volumetric Flask (Product Number: BR36182, Sigma-Aldrich, USA); Hand Gloves (Model: Nitrile Examination Gloves, Kimberly-Clark Professional, USA); Water Bath (Model: Grant SUB Aqua Pro, Grant Instruments, UK); UV-Visible Spectrophotometer (UV-Vis) (Model: UV-2600, Shimadzu Corporation, Japan), and Flame Atomic Absorption Spectrometer (AAS) (Model: Analyst 400, PerkinElmer, USA) were prepared.

2.2. Reagents

Hydrochloric acid (HCl, CAS Number: 7647-01-0, Sigma-Aldrich, Germany), sodium hydroxide (NaOH, CAS Number: 1310-73-2, Sigma-Aldrich, Germany), sodium thiosulphate ($\text{Na}_2\text{S}_2\text{O}_3$, CAS Number: 7772-98-7, Sigma-Aldrich, Germany), sulphuric acid (H_2SO_4 , CAS Number: 7664-93-9, Sigma-Aldrich, Germany), potassium hydroxide (KOH, CAS Number: 1310-58-3, Sigma-Aldrich, Germany), sodium chloride (NaCl, CAS Number: 7647-14-5, Sigma-Aldrich, Germany), boric acid (H_3BO_3 , CAS Number: 10043-35-3, Sigma-Aldrich, Germany), catalyst (CAS Number: 7778-80-5, Potassium (K, Sigma-Aldrich, Germany), distilled water (from the Benue State University

laboratory) were prepared.

2.3. Sample collection and preparation

Samples of these beverages were prepared in three different locations within the Benue State University environment and taken to the laboratory (Department of Chemistry) for analysis. The samples were stored in a refrigerator at 4 °C and used periodically until the analysis was completed.

2.4. Proximate analyses

2.4.1. Determination of moisture content

Moisture was determined using the previous methods [13]. 2.0 g of the sample was mixed and placed into the weighed crucible, and the weight of the crucible plus the weight of the un-dried sample was recorded as W_2 . The crucible and contents were kept in a moisture oven at 105 °C for 1 hour. The samples were removed from the oven, cooled in a desiccator for 30 minutes, and weighed. This process continued until a constant weight was observed, and the observed weight was recorded as W_3 [14]. The moisture content was calculated by Equations 1 and 2.

$$\% \text{ Moisture} = \frac{\text{weight loss}}{\text{Sample weight}} \times 100 \quad (\text{Eq.1})$$

$$\% \text{ Moisture} = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \quad (\text{Eq.2})$$

Where W_1 = weight of the empty crucible

W_2 = weight of crucible + food sample before drying.

W_3 = weight of crucible + food sample after drying.

2.4.2. Determination of ash content

The ash was determined using the method described by Akobundu et al. [15]. A crucible was placed in an oven regulated at 105°C for 30 minutes to dry. It was removed, cooled in a desiccator, weighed, and recorded as W_1 . 2.0 g of the sample was placed in the crucible, and the weight of the crucible plus sample was recorded as W_2 . The crucible containing the sample was heated or incinerated

in a muffle furnace at 200°C for 4 h. The ash was cooled in a desiccator and weighed; the weight was recorded as W_3 . The ash content was calculated using Equations 3 and 4.

$$\% \text{ Ash} = \frac{\text{weight of ash}}{\text{Weight of sample}} \times 100 \quad (\text{Eq.3})$$

$$= \frac{W_3 - W_1}{W_2 - W_1} \times 100 \quad (\text{Eq.4})$$

Where: W_1 = weight of the empty crucible

W_2 = weight of crucible + food before drying and/or ashing

W_3 = weight of crucible + ash

2.4.3. Determination of crude fibre

The fiber was determined using the method described by Amusa et al. [16]. 2.0 g of the sample was weighed in a beaker, 100 mL of a solution containing 1.25 g of NaOH was added, and the volume was made up to 200 mL with distilled water. The final mixture was boiled for 30 minutes and then filtered through a thin, closed pad of washed and ignited asbestos in a Gooch crucible. The final residue was put in a crucible, dried in an oven at 100°C for 30 minutes, and then cooled in a desiccator. The weight of the oven-dried residue was recorded as W_1 . It was afterward incinerated in a muffle furnace at 200°C for 1 hour until a constant weight was observed. The weight of the crucible and ash were equally noted. The loss in weight after incineration multiplied by 100 is the percentage of the crude fiber (Eq.5).

$$\% \text{ Crude fibre} = \frac{W_1 - W_2}{W_0} \times 100 \quad (\text{Eq.5})$$

Where: W_1 = Weight of crucible + residue before ashing

W_2 = Weight of crucible + ash

W_0 = Weight of sample

2.4.4. Determination of fat content

Fat in the samples was determined using the standard method described by Thiex et al. [17]. 250 mL clean boiling flask was dried in an oven at 105 – 110°C for 30 minutes and placed in a desiccator to cool. 2.0

g of the sample was weighed accurately to a labeled extraction thimble. 300ml of petroleum ether (boiling point 40-60°C) was filled into previously weighed, cooled boiling flasks (250 mL). The extraction thimble was plugged lightly with cotton wool. The Soxhlet apparatus was assembled with its contents and allowed to reflux for about 6 hours. The petroleum ether in the flask was distilled and drained into a container for reuse. Almost free of petroleum ether, the flask was dried in an oven at 105-110°C for 1 hour. The flask and the contents were placed into a desiccator, allowed to cool, and then weighed. The amount of fat extracted was obtained from the difference between the weight of the flask before and after the extract was dried, as Equations 6 [18]. The obtained weight was expressed as a percentage of the 2.0 g sample used.

$$\% \text{ Total fat} = \frac{W_3 - W_2}{W_1} \times 100 \quad (\text{Eq.6})$$

Where: W_1 = Weight of sample (g)

W_2 = Weight of flask (g)

W_3 = Weight of flask + fat (g)

2.4.5. Determination of crude protein content

Protein in the samples was determined using the standard method described by Wilson et al. [19]. 2.0 g of sample was weighed and poured into the Kjeldahl flask. 2.0 g of catalyst was similarly weighed and transferred into the flasks. 20 mL concentrated H_2SO_4 and a glass bead (glass beads prevent bumping during heating) were added, and the heat was done gently in the heating mantles. There was occasional shaking till the solution assumed a green color (the temperature of the digester was above 300 °C for 2 hours). The resultant solution was cooled and washed down with distilled water and rinsed gently until the green colour disappeared, and then it was allowed to cool. The digest was transferred with several washings into a 250 mL volumetric flask and made up to the mark with distilled water. The resultant solution was distilled using a Markham distillation apparatus.

2.4.6. Determination of Protein distillation,

Titration and Carbohydrate

The Markham distillation apparatus was steamed through for about 15 minutes before use. A 100 mL conical flask containing 30 mL of 4 % boric acid was placed under the condenser such that the condenser tip was under the liquid. 10 mL of the digest was pipetted into the body of the apparatus via the small funnel aperture, washed down with 50 mL distilled water, and added 50 mL of 40 % NaOH. The distillation was run at 200 °C until about 100 mL of distillate was collected. The receiving flask was removed, the tip of the condenser was washed down into the flask, and the condensed water was removed. The solution in the receiving flask was titrated using HCl (0.1 N) and a few drops of methyl red indicator. The colour changed from transparent yellow to orange, and the final burette reading was recorded. The nitrogen content was finally calculated, hence the protein content of the drinks [20]. The nitrogen (%) and crude protein (%) were calculated by Equations 7 and 8. The crude carbohydrate content was obtained using the difference (AOAC method). The major components of any foodstuff are expressed in terms of 100 %. Therefore, the sum of all the other components determined subtracted from 100 gives the crude carbohydrate content. The percentage of crude carbohydrate content was determined by a differential method as follows by Equation 9.

$$\% \text{ Nitrogen} = \frac{\text{Titre value} \times \text{NA} \times \text{AF} \times \text{MW N}_2}{\text{Weight of sample} \times \text{DF}} \quad (\text{Eq.7})$$

$$\% \text{ Crude Protein} = \% \text{ N} \times \text{F} \times \text{DF} \quad (\text{Eq.8})$$

$$\% \text{ Carbohydrate} = 100 - (\% \text{ Moisture} + \% \text{ Ash} + \% \text{ fiber} + \% \text{ fat} + \% \text{ protein}) \quad (\text{Eq.9})$$

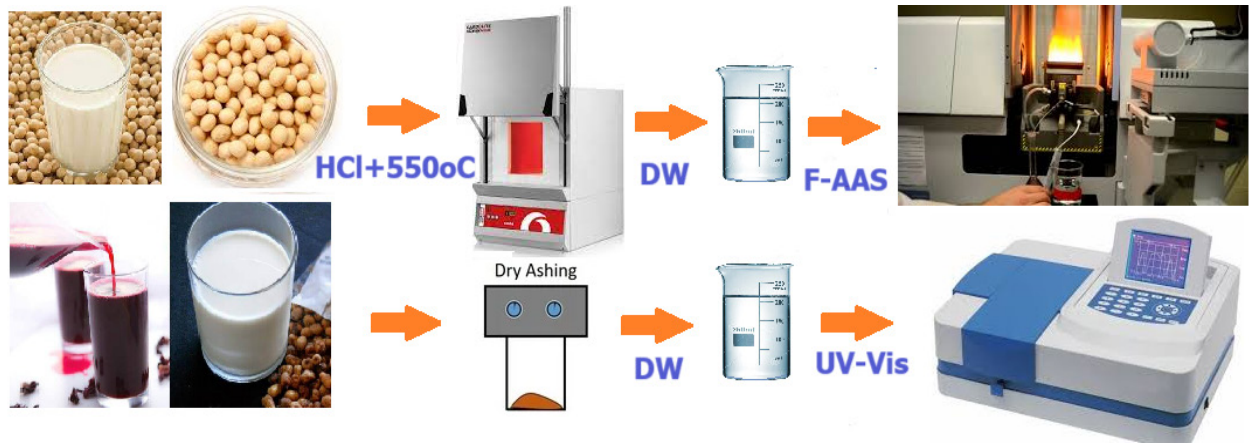
Where F is the conversion factor = 6.25
DF=Dilution Factor, NA: Normality of Acid, AF: acid Factor, MW: Molecular Weight

2.5. Physico-chemical characterization

Titrateable acidity was determined using the method described by Adeiye et al. [21]. Approximately 20 g of the sample was weighed into a 250 mL conical flask and diluted with twice its volume of distilled water. 2 mL of phenolphthalein indicator was added to the mixture, and the mixture was titrated with 0.1 N NaOH to a persistent pink color. The titrateable acidity was reported as % lactic acid by weight using 1 mL of NaOH (0.1M) = 0.0090 g [22]. The pH of the sample was measured by an electrometric method using a laboratory pH Meter Hanna model H1991300, and the value was recorded. Approximately 40 mL of the sample was filled into a 50 mL beaker for the viscosity test. The viscosity test was measured using a standard Brookfield viscometer, and the value was recorded. Osanloo et al. reported validating a new and cost-effective method based on AgNPs coating on micro glassy balls for mercury vapor removal [23]. Also, apparent colloidal stability was measured using the method of Omueti et al. [24]. The sample was placed in a graduated tube and held in racks in the refrigerator undisturbed at 4°C. Changes in apparent colloidal stability were indicated by separation into two layers. The level of the visible line of demarcation between the settled and remaining portion of the sample solution was measured (height in cm) and recorded over 72 h [25].

2.6. Analysis Procedures

Flame atomic absorption spectrophotometry (F-AAS) and UV-Vis spectrometry (Schema 1) determined zinc, calcium, magnesium, potassium, and phosphorus minerals. One gram of each was dry-ash in a muffle furnace at 550 °C for 5 hours until a white residue of constant weight was obtained. The minerals were extracted from ash by adding 20.0 mL of 2.5 % HCl and heating in a steam bath to reduce the volume to about 7.0 mL, and this was transferred quantitatively to a 50 mL volumetric flask. It was diluted to volume (50 mL) with deionized water and stored in clean polyethylene bottles. The mineral contents were determined using F-AAS (model 2380 spectrophotometer, PerkinElmer, Waltham, MA, USA).



Schema 1. The procedure for determination of Zn, Ca, Mg, K, and P by F-AAS and UV-Vis spectrometry

3. Results and Discussion

In this research, the proximate analyses, physicochemical characterization, and mineral composition of soy milk, Kunu, and Zobo sold within the Benue State University environment

were analyzed, and the results are presented in **Tables 1-3** and **Figures 1-3**. Also. The Comparative Analysis of the proximate, physicochemical, and mineral composition of soy milk, Kunu, and Zobo compared to other works in **Table 4**.

Table 1. The proximate analyses of soy milk, *Kunu*, and *Zobo* (%)

S/N	Parameters	Soy milk	Kunu	Zobo
1	Moisture content	77.18 ± 2.10	80.20 ± 1.21	82.89 ± 1.33
2	Ash content	1.02 ± 0.05	0.25 ± 0.01	0.31 ± 0.02
3	Crude fibre	4.16 ± 1.12	5.40 ± 1.50	4.12 ± 1.10
4	Crude protein	12.17 ± 1.25	8.75 ± 1.11	6.54 ± 1.05
5	Crude fat	2.10 ± 0.22	1.80 ± 1.01	1.60 ± 0.01
6	Carbohydrate content	3.37 ± 1.15	3.60 ± 1.51	4.54 ± 1.55

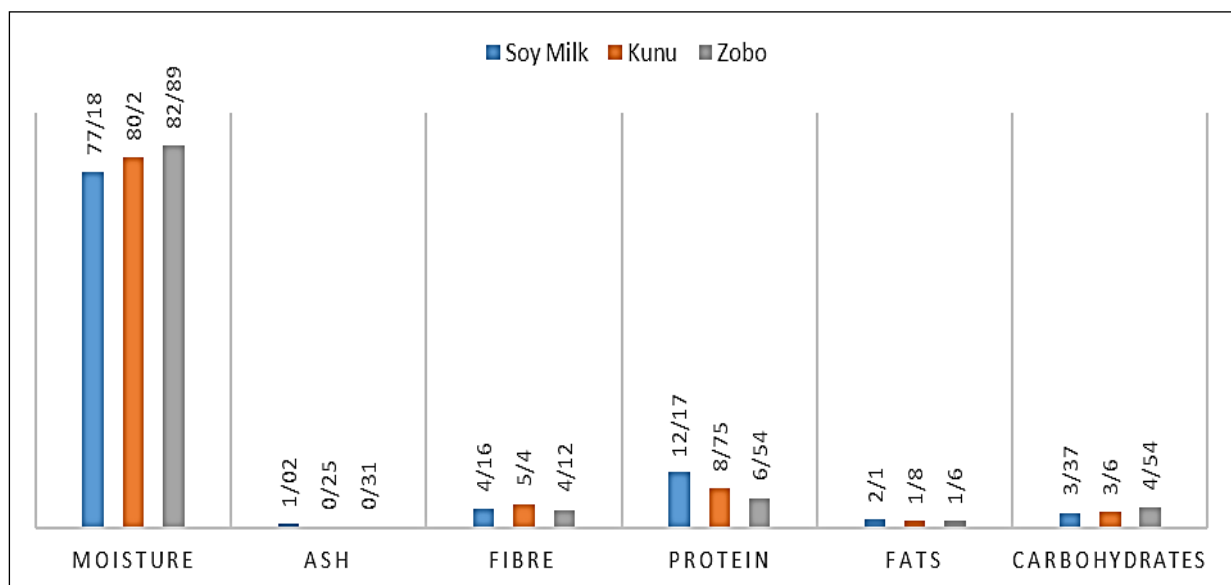
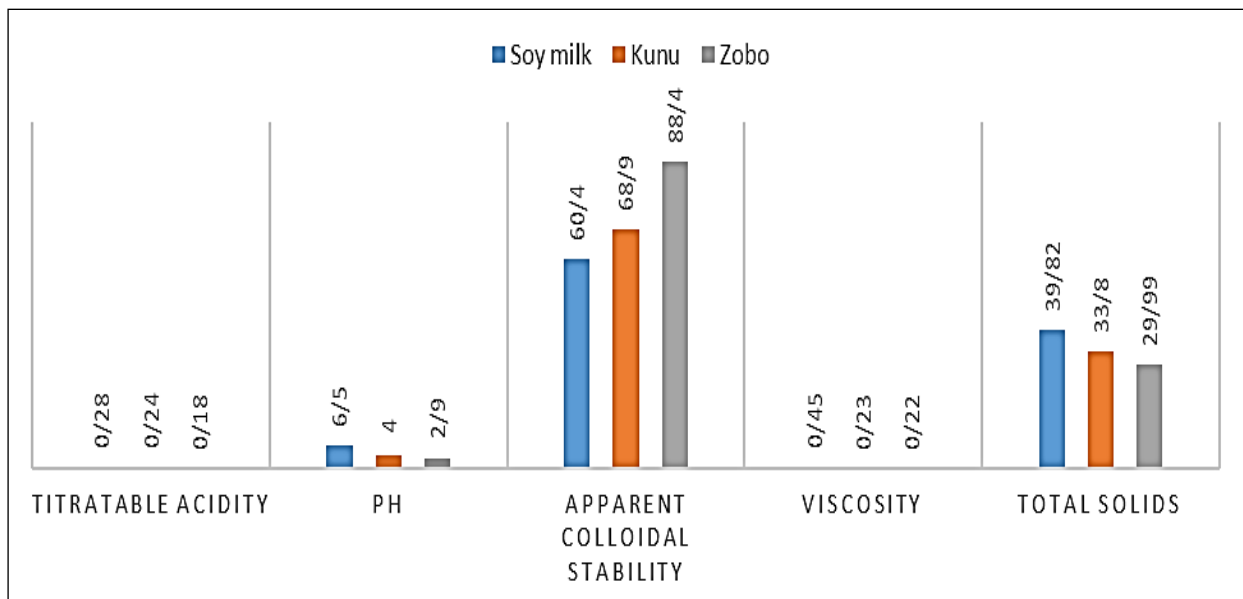


Fig. 1. Shows the graphical representation of the proximate analyses of soy milk, *Kunu* and *Zobo* (%)

Table 2. The physicochemical characterization of soy milk, *Kunu* and *Zobo*

S/N	Parameters	Soy milk	Kunu	Zobo
1	Titrateable acidity (%)	0.28 ± 0.03	0.24 ± 0.02	0.18 ± 0.01
2	pH (%)	6.50 ± 1.25	4.00 ± 1.52	2.90 ± 0.22
3	Apparent colloidal stability (%)	60.40 ± 3.25	68.90 ± 3.55	88.40 ± 3.95
4	Viscosity (Centipoise (cP))	0.45 ± 0.02	0.23 ± 0.01	0.22 ± 0.01
5	Total solids (%)	39.82 ± 2.23	33.80 ± 2.32	29.99 ± 1.11

**Fig. 2.** Shows the graphical representation of the Physico-chemical Characterization of soy milk, *Kunu* and *Zobo* in %, viscosity in Centipoise (cP)**Table 3.** The results of the mineral composition of Soy milk, *Kunu* and *Zobo* in mg 100 g⁻¹

S/N	Parameters	Soy milk	Kunu	Zobo	WHO limit (2021)
1	Zinc	1.35 ± 0.03	3.61 ± 0.23	2.57 ± 0.11	3.00
2	Calcium	38.13 ± 2.55	27.48 ± 2.22	99.20 ± 3.55	75.00
3	Magnesium	12.61 ± 1.25	33.24 ± 2.01	51.84 ± 3.52	50.00
4	Potassium	64.02 ± 3.43	102.58 ± 4.25	91.19 ± 3.22	65.00
5	Phosphorus	0.320.03	0.570.02	0.540.01	0.36

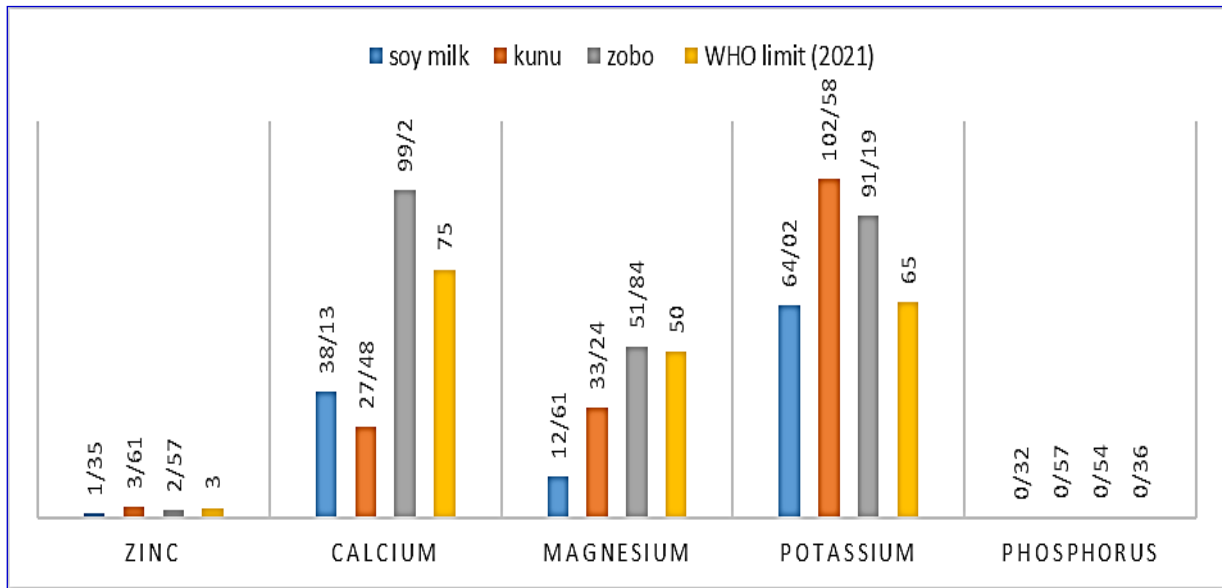


Fig. 3. Mineral composition of soy milk, *Kunu*, and *Zobo* in mg 100 g⁻¹

Table 4. Comparative Analysis of the proximate, physicochemical, and mineral composition of soy milk, *Kunu*, and *Zobo*

Parameter	Soy Milk (Found)	Kunu (Found)	Zobo (Found)	Other Studies	Ref.
Moisture Content (%)	77.18±2.10	80.20±1.21	82.89±1.33	75-85% (varies)	[13]
Ash Content (%)	1.02±0.05	0.25±0.01	0.31±0.02	0.5-1.5% (soy milk)	[15]
Crude Fibre (%)	4.16±1.12	5.40±1.50	4.12±1.10	3-6% (varies)	[16]
Crude Protein (%)	12.17±1.25	8.75±1.11	6.54±1.05	10-12% (soy milk)	[19]
Crude Fat (%)	2.10±0.22	1.80±1.01	1.60±0.01	1.5-3% (varies)	[17]
Carbohydrate Content (%)	3.37±1.15	3.60±1.51	4.54±1.55	3-5% (varies)	[20]
pH	6.50±1.25	4.00±1.52	2.90±0.22	6.0-7.0 (soy milk)	[22]
Viscosity (Centipoise (cP))	0.45±0.02	0.23±0.01	0.22±0.01	0.4-0.5 (soy milk)	[23]
Total Solids (%)	39.82±2.23	33.80±2.32	29.99±1.11	30-40% (soy milk)	[24]
Zinc (mg 100 g ⁻¹)	1.35±0.03	3.61±0.23	2.57±0.11	1-3 mg 100 g ⁻¹ (varies)	[26]
Calcium (mg 100 g ⁻¹)	38.13±2.55	27.48±2.22	99.20±3.55	25-100 mg 100 g ⁻¹ (varies)	[27]
Magnesium (mg 100 g ⁻¹)	12.61±1.25	33.24±2.01	51.84±3.52	10-50 mg 100 g ⁻¹ (varies)	[28]
Potassium (mg 100 g ⁻¹)	64.02±3.43	102.58±4.25	91.19±3.22	50-100 mg 100 g ⁻¹ (varies)	[29]
Phosphorus (mg 100 g ⁻¹)	0.32±0.03	0.57±0.02	0.54±0.01	mg 100 g ⁻¹ (varies)	[30]

3.1. Discussion

The parameters obtained for the proximate analyses, physicochemical characterization, and mineral composition of Soy milk, *Kunu*, and *Zobo* sold within Benue State University environment are presented in Tables 1-3. Table 1 presents the proximate analyses of soy milk, *Kunu*, and *Zobo*, indicating their respective percentages of various nutritional components. The moisture content is

highest in *Zobo* (82.891.33%) and lowest in soy milk (77.182.10%). Soy milk has the highest ash content (1.020.05%), while *Kunu* has the lowest (0.250.01%). In terms of crude fiber, *Kunu* leads with 5.401.50%, followed by soy milk (4.161.12%) and *Zobo* (4.121.10%). Soy milk also has the highest crude protein content at 12.171.25%, with *Kunu* and *Zobo* trailing at 8.751.11% and 6.541.05%, respectively. The crude fat content is

slightly higher in soy milk (2.100.22%) compared to Kunu (1.801.01%) and Zobo (1.600.01%). Lastly, carbohydrate content is highest in Zobo (4.541.55%), with Kunu (3.601.51%) and soy milk (4.541.55%) having slightly lower values. [Table 2](#) presents the physico-chemical characterization of three beverages: soy milk, Kunu, and Zobo. The titratable acidity values indicate that soy milk has the highest acidity ($0.28 \pm 0.03\%$), followed by Kunu ($0.24 \pm 0.02\%$) and Zobo ($0.18 \pm 0.01\%$). The pH levels show that soy milk is the least acidic (pH 6.50 ± 1.25), Kunu is more acidic (pH 4.00 ± 1.52), and Zobo is the most acidic (pH 2.90 ± 0.22). Apparent colloidal stability is highest in Zobo ($88.40 \pm 3.95\%$), indicating better suspension of particles, while soy milk has the lowest stability ($60.40 \pm 3.25\%$). Viscosity measurements reveal that soy milk is the most viscous (0.45 ± 0.02), whereas Kunu and Zobo have similar, lower viscosities (0.23 ± 0.01 cP and 0.22 ± 0.01 cP, respectively). Total solids content is highest in soy milk ($39.82 \pm 2.23\%$), followed by Kunu ($33.80 \pm 2.32\%$) and Zobo ($29.99 \pm 1.11\%$). These parameters highlight significant differences in the physical and chemical properties of the three beverages. [Table 3](#) presents the mineral composition of soy milk, Kunu, and Zobo, compared to the WHO limit [\[26\]](#). Zinc content is highest in Kunu (3.61 ± 0.23 mg 100 g⁻¹), exceeding the WHO limit of 3.00 mg 100 g⁻¹, while soy milk has the lowest zinc content (1.35 ± 0.03 mg 100 g⁻¹). Calcium levels are highest in Zobo (99.20 ± 3.55 mg 100 g⁻¹), surpassing the WHO limit of 75.00 mg 100 g⁻¹, with soy milk having a moderate amount (38.13 ± 2.55 mg 100 g⁻¹). Magnesium content is highest in Zobo (51.84 ± 3.52 mg 100 g⁻¹), also above the WHO limit of 50.00 mg 100 g⁻¹, whereas soy milk has the lowest (12.61 ± 1.25 mg 100 g⁻¹). Potassium is most abundant in Kunu (102.58 ± 4.25 mg 100 g⁻¹), exceeding the WHO limit of 65 mg 100 g⁻¹, with soy milk containing the least (64.02 ± 3.43 mg 100 g⁻¹). Phosphorus levels are low across all beverages but highest in Kunu (0.57 ± 0.02 mg 100 g⁻¹) and slightly above the WHO limit of 0.36 mg 100 g⁻¹ [\[27\]](#). This table highlights the

varying mineral profiles of these beverages and their compliance with WHO standards. Moisture content determines a sample's water content and, indirectly, its dry matter content. It is also an indicator of the flour sample's storage stability [\[28\]](#). Moisture levels above 14% make substances susceptible to microbial growth, reducing their storability [\[29\]](#). Unfortunately, the moisture levels of soy milk, Kunu, and Zobo drinks in this investigation exceed the 14% spoilage threshold. This means these beverages are prone to microbial growth and have a shorter shelf life. These results are consistent with previous findings by Tunde et al. [\[30\]](#), who reported that the moisture content in these drinks is greater than 80%. Ash content measures the total minerals present in a product. The ash values of soy milk, Kunu, and Zobo drinks are 1.02 ± 0.01 , 0.31 ± 0.05 , and 0.23 ± 0.03 , respectively, indicating that soy milk contains the highest mineral content among the evaluated products. Fiber has been shown to improve digestion and reduce the risk of constipation in consumers [\[31\]](#). Kunu drink has the highest crude fiber content at 5.40 ± 1.50 , likely due to ingredients such as potatoes or ginger. Soy milk was found to have the highest protein content among the analyzed products. This is because its main ingredient, soybeans, is a high-protein food, unlike Kunu and Zobo, which primarily contain minerals. The crude fat content also varies among the products, with soy milk having the highest fat content due to its oilseed base. The carbohydrate content of soy milk, Kunu, and Zobo drinks was found to be 3.37 ± 1.15 , 3.60 ± 1.51 , and 4.54 ± 1.55 , respectively [\[32\]](#). These results are significantly higher than those reported by Hopkins et al. [\[33\]](#). As shown in [Table 2](#), the titratable acidity values for soy milk, Kunu, and Zobo were found to be 0.28 ± 0.03 , 0.24 ± 0.02 , and 0.18 ± 0.01 , respectively. The higher acidity of soy milk could provide better storage stability against acid-intolerant microorganisms. The pH of Kunu, recorded at 4.00 ± 1.52 , was higher than that of Zobo at 2.90 ± 0.22 but lower than that of soy milk at 6.50 ± 1.25 . The pH of soy milk was also higher than the 5.37-5.84 range

reported by Crowley et al. [34]. High levels of acetic amino acids in soybean-based beverages might contribute to the higher pH of soy milk. The more acidic pH of these drinks could be advantageous as it may inhibit the growth of pathogens that cause gastrointestinal problems [35]. Sugars and other macromolecules typically affect viscosity in food systems through their interaction with the solution or solvent [36]. The viscosities of soy milk, Kunu, and Zobo were found to be 0.45 ± 0.02 , 0.23 ± 0.01 , and 0.22 ± 0.01 , respectively. The high sugar content in soybeans might contribute to the increased viscosity of soy milk. The total solids content values of 39.82 ± 2.23 for soy milk, 33.80 ± 2.32 for Kunu, and 29.99 ± 1.11 for Zobo observed in this study may be attributed to the processing methods. Soaking and blanching improve total solids extraction [37]. The higher level of total solids in soy milk may be due to the higher levels of suspended particles contributed by the soybeans [38,39], suggesting that the total solids of soy milk could be improved by adding soybean flour. Increasing the total solids enhances the nutritive value of the product and improves quality sustainability [40]. The mineral composition of soy milk, Kunu, and Zobo reveals varying compliance with WHO permissible limits. The amounts of zinc, calcium, magnesium, potassium, and phosphorus in soy milk fall within the WHO-recommended limits. For Kunu, zinc, potassium, and phosphorus levels slightly exceed the WHO limits. In Zobo, calcium, magnesium, potassium, and phosphorus levels are slightly above the WHO limits. This indicates that while soy milk meets all WHO standards for these minerals, Kunu and Zobo exceed some of these recommended levels. Table 4 displays a comparative analysis of the findings from this study with those obtained through various methods in prior research for soy milk, Kunu, and Zobo. The results indicate that the values obtained generally align with those reported in other studies, albeit with slight deviations attributed to distinct preparation techniques and ingredient origins. Soy milk typically contains a higher moisture content than

Kunu and Zobo, falling within 75-85% [41], whereas Kunu and Zobo exhibit slightly lower moisture levels. The ash content of soy milk is generally higher (0.5-1.5%) than Kunu and Zobo (0.2-0.5%). However, all three beverages share similar ranges in crude fiber content, typically falling between 3-6%. In terms of protein content, soy milk stands out with a higher proportion (10-12%) compared to Kunu and Zobo (5-8%) [42,43]. Similarly, soy milk contains more crude fat content (1.5-3%) than Kunu and Zobo. Carbohydrate content, however, remains comparable across all beverages, ranging from 3-5%. Regarding pH levels, soy milk tends to be more neutral (pH 6.0-7.0) compared to the acidic nature of Kunu and Zobo (pH 3.0-4.5) [42,43]. Viscosity measurements show soy milk has a higher viscosity (0.4-0.5 cP) than Kunu and Zobo (0.2-0.3 cP). Total solids content varies, with soy milk generally having a higher range (30-40%) compared to Kunu and Zobo (25-35%) [44]. The mineral composition also differs among the beverages. For instance, soy milk contains higher levels of calcium (25-100 mg 100 g⁻¹) compared to Kunu and Zobo. Conversely, Kunu and Zobo exhibit higher levels of zinc (1-3 mg 100 g⁻¹) and potassium (50-100 mg 100 g⁻¹) than soy milk.

4. Conclusion

From this study, locally made (processed) soy milk, *Kunu*, and Zobo beverage drinks sold at Benue State University, Makurdi, contain appreciable amounts of fats, moisture, fiber, ash, carbohydrates, and high amounts of protein and can supply the protein requirements for the proper functioning of the body. The results show that the pH values of soy milk, *Kunu* drink, and Zobo beverage drinks are low (acidic); this is an advantage because the drinks inhibit the growth of disease-causing microorganisms that can facilitate spoilage. In conclusion, locally made soy milk, *Kunu*, and Zobo drinks sold at Benue State University, Makurdi, Nigeria, contain essential ingredients in a good range of proportions and are safe for consumption.

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