

Evaluation Of Nutritional Quality And Antinutrient Profile Of Wheat-Sorghum-Bombax Costatum Calyces Composite Flour

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Abstract

Background: In many parts of the developing world, heavy reliance on refined wheat flour has limited the use of nutrient-rich indigenous crops and contributed to poor dietary quality. Identifying alternative flour sources from locally available materials can enhance food security and improve nutritional outcomes. Sorghum, a hardy cereal adapted to dry environments, provides fibre, minerals, and beneficial phytochemicals, while *Bombax costatum* calyces are traditionally consumed and represent a valuable source of micronutrients. However, plant-based ingredients often contain antinutritional compounds that may interfere with nutrient absorption. Investigating the nutritional value and antinutrient content of wheat-sorghum-Bombax composite flour will generate useful information for developing affordable, wholesome, and locally acceptable food formulations.

Material and methods: In this study six (6) formulations were used in composite flour production. Wheat flour was partially replaced with sorghum flour and *Bombax costatum* calyces flour at different ratios (100:0:0%, 20:80:0%, 20:70:10%, 20:60:20%, 20:50:30%, and 20:40:40%) with the 100:0:0 as control. Standard methods were employed in raw material preparation and analyses (proximate, minerals, vitamins, and anti-nutrients). The data obtained was subjected to analysis of variance using SPSS version 25, and the Duncan multiple range test was used for mean separation.

Results: Results showed that the addition of sorghum and *Bombax costatum* calyces flour enhanced the nutritional profile of the flour blends. Fiber (2.41-8.70%), ash (2.11-4.21%), fat (4.04-4.81%), and moisture (10.11-13.98%) levels increased, while protein (10.49-13.19%) and carbohydrate contents (61.68-65.24%) decreased compared to 100% wheat samples in flour. Mineral and vitamin contents increased with the level of *Bombax costatum* calyces inclusion in the flour. The composite flour samples notably contain higher amounts of essential minerals such as iron, calcium, magnesium, potassium, and phosphorus, along with vitamins A, C, and E. Although some antinutritional components were detected, their levels were generally low.

Conclusion: The study demonstrates that incorporating sorghum and *Bombax costatum* calyces flour into wheat-based composite flour can improve its nutritional benefits. The study showed potential of *Bombax costatum* calyces as a functional ingredient for developing healthier, more diverse composite flour blends.

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I. Introduction

Composite flours are known as mixed flours as they include starches & other ingredients that replace wheat partially and totally and are used for the production of bakery and pastry products [1]. Composite flours have gained increasing attention because regular consumption has been associated with a reduced risk of several lifestyle-related disorders. This growing interest has positioned them prominently within the commercial food and nutrition sector. As consumers become more health-conscious and seek convenient but wholesome dietary options, especially within the constraints of demanding daily schedules, products formulated from composite flours are emerging as practical alternatives that combine nutritional benefits with ease of use, as reported by Banu et al., [1]. The FAO stated that the use of composite flour for the fabrication of various food products would be advantageous if the significance of wheat flour could be reduced or even removed, and the demand for bread and pastry products could be met by the routine use of domestically grown products as a replacement for wheat. The manufacture of bakery products using composite flour exhibited some virtuous features, with some properties similar to wheat-flour bread; however, the texture and some properties of composite flour differ, with enhanced nutritional and appearance values [2]. No doubt, wheat is a good source of calories, but it is considered a poor cereal as it is deficient in essential amino acids, namely lysine and threonine. Thus, the addition of wheat flour with other inexpensive staples like cereals & pulses benefits the nutritional status of wheat products. New

composite flour mixes are being introduced by emerging food industries and also by health professionals and nutritionists to combat the deep-rooted food insecurity, malnutrition, and certain diseases in children and adults. These composite flour mix prepared by combining cereals and legumes, are economical and contain locally available ingredients to improve the overall food and nutritional quality [3].

Despite its technological advantages, the exclusive use of wheat in composite flour production presents economic and nutritional challenges. Nigeria depends heavily on wheat importation to meet industrial and consumer demands, leading to high production costs and pressure on foreign exchange reserves [4, 5]. Nutritionally, conventional wheat spaghetti is relatively low in dietary fibre, minerals, and bioactive compounds, which are increasingly recognized as important in preventing diet-related non-communicable diseases such as diabetes and cardiovascular disorders [6, 7]. These limitations have stimulated growing interest in the development of spaghetti from composite flours that incorporate locally available, nutrient-dense raw materials [8].

Sorghum is a rich source of complex carbohydrates, dietary fibre, minerals, and phenolic compounds with antioxidant activity [9]. Incorporation of sorghum flour into wheat-based products has been reported to enhance fibre content, improve mineral availability, and lower the glycaemic response of cereal foods [10]. However, sorghum is gluten-free, and its incorporation into pasta formulations can adversely affect dough handling properties, cooking loss, texture, and overall product acceptability if not carefully optimized [11].

Research has expanded beyond cereals to explore underutilized plant materials with functional and nutritional advantages. *Bombax costatum*, commonly known as the red silk cotton tree (*Genger*) in Tiv, is indigenous to West Africa, and its dried calyces are traditionally used as soup thickeners in many Nigerian households [12]. The calyces are rich in mucilage, dietary fibre, and minerals, which confer thickening, water-binding, and stabilizing properties in food systems [13]. These functional attributes suggest that *Bombax costatum* calyces flour may help improve the texture and nutritional quality of cereal-based products [12]. The study is therefore aimed at producing composite flour for utilization in the pastry industry

II. Materials And Methods

Source of raw Materials: *Bombax costatum* calyces were collected from a local farmer in Yandev, Gboko Local Government Area of Benue State, while sorghum and wheat flour were purchased from Wurukum market in Makurdi Local Government Area of Benue State and transported to the Department of Food Processing Laboratory, Joseph Sarwuan Tarkaa University, Makurdi, for processing.

Methods

Production of sorghum flour: Sorghum grains were cleaned to remove extraneous plant parts, broken seeds, and stones, then washed, sun-dried (12 h), dry-milled (hammer mill), and sieved (0.2 mm mesh screen) using a modified method of Hallen et al., [14]. The flour was packaged in an airtight plastic container for further use. The flow chart for producing sorghum flour is shown in Figure 2.1.

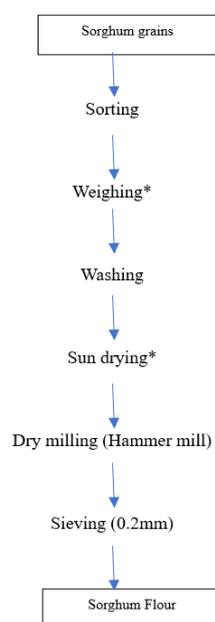


Figure 1: Flow chart for production of sorghum flour
Source: Hallen et al [14] Modified*

Production of *Bombax costatum* calyces flour

Bombax costatum calyces were collected from a selected tree as they dropped, without the influence of any human activity. Petals were manually detached using hands while the calyx was washed thoroughly to remove dust and other adhering soil, which was further sun-dried, milled into powder, and sieved with a 100µm screen mesh to obtain a fine powder. The flow chart for the production of sorghum flour is presented in Figure 2.2

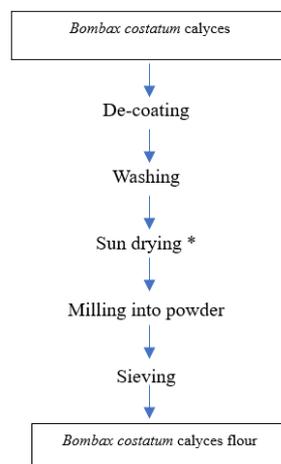


Figure 2: Flow chart for preparation of *Bombax costatum* calyces flour
Source: Imam-Fulani et al [15] modified

Formation of Wheat-Sorghum-*Bombax costatum* Calyces Flour: Wheat-sorghum flour was blended in a food blender at 12 rpm with *Bombax costatum* flour at ratios of 100:0:0, 20:80:0, 20:70:10, 20:60:20, 20:50:30, and 20:40:40 (wheat: sorghum: *Bombax costatum*), while 100% wheat flour (100:0:0) served as the control.

The sorghum flour decreases as the ratio of *Bombax costatum* increases to 40%, while wheat remains constant at 20%. The blended flours were packaged in an airtight plastic container for future use. The blend formulation of Wheat-Sorghum-*Bombax costatum* flour is shown in Table 1.

Table 2.1 Formulation of wheat-sorghum-*Bombax costatum* calyces flour blends

| Sample | Wheat flour% | Sorghum flour% | <i>Bombax costatum</i> calyces flour |
|--------|--------------|----------------|--------------------------------------|
| A | 100 | 0 | 0 |
| B | 20 | 80 | 0 |
| C | 20 | 70 | 10 |
| D | 20 | 60 | 20 |
| E | 20 | 50 | 30 |
| F | 20 | 40 | 40 |

Source: Akinyemi et al [16] Modified*

Preparation of Wheat-Sorghum -*Bombax costatum* dough: Flour (300g) and water (150mL) were the only ingredients used in preparing the dough. To make the dough, different percentage weight fractions of flours listed in Table 2.1 were added to warm water for each formulation, and the mixture was heated to 69.5°C in a water bath for 40 minutes. Afterwards, the *Bombax costatum* calyces were cooled to about 40°C in an ice water bath, then added to the remaining flour to form a homogeneous dough using a domestic blender (KitchenAid 4.5-quart tilt-head stand mixer, Model Classic Plus KSM75WH, St. Joseph, MI, USA). Finally, kneading was performed for 20 minutes.

Proximate Composition of the Composite Flour

Determination of moisture content: Moisture content was determined using the oven drying method as outlined by Nwafor et al. [17]. Exactly 5 g of the sample was weighed into pre-weighed, dry crucibles and heated in an oven at 105°C for 3 hours. Cooling and weighing of the dried samples were performed at 30-minute intervals until there was no weight change after three successive measurements. The final weight of the dried samples was recorded, and the moisture content was calculated as described by equation 1.

$$\text{Moisture content}(\%) = \frac{w_1 - w_2}{w_1 - w_0} \times \frac{100}{1} \tag{1}$$

Where, W₀ =weight of dish only, W₁= weight of dish and sample after drying, W₂ =weight of dish and sample before drying, W₁-W₀ = weight of sample originally before drying.

Determination of Ash content: Total ash content was determined by dry ashing according to Nwafor et al., [17]. 5 g of the sample was weighed in dry crucibles, carbonised on a hot plate and heated on a muffle furnace at 600 °C for 8 h after which they were cooled in a desiccator and weighed. Ash content was determined by the difference in weight after cooling the samples in desiccators at ambient temperatures. Percentage Ash was calculated as described by equation 2:

$$\text{Ash (\%)} = \frac{\text{weight of ash}}{\text{weight of sample}} \times \frac{100}{1} \quad 2$$

Determination of crude fat: Crude fat was determined by the Soxhlet extraction method as outlined by Nwafor et al., [17]. 5 g of dried samples were weighed into a preconditioned extraction thimble (W₀) and placed in the Soxhlet extraction apparatus. The fat content of the samples was extracted using petroleum ether and boiled under reflux for 6 h. The extraction thimbles were then removed and dried in an oven at 105 °C for 30 min, then cooled and weighed (W₁). The percentage of fat content was calculated as described in equation 3:

The fat content was calculated as

$$\text{Fat (\%)} = \frac{\text{weight of fat}}{\text{original weight of sample}} \times \frac{100}{1} \quad 3$$

Determination of crude protein: Protein content was determined using the method described by Mi & Ejeh [18]. Nitrogen content was determined using the micro-Kjeldahl procedure. 0.5 g of the sample was weighed, heated and digested using conc. Sulphuric acid with the aid of a catalyst mixture. The digest was neutralised with alkali and distilled into a boric acid solution. The borate anions formed are titrated with standardised acid, which is converted to nitrogen in the sample. The protein content was calculated using the formula. The percentage Nitrogen was calculated as shown in equation 4.

$$\% \text{ Nitrogen} = \frac{\text{titre} \times 0.0014 \times \text{dilution factor}}{\text{weight of sample}} \times \frac{100}{1} \quad 4$$

$$\% \text{ Protein} = \% \text{ Nitrogen} \times \text{Factor (6.25)} \quad 5$$

Determination of crude fibre: Crude fibre was determined using a method described by Nwafor et al. [17]. Exactly 2 g of samples were digested in a conical flask with 100 mL of Trichloroacetic acid (TCA). This solution was boiled and refluxed for 40 min. After digestion, the flask was removed from the heater, cooled and the solution filtered with (Whatman number 1) filter paper. 1 g of the residues was washed with distilled water several times and once with methylated spirit. The residue was transferred to a porcelain (Evaporating dish) dish and heated for 24 h at 500 °C. The porcelain dishes were later taken to the desiccator to cool and their weight was taken. The digested residue after drying was ashed at 600 °C for 6 h, cooled and its weight recorded. The crude fibre was calculated using equation 6:

$$\text{Fibre (\%)} = \frac{\text{final weight of crucible} - \text{initial weight of crucible}}{\text{original weight of sample}} \times \frac{100}{1} \quad 6$$

Determination of carbohydrate (%): The total carbohydrate content was estimated by difference as previously reported by Nwafor et al., [17] using equation 7:

$$\text{Total Carbohydrate (\%)} = 100 - (\% \text{ moisture} + \% \text{ Ash} + \% \text{ Fat} + \% \text{ protein} + \text{ fibre}). \quad 7$$

Determination of Minerals Composition of the Composite Flour: The sample was dried in an oven at 105 °C for 24 hours at constant weight. The collected sample was ground using a porcelain mortar and pestle. It was then labeled, placed in dry plastic containers, and stored in desiccators until digestion. A 3 g portion of the ground sample was carefully weighed with a digital chemical balance, then mixed with 20 mL HNO₃, 4 mL HClO₄, and 2 mL H₂SO₄. The mixture was heated on a hot plate for one hour until digestion was complete. The digest was stored in pre-cleaned polyethylene bottles for analysis using an Atomic Absorption Spectrophotometer.

Determination of Vitamin Composition of the Composite Flour

Determination of asorbic acid (Vitamin C): Vitamin C content was determined according to [19]. Five grams of the sample were weighed into an extraction tube, and 100 mL of EDTA/TCA (2:1) extracting solution was added. The mixture was shaken for 30 minutes. It was then transferred into a centrifuge tube and centrifuged at 3000 rpm for 20 minutes. The supernatant was transferred into a 100 mL volumetric flask and made up to the mark with the extracting solution. Then, 20 mL of the extract was pipetted into a separate volumetric flask, and 1% starch indicator was added. The solution was titrated with 20 % CuSO₄ solution until a dark endpoint was reached.

Determination of Vitamin A: Vitamin A was determined according to the method of [19]. One gram (1g) of the sample was weighed and macerated with 20 mL of petroleum ether. It was evaporated to dryness, and 0.2 mL of

chloroform acetic anhydride was added, and 2 mL of TCA chloroform was added, and the absorbance was measured at 620 nm. Then the concentration of vitamin A will be extrapolated from the standard curve.

Determination of Vitamin E: One gram (1g) of the sample was weighed and macerated with 20 mL of ethanol. One milliliter (1ml) of 0.2 % ferric chloride in ethanol was added, then 1ml of 0.5 % α , α -dipyridyl was added, it was diluted to 5 mL with distilled water, and absorbance was measured at 520 nm. The concentration of Vitamin E was extrapolated from the standard curve. [19]

Determination of Antinutrient Composition of the Composite Flour

Oxalate determination: The oxalates were determined using the method described by Savage et al., [20] with slight modification. Oxalates were extracted from 0.5 g of composite flour samples with 50 mL of 0.2M HCl and then incubated in a water bath at 80 °C for 15 min. The extracts were allowed to cool to ambient temperature before being transferred to a 100 mL volumetric flask; the final volume was adjusted with water. Subsequently, the extracted samples were centrifuged at 2800 rpm for 15 min. The supernatant was filtered through a 0.45 μ m cellulose acetate filter (Sartorius, Gottingen, Germany) before analysis with High-Performance Liquid Chromatography (HPLC). The HPLC system used consisted of a binary pump (model ProStar 210, Varian, USA), auto-sampler (model Triathlon, Spark, Holland) with a UV detector set at 210 nm (model Waters 2487 Dual λ , absorbance detector, Waters Corporation, USA). Separation was conducted in a Supelco reversed-phase column (4.6mm I.D.×250mm length). The mobile phase was 0.25 g/100 mL of dehydrogenase phosphate and 0.0025 mol/L tetrabutylammonium hydrogen sulphate, buffered at pH 2.0 with ortho-phosphoric acid. The column temperature was set at ambient temperature, and the total running time was 20 min at a flow rate of 1 mL/min. The injection volume was 5 μ L. Identification of oxalic acid was carried out by comparing the HPLC retention time of unknown peaks to the chromatogram with added standard.

Phytate determination: The method of Abera et al., [21] was modified to determine the phytate content. Phytate was extracted from 1 g of the sample with 20 mL of 2.4% (v/v) hydrochloric acid (HCl) by shaking at room temperature for 2 h, followed by high-speed centrifugation of the suspension for 15 min. The supernatant decanted and filtered through Whatman No. 1 filter paper. A 3 mL aliquot of filtrate was diluted to 18 mL with distilled water, and the diluted sample was passed through a 200–400 mesh AG1-X8 chloride anion exchange resin (Bio-Rad Laboratories GmbH, Munchen, Germany). Inorganic phosphorus was eluted with 0.07M sodium chloride (NaCl), followed by the elution of phytate with 0.7M NaCl. Phytate was determined colorimetrically based on the pink colour of Wade reagent, which is formed upon the reaction of the ferric ion and sulfosalicylic acid. One millilitre of Wade reagent (0.03% solution of $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ containing 0.3% (v/v) sulfosalicylic acid in water) was added to 3 mL of the clear supernatant sample and then centrifuged at 2000 rpm for 15 min. The absorbance was measured by a spectrophotometer (model Genesys G10S, USA) at 500 nm. The phytate content was calculated using a standard phytic acid curve, and results were expressed as mg/100 g.

Trypsin inhibitor determination: About 1 gram of each sample A and B was dispersed in 50 mL of 0.5 m NaCl solution. The mixture was stirred for 30 min at room temperature and centrifuged at 1500 rpm for 5 min. The supernatants were filtered, and the filtrates were used for the assay. 2 mL of the standard trypsin solution was added to 10 mL of the substrate of each sample. The absorbance of the mixture was taken at 410 nm using 10 mL of the same substrate as a blank [22]. **Alkaloid determination:** 5 g of each sample was dispersed into 50 mL of 10 % acetic acid in ethanol; the mixture was shaken and allowed to stand for 4 h before filtration. The filtrate was evaporated to one-quarter of the original volume. Concentrated NH_4OH was added dropwise to each sample to precipitate the alkaloid. The precipitate was filtered off with weighed filter paper and washed with 1% NH_4OH solution. The precipitates in each case will be dried at 60°C for 30 min and reweighed.

Data Analysis: All analyses were carried out in triplicate, and SPSS version 20.0 was used for data analysis. The data were analyzed with analysis of variance (ANOVA) to identify significant differences between means, which were expressed as mean \pm standard deviation (SD). The Duncan multiple range test was employed for mean separation.

III. Results

Proximate composition of flour blends: The proximate composition of wheat-sorghum -*Bombax costatum calyces* flour blends is presented in Table 1. The moisture content of the blends ranged from 10.11% to 13.98% with the 20: 80: (wheat-sorghum) having significantly ($p < 0.05$) the highest (13.98%) moisture content, while the blend of 20:40:40 (wheat-sorghum- *costatum calyces*) had the least (10.11%).

The protein content of the blend's samples ranged from 10.49 to 12.45%, with that of wheat-sorghum-*Bombax costatum calyces flour* blend being the lowest (10.49%) compared to 10.62%, 11.86%, 12.19% and

12.45% for the blends containing 30%, 20%, 10% and 0% *Bombax costatum calyces* substitution, respectively for (wheat-sorghum- *Bombax costatum calyces*). There was a significant ($p>0.05$) decrease in protein content with the addition of *Bombax costatum calyces*.

The fat content of the blend's samples ranged from 4.04 to 4.81%. There was a significant difference ($p < 0.05$) in the fat content of all the sample blends, with sample 20:40:40 having the highest value (4.81%), while sample 20:80 had the least (4.04%), compared to the 6.65% of the control.

The crude fibre of the formulated sample ranged from 3.70% to 8.70%. The fibre content increased with increasing level of *Bombax costatum calyces*. The highest fibre (8.70%) was recorded in the sample 20:40:40 wheat-sorghum- *Bombax costatum calyces* flour, while the lowest fibre content (3.70%) was observed in 20:80 (wheat-sorghum), comparable to the 2.41% of the 100% wheat control.

The ash content of the composite samples showed a significant ($p<0.05$) difference with values ranging from 2.75% to 4.21%. The ash content increased with increasing level of *Bombax costatum calyces* in the blends. The lower value (2.75%) was found in the sample containing a 20:80 (wheat-sorghum) ratio, while the highest ash content (4.21%) was obtained for the sample containing 40% *Bombax costatum calyces* flour, indicating the presence of high mineral content of *Bombax costatum calyces*, contrary to the control (100 % wheat) having 2.11%

The carbohydrate content of the formulated samples ranged from 61.12% to 69.30%. There was a significant difference ($p>0.05$) in all the samples with the highest value obtained in the sample containing 100% wheat and the lowest obtained from the sample containing 40% *Bombax costatum calyces* flour. The carbohydrate content of the blends decreased considerably from 68.71% wheat-sorghum flour to 61.12% to the blends containing 40% *Bombax costatum calyces* flour.

Mineral composition of flour blends: The mineral composition of wheat-sorghum- *Bombax costatum calyces* composite flours is shown in Table 2. The iron content of the blend's samples ranged from 7.90 mg/100g to 10.38 mg/100g with the blends of 20:80 (wheat: sorghum) and 20:40:40: for wheat, sorghum, and *Bombax costatum calyces* flour blends having the least 7.90 mg/100g and highest 10.37 mg/100g values, respectively.

The calcium content obtained from the blend flours varied from 31.26 mg/100g to 36.88 mg/100g. The highest mineral value, 36.88 mg/100g was obtained in the sample containing 20:40:40 formulation (wheat: sorghum: *Bombax costatum calyces*), and the lowest value, 31.26 mg/100g occurred in the sample with 20:80 formulation (wheat: sorghum). There was a significant ($p>0.05$) difference among the samples. The calcium content increased with the addition of *Bombax costatum calyces*.

The magnesium content of the blended samples ranged from 17.47 to 57.93 mg/100g. There was an increase in the magnesium content with addition of *Bombax costatum calyces*. Higher value is observed in the sample with 40% *Bombax costatum calyces* substitution and lower value is obtained in the sample with 80% sorghum flour, whereas the control had 15.10 mg/100g.

The potassium of the composite flour ranged between 99.11 mg/100g and 183.15 mg/100g. The highest potassium value of (183.15 mg/100g) was observed in the sample containing 20: 40: 40 (wheat: sorghum: *Bombax costatum calyces*.) formulation, while the least value (99.11 mg/100g) was found in sample 20: 80 (wheat: sorghum). Compared to 83.15 mg/100g of the wheat control.

The phosphorus content of the composite flour ranged from 37.30 to 42.78 mg/100g. The phosphorus content of the blend containing 80% sorghum flour was lowest (37.30 mg/100g), and that of other blends increased with increasing level of *Bombax costatum calyces* flour.

Vitamin content of flour blends: The vitamin composition of wheat-sorghum-*Bombax costatum calyces* flour blends is presented in Table 3.3. The vitamin C content of the blends increased with the increasing level of *Bombax costatum calyces* addition. The values ranged from 0.26 mg/100g to 0.37 mg/100g. The highest vitamin C value (0.37 mg/100g) was obtained in the sample containing 20:40:40 formulation (wheat-sorghum- *Bombax costatum calyces*) and the least value (0.26 mg/100g) occurred in the sample with 20:80 (wheat-sorghum). The vitamin C increased with the addition of *Bombax costatum calyces* flour.

Vitamin A content of the composite flours varied between 0.07 mg/100g and 0.19 mg/100g, with a significant difference among all the samples. The vitamin A content of the blends increased significantly ($p<0.05$) with increased level of *Bombax costatum calyces*.

Vitamin E content of the composite flour ranged from 0.15 mg/100g to 0.41 mg/100g. The vitamin E content of the blend containing 20:80 (wheat-sorghum) flour was lowest (0.15 mg), and that of other blends increased with increasing level of *Bombax costatum calyces* flour.

Anti-nutritional content of flour blends: Table 3 shows the anti-nutrient content of wheat-sorghum- *Bombax costatum calyces* composite flours. The oxalate content of the composite flour ranged from 0.0310 mg/100g to 0.0810 mg/100g. The oxalate content of the 40% *Bombax costatum calyces* had the lowest value, with 0.0310 mg/100g while the formulation with 20:80 had the highest (0.0810 gm/100g).

The phytate content ranged from 0.0405 mg/100g to 0.0620 mg/100g. There was a gradual decrease in the phytate with increasing level of *Bombax costatum calyces*, The sample with 40% *Bombax costatum calyces* flour has the lowest value with 0.0040 mg/100g, and (20:80) wheat-sorghum had the highest value (0.0620 mg/100g).

The trypsin content of the composite flour varied from 0.0003 mg/100g to 0.0109 mg/100g. The wheat-sorghum flour (20: 80) had the highest trypsin content of 0.0109 mg/100g, while the formulation blends containing 40% *Bombax costatum calyces* had the lowest trypsin content of 0.0003 mg/100g. The trypsin content of the composite flour decreases with an increase in *Bombax costatum calyces* flour

IV. Discussion

Proximate composition of wheat-sorghum-*Bombax costatum* flour

The proximate composition of wheat-sorghum -*Bombax costatum calyces* flours is shown in Table 1. The moisture content of the blends ranged from 10.11% to 13.98%. The moisture content decreased with the addition of *Bombax costatum calyces*. The values of the moisture content of the samples (10.11 to 13.98%) are comparably higher than 8.25 to 8.72% reported by Akinyemi et al. [16] for a blend of wheat flour and plantain, 8.2 to 8.7 % as recorded by Mishra et al., [23] for wheat bran, Oat fibre and psyllium husk blends but lower than 60.7 to 65.3 % reported for jackfruit, rice flour blend pasta [24]. This may be due to the effect of drying at different temperatures. Low moisture content of this study incorporated with *Bombax costatum calyces* is an indication that the composite flour blends may have prolonged shelf life if properly packaged [25]. Higher moisture content is not a desirable quality of food products because it can influence microbial growth and cause spoilage. [26]. Moisture content is one of the valuable factors in the preservation of food materials [16]. In general, the moisture content of this study is, however, within the acceptable range of <14%, as recommended by USRDA [27]

The protein content of the composite flour samples ranged from 10.49 to 12.45%, showing significant ($p>0.05$) decrease among the samples with the addition of *Bombax costatum calyces*. These values are relatively within 10.86 to 15.36% reported by Akinyemi et al., [16], 11.2 to 11.8% of Mishra et al., [23], and 11.27 -14.84 % as documented by Thatsanasuwan et al., [24], but lower than 13.68 to 14.28% reported by Tukura et al. [28]. The protein values were within the recommended range of 10-35% as reported by USRDA [27]. Protein has been shown to play a vital role in organoleptic properties of food, boost the immune system, and play a key role in cell division and growth [29]. Protein can serve as a fuel source to the body.

The fat content of the blend's composite flour ranged from 4.04 to 4.48%, indicating an increase in the level of *Bombax costatum calyces* 'substitution. *Bombax costatum calyces* generally is a good source of fat. The fat content of the formulation is higher than 1.4 to 1.8% as reported by Mishra et al. [23] for wheat bran, Oat fibre and psyllium Husk and 2.40 to 2.75 % James et al., [30] for wheat, Bambara nut and cassava flours, but lower than 9.12 to 11.84 for wheat flour and plantain spaghetti blends as reported by Akinyemi et al., [16]. The fat content in this study was found to be lower than 20 to 30 % recommended dietary allowance (RDA). However, it can be augmented by other dietary sources. Fats are reported to have health benefits, including lowering blood cholesterol levels and improving the absorption of water-soluble minerals; however, low-fat foods are suitable for weight watchers [31]. A relatively low-fat content in spaghetti could be desirable because it helps inhibit rancidity, preserving its pleasant taste and extending its shelf life. Lipids provide very good sources of energy and aid in the transport of fat-soluble vitamins, insulate and protect internal tissue, and contribute to important cell processes [32]. Furthermore, higher fat composition may cause rancidity and encourage contamination of flours.

The crude fibre content of the composite flour blends ranged from 3.70% to 8.70%. The fibre contents of this study were reported higher than that of Animashaun et al., [33] and Edet et al., [34] who reported crude fibre range of 0.23% to 0.79%, and are comparably higher than 2.41 to 2.98% previously reported for wheat flour and plantain blend by Akinyemi et al., [16] and 1.33 to 2.67 % by James et al. [30], for the blends of wheat, Bambara nut and cassava flour but within the ranged of 2.0 to 8.2% as documented by Mishra et al., [23]. The fibre content increased with increasing levels of substitution with *Bombax costatum calyces*. The increased value indicates that *Bombax costatum calyces* are a good source of fibre. The fibre content was below the recommended range of 10 to 35% of the USRDA, [27]. Fibre assists digestion and keeps the gastrointestinal tract healthy, adds bulk to the stomach, helps keep blood sugar stable, and reduces constipation [35]. The viscous and fibrous structure of dietary fibre controls the release of glucose with time in the blood, which helps in the proper control and management of diabetes mellitus and obesity [36].

The results for the ash content of the composite flour show values ranging from 2.11% to 4.21% (see Table 3.1 for the raw flour blends). The ash content increased with increasing level of *Bombax costatum calyces* in the flour blends. Ash content is an indication of the raw mineral profiles of food products. The increase in ash content indicates the high mineral content of *Bombax costatum calyces*. The ash content in the present study is higher than the 1.08 to 1.50% reported by James et al., [30] and the 1.78 to 2.40% reported by Akinyemi et al. [16], as well as the 1.5 to 2.3% reported by Mishra et al., [23]. The high mineral content of the composite flour blends is advantageous for preventing micronutrient malnutrition through food supplementation.

The carbohydrate content of the *Bombax costatum calyces* blends samples ranged from 61.68% to 65.30%, decreasing considerably from 65.30% wheat -sorghum blends to 61.68% in the blends containing 40% *Bombax costatum calyces*. However, the values are within the range of 59.53 to 67.08% as reported by Akinyemi et al., [16] in wheat flour and plantain. and slightly below the 75.10 to 77.32 % as reported by James et al., [30] in the blend of wheat flour, cassava flour, and Bambara nut flour. Carbohydrates, apart from supplying energy to cells such as the brain, muscles, and blood, and contributing to mechanisms, act as a mild natural laxative, and spare proteins as an energy source [37]. It is therefore inferred that the formulated composite flour blends are rich in energy and can provide energy for growing infants.

Mineral composition of wheat-sorghum-Bombax costatum: The values of mineral composition of wheat-sorghum- *Bombax costatum calyces* flour are shown in Table 2. There was a significant difference ($p>0.05$) among the samples for all the minerals, with a significant increase in the addition of *Bombax costatum calyces* to the flour. The iron content of the composite flour ranged from 7.90 mg/100g to 10.38 mg/100g with the blends 20:80 of (wheat: sorghum) and 20:40:40, for wheat, sorghum, and *Bombax costatum calyces* blends having the least and highest values, respectively. The iron content significantly increased with the addition of *Bombax costatum calyces*, demonstrating that *Bombax costatum* is a good source of iron. The iron content of the study samples was significantly low to recommended daily allowance of 16 mg/day to 18 mg/day for men and 12 mg/day for women [27]. Iron has several functions in the human body, including being a constituent of the hemoglobin molecule (70%), myoglobin stored in muscles, an activating molecule for several enzymes, and a component of storage molecules such as ferritin and hemosiderin. Iron deficiency anaemia is characterized by small red cells (microcytosis) with low haemoglobin [38].

The calcium content in the composite flour samples ranged from 31.26 mg/100 g to 36.388 mg/100 g, with significant differences between them at $p<0.05$. The calcium level increased as more *Bombax costatum calyces* were added to the formulation. These values were lower and below the USRDA (1000 to 1200 mg) recommended daily calcium intake for adults aged 19 and above, 1300 mg for adolescents (9 to 18 years), and 700 to 1000 mg/day for pregnant and lactating women. Although the calcium levels in this study are below the recommended daily intake, they can still contribute to overall calcium intake when combined with other diets. Calcium plays a crucial role in blood clotting, muscle contractions, and the healthy growth and development of infants and children, as well as promoting bone formation. It is also an important component of intracellular processes in insulin-responsive tissues like skeletal muscle and adipose tissue [39]. However, low calcium intake can lead to rickets in children, osteomalacia in adults, and osteoporosis, or bone thinning, in older individuals [40].

The magnesium content in the composite flour blends ranged from 17.47 mg/100g to 57.93 mg/100g, as seen in Table 2 of the study. A significant increase in magnesium levels was observed as the ratio of *Bombax costatum calyces* increased. However, magnesium levels were still below the USRDA of 80 to 130 mg/day for infants and children, 240 mg/day for adolescents and adults, 420 mg/day for men, and 310 mg/day for women. Magnesium helps maintain electrical potentials in nerves, activates many enzymes, and works with calcium to support muscle contraction, blood clotting, blood pressure regulation, and lung function [41]. It is essential for all biosynthetic processes, including glycolysis, cyclic ATP formation, energy-dependent membrane transport, and genetic code transmission [42]. Magnesium is a vital component of all cells and is necessary for enzymes involved in energy use and bone formation [43].

The blended composite flour samples showed potassium levels ranging from 99.11 mg/100g to 83.15 mg/100g. There was a significant difference ($p>0.05$) between the samples as shown in Table 3.2. These values were well below the USRDA value for both men and women adults (4700 mg/day). The potassium levels in the samples were higher than the 113.46 to 133.81 mg/100g reported by Arukwe et al., [40]. This could be due to *Bombax costatum calyces* being a good source of potassium. Potassium is essential in blood clotting, muscle contraction, as an intracellular cation-most of which is bound to protein-and, along with sodium, influences osmotic pressure and helps maintain normal pH balance [44].

The phosphorus content in the composite flour blends ranged from 37.30 mg/100g to 42.78 mg/100g. There was a significant decrease in phosphorus levels with the addition of *Bombax costatum calyces* in the flour. These results agree with previous findings that *Bombax costatum calyces* are a good source of phosphorus [45]. The values observed in this study are lower than the 700 mg/day recommended by USRDA for adult males and females. Phosphorus plays a vital role in ATP formation, normal bone growth, blood sugar regulation, and cell growth [44]. It is an essential element involved in numerous biological processes, including maintaining cell membrane integrity, nucleic acid synthesis, ATP production, and acid-base homeostasis [46]. Overall, considering these factors, *Bombax costatum* generally presents a good potential for supplementation in mineral-deficient diets and products, supporting the core objectives of this study.

Vitamin composition of wheat-sorghum-Bombax costatum flour: The results for vitamin C, A, and E contents in the composite flour ranged from 0.26 mg/100g to 0.37 mg/100g, 0.07 mg/100g to 0.19 mg/100g, and 0.15 mg/100g to 0.41 mg/100g for vitamins C, A, and E, respectively, as shown in Table 3.3. Statistical differences were observed in all the samples tested. Vitamins are essential nutrients beneficial to humans because of their involvement in biochemical activities, especially in the Krebs cycle pathway, which helps maintain body temperature and provide energy, even during sleep or rest. Vitamin C is necessary for maintaining health, gum health, wound healing, removing excess oxygen from the system, and acts as a powerful antioxidant [16]. Seaman [47] reported that vitamin C is vital for collagen formation, iron absorption, and the metabolism of certain proteins and folic acid. It also prevents oxidation of other vitamins, assists in the metabolism of acids and calcium, stops internal bleeding, strengthens blood vessels, and helps maintain strong bones and teeth. Additionally, it enhances stamina, supports the integrity of body cells, prevents infections, colds, fatigue, and stress, reduces allergies, and aids in healing burns [48]. Vitamin A is very important for growth, reproduction, good vision, healthy skin, hair, and nails, and for maintaining energy balance in the human body, as reported in Akinyemi et al., [16]. The vitamin A content increases with the inclusion of *Bombax costatum* calyces. According to Edet et al., [34], vitamin A also regulates the immune system, helping to fight infections by producing white blood cells that destroy harmful bacteria and viruses.

Table 1: Proximate composition (%) of Wheat-Sorghum-Bombax costatum flour blends

| F:SF:BF | Moisture | Protein | Fat | Fiber | Ash | Carbohydrate |
|----------|--------------------------|--------------------------|-------------------------|-------------------------|-------------------------|--------------------------|
| 100:0:0 | 10.40 ^a ±0.07 | 13.19 ^e ±0.01 | 6.65 ^f ±0.21 | 2.41 ^a ±0.56 | 2.11 ^a ±0.01 | 65.24 ^f ±0.28 |
| 20:80:0 | 13.98 ^b ±0.01 | 12.45 ^e ±0.07 | 4.04 ^a ±0.06 | 3.70 ^b ±0.14 | 2.75 ^b ±0.01 | 63.08 ^e ±0.16 |
| 20:70:10 | 12.60 ^c ±0.14 | 12.19 ^d ±0.01 | 4.48 ^b ±0.11 | 3.85 ^c ±0.07 | 2.85 ^c ±0.01 | 64.03 ^d ±0.09 |
| 20:60:20 | 11.12 ^d ±0.57 | 11.86 ^e ±0.02 | 4.63 ^c ±0.04 | 5.63 ^d ±0.04 | 3.16 ^d ±0.06 | 63.60 ^d ±0.44 |
| 20:50:30 | 10.50 ^e ±0.01 | 10.62 ^b ±0.01 | 4.74 ^d ±0.05 | 6.85 ^e ±0.07 | 3.85 ^e ±0.06 | 63.44 ^b ±0.19 |
| 20:40:40 | 10.11 ^s ±0.01 | 10.49 ^a ±0.04 | 4.81 ^e ±0.01 | 8.70 ^f ±0.28 | 4.21 ^f ±0.01 | 61.68 ^a ±0.35 |

Values are means ± standard deviation of triplicate (3) determination Means within a column with the same superscript are not significantly different (p<0.05)

WF=Wheat flour, SF=Sorghum flour, BF= *Bombax costatum calyces* flour

Table 2: Mineral composition (mg/100g) of wheat-sorghum-Bombax costatum flour blends

| WF:SF:BF | Iron | Calcium | Magnesium | Potassium | Phosphorus |
|----------|--------------------------|--------------------------|--------------------------|---------------------------|--------------------------|
| 100:0:0 | 6.11 ^a ±0.00 | 28.00 ^a ±0.00 | 15.10 ^a ±0.00 | 83.15 ^a ±0.00 | 35.38 ^a ±0.00 |
| 20:80:0 | 7.90 ^b ±0.00 | 31.26 ^b ±0.00 | 17.47 ^b ±0.01 | 99.11 ^b ±0.00 | 37.30 ^b ±0.00 |
| 20:70:10 | 8.39 ^c ±0.00 | 32.99 ^c ±0.01 | 29.17 ^c ±0.02 | 122.15 ^c ±0.00 | 39.35 ^c ±0.00 |
| 20:60:20 | 8.97 ^d ±0.00 | 35.53 ^c ±0.00 | 38.32 ^d ±0.00 | 127.01 ^d ±0.00 | 40.89 ^d ±0.00 |
| 20:50:30 | 9.97 ^e ±0.01 | 35.77 ^d ±0.00 | 55.31 ^e ±0.00 | 180.15 ^e ±0.00 | 41.92 ^e ±0.01 |
| 20:40:40 | 10.38 ^f ±0.00 | 36.88 ^e ±0.00 | 57.93 ^f ±0.20 | 183.15 ^f ±0.22 | 42.78 ^f ±0.01 |

Values are means ± standard deviation of triplicate (3) determination Means within a column with the same superscript are not significantly different (p<0.05)

WF=Wheat flour, SF=Sorghum flour, BF= *Bombax costatum calyces* flour

Table 3: Vitamins composition of Wheat-Sorghum-Bombax costatum flour blends

| Sample | Vitamin C (mg/100g) | Vitamin A(mg/100g) | Vitamin E(mg/100g) |
|----------|-------------------------|--------------------------|-------------------------|
| 100:0:0 | 0.18 ^a ±0.01 | 0.010 ^a ±0.01 | 0.03 ^a ±0.03 |
| 20:80:0 | 0.26 ^b ±0.00 | 0.07 ^b ±0.00 | 0.15 ^b ±0.15 |
| 20:70:10 | 0.29 ^c ±0.01 | 0.08 ^c ±0.00 | 0.30 ^c ±0.30 |
| 20:60:20 | 0.32 ^d ±0.01 | 0.11 ^d ±0.00 | 0.33 ^d ±0.33 |
| 20:50:30 | 0.35 ^e ±0.01 | 0.14 ^e ±0.01 | 0.37 ^e ±0.37 |
| 20:40:40 | 0.37 ^e ±0.01 | 0.19 ^f ±0.01 | 0.41 ^f ±0.41 |

Values are means ± standard deviation of triplicate (3) determination Means within a column with the same superscript are not significantly different (p<0.05)

WF=Wheat flour, SF=Sorghum flour, BF= *Bombax costatum calyces* flour

Table 4: Antinutrients composition (mg/100g) of wheat-sorghum-Bombax costatum flour blends

| WF:SF:BF | Oxalate | Phytate | Trypsin inhibitor |
|----------|-------------------------|-------------------------|--------------------------|
| 100:0:0 | 0.04 ^b ±0.70 | 0.05 ^b ±0.07 | 0.01 ^b ±0.01 |
| 20:80:0 | 0.08 ^c ±0.20 | 0.06 ^d ±0.06 | 0.01 ^c ±0.02 |
| 20:70:10 | 0.08 ^c ±0.12 | 0.06 ^d ±0.04 | 0.01 ^c ±0.02 |
| 20:60:20 | 0.07 ^d ±0.19 | 0.05 ^e ±0.03 | 0.01 ^{bc} ±0.04 |
| 20:50:30 | 0.07 ^e ±0.07 | 0.05 ^b ±0.04 | 0.01 ^b ±0.02 |
| 20:40:40 | 0.03 ^a ±0.04 | 0.04 ^a ±0.04 | 0.03 ^a ±0.02 |

Values are means ± standard deviation of triplicate (3) replications. Means within a column with the same superscript are not significantly different (p<0.05). WF=Wheat flour, SF=Sorghum flour, BF= *Bombax costatum calyces* flour

Anti-nutritional composition of wheat-sorghum-*Bombax costatum* flour: Anti-nutritional factors are chemical compounds naturally produced in food and/or feedstuffs by the normal metabolism of species, which have effects that are contrary to optimal nutrition [49]. These factors also reduce the maximum utilization of nutrients, especially proteins, vitamins, and minerals, thereby hindering the efficient use of nutrients in food and reducing its nutritive value [50]. The results for the antinutritional factors in spaghetti blends and flour are shown in Table 3.4. There was no significant ($p>0.05$) decrease in any of the samples studied, in the flours incorporated. The oxalate content ranged from 0.0310 mg/100g to 0.810 mg/100g in the flour blends. A gradual decrease in oxalates was observed in composite flour samples containing *Bombax costatum* calyces, with no significant difference across all samples. The oxalate content was lowest in samples with *Bombax costatum* calyces and highest in the 20:80:0 mixture. Okafor [51] reported that the oxalate content of African yam bean (*Sphenostylis stenocarpa*), maize (*Zea mays*), and defatted coconut (*Cocos nucifera*) ranged from 0.08 to 0.30 mg/100g, which is higher than the levels reported in this study. The phytate content in the flour blends it ranged from 0.04 mg/100g to 0.06 mg/100g. Phytate levels decreased gradually as the level of *Bombax costatum* calyces increased. The phytate content reported here is lower than that of a composite flour containing 39.4% raw oat cereal [52] and is also much lower than the 25.7-39.4% range reported in malted sorghum-soy flour [53]. The sample with 40% *Bombax costatum* calyces flour had the lowest phytate level at 0.0405 mg/100g, while the wheat-sorghum (20:80) sample had the highest at 0.06 mg/100g. The trypsin activity in the blends ranged from 0.03mg/100g to 0.01 mg/100g. The wheat-sorghum composite flour (20:80) exhibited the highest trypsin content at 0.01 mg/100g, while the spaghetti containing 40% *Bombax costatum* calyces had the lowest at 0.0003 mg/100g. Trypsin activity decreased as the level of *Bombax costatum* calyces increased. The values obtained for trypsin inhibitors in these products were well below the critical threshold of 0.25 mg/100g reported by Adeoti & Osundahunsi [54], indicating that the formulated products are safe and unlikely to affect nutrient bioavailability.

V. Conclusion

The study showed that the blends from wheat–sorghum–*Bombax costatum* calyces flour have better nutrition and acceptable qualities. Adding sorghum and *Bombax costatum* calyces increased dietary fiber, minerals, and vitamins, while antinutritional factors remained low. The study confirms that *Bombax costatum* calyces can be effectively combined with sorghum and wheat to produce nutritionally improved and consumer-acceptable blends, encouraging the use of locally available raw materials and reducing dependence on imported wheat.

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