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Effects of Refrigeration and Daily Decantation on the Nutritional Composition and Antinutritional Factors of Soaked Sorghum (*Sorghum bicolor*)

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ABSTRACT

Sorghum (*Sorghum bicolor*), normally known as guinea corn, is an important Nigerian cereal whose nutritional composition may vary during processing and storage. This study compared the proximate composition, mineral content, antinutritional factors and vitamin C of soaked guinea corn stored under refrigeration and daily decantation. A single batch was divided into two portions: one refrigerated at 4 ± 2 °C without water replacement, and the other maintained at 28 ± 2 °C with daily water replacement for 21 days. Proximate composition was determined using AOAC methods, minerals by atomic absorption spectrophotometry, and antinutritional factors and vitamin C using laboratory procedures. Results were expressed as mean ± standard deviation of triplicate determinations and analysed descriptively. Refrigerated samples recorded higher ash (0.96%), fibre (3.54%) and carbohydrate (42.33%), while decanted samples had higher moisture (56.00%), lipid (2.18%) and protein (2.84%). Refrigerated samples contained more calcium, copper, sodium, potassium and iron, whereas decanted samples had higher zinc and manganese. Decanted samples also recorded lower phytate and oxalate but higher vitamin C (3.03 mg/100 g) than refrigerated samples (2.17 mg/100 g). These findings demonstrate differences in measured nutritional composition between the storage conditions. However, the study was limited by the use of one experimental batch, and nutrient losses through discarded water were not assessed. Further independently replicated studies incorporating dry-matter standardisation, nutrient-retention calculations and microbiological assessment are necessary before recommending either method for prolonged household storage

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INTRODUCTION

Sorghum (Sorghum bicolor) is a cereal crop commonly cultivated in Africa and other parts of the world. In Nigeria, guinea corn is consumed in various traditional foods and beverages, including ogi, kunu and agidi. Its nutritional importance is influenced by its proximate composition, mineral content and the presence of antinutritional factors that may affect nutrient digestibility and bioavailability (Zubair et al., 2023).

Although sorghum provides vital nutrients, its nutritional quality may be limited by relatively low concentrations of certain essential amino acids and the presence of antinutritional compounds such as oxalate, phytate, tannins and saponins. These compounds may interact with minerals and proteins, thereby influencing nutrient availability (Soni et al., 2022; Zubair, 2023). The nutritional composition of sorghum also varies according to environmental conditions, cultivar, harvesting, processing and storage practices (Adebo & Kesa, 2023).

Traditional processing methods such as soaking, fermentation, malting and sprouting are commonly used to improve the processing characteristics and nutritional quality of cereals. Previous studies have demonstrated that these treatments can influence proximate composition, antinutritional factors and mineral concentrations. Keyata et al (2021) reported that washing, soaking and malting influenced the nutritional composition and antinutritional factors of sorghum. Similarly, Rugwete et al. (2024) reported changes in the nutritional and antinutritional composition of red sorghum following different processing treatments.

However, fermentation and subsequent storage are distinct processes. Fermentation involves biochemical and microbial changes during processing, whereas post-soaking storage concerns the conditions under which the prepared material is maintained after soaking and blending. In traditional cereal processing, soaked materials may be refrigerated or kept at ambient temperature with regular replacement of the surrounding water. These practices may influence the measured nutritional composition through moisture changes, continued biochemical activity and possible leaching of soluble nutrients into discarded water.

Although previous studies have investigated the effects of sorghum processing and grain storage on nutritional composition, limited information is available on the comparative nutritional characteristics of soaked sorghum maintained under refrigeration and daily decantation conditions. Understanding these differences is important because household storage practices may influence the composition of traditional cereal preparations. This study aimed to compare the proximate composition, mineral concentrations, antinutritional factors and vitamin C content of soaked sorghum stored under refrigeration and daily decantation conditions.

Materials and Methods

Study Design

The experiment was carried out at the University of Benin, Benin City, Edo State, Nigeria, over 24 days (3 days of soaking followed by 21 days of storage). Two storage treatments were compared: refrigerated guinea corn (RGC),

kept at 4 ± 2 °C without decantation, and decanted guinea corn (DGC), kept at 28 ± 2 °C with daily replacement of the water. Both treatments were derived from one soaking batch, so the design provides analytical replication only and not independent biological replication.

Material

Guinea corn was purchased from a local market in Benin City and authenticated at the Herbarium Section, Department of Plant Biotechnology, University of Benin, under voucher number DUBH-S468. Sand and stones were removed and the grains were washed with distilled water.

Procedure

A 280 g portion was soaked in 600 ml of cold distilled water in a plastic container for three days at room temperature to allow fermentation, then blended into a smooth slurry (Philips blender) and divided into two equal portions.

The RGC portion was placed in a clean airtight container and refrigerated at 4 ± 2 °C for 21 days without decantation. The DGC portion was kept in a container at 28 ± 2 °C, and each day the supernatant was discarded and replaced with 200 ml fresh distilled water for 21 days, following the traditional method of preserving ogi, the discarded water was not analysed.



Table 1: Proximate

Proximate Analysis

Moisture, ash, crude lipid, crude fibre and crude protein were determined by AOAC (1990) methods. Moisture was determined by oven drying at 105 °C to constant mass, ash by incineration in a muffle furnace, crude lipid by Soxhlet extraction with petroleum ether, crude fibre by sequential acid and alkali digestion followed by drying and ashing, and crude protein from nitrogen determined by the Kjeldahl procedure. Carbohydrate was estimated by difference: % carbohydrate = 100 − (% moisture + % ash + % protein + % lipid + % fibre). Proximate values are reported as analysed (fresh weight). Because moisture differed between treatments, values were also expressed on a dry-matter basis as value ÷ (100 − mean moisture %) × 100, using the mean moisture of each treatment.

The proximate composition results were converted to a dry-weight basis to account for differences in moisture content between the refrigerated and decanted samples. The conversion was performed using the following formula:

$$\text{Dry-weight value} = \frac{\text{As–is value x 100}}{100 - moisture\ content\ (\%)}$$

Mineral Analysis

Calcium, copper, zinc, manganese, sodium, potassium and iron were determined by atomic absorption spectrophotometry. A 1.0 g portion of dried, ground sample was digested with mixed acid, heated until clear, cooled, filtered through Whatman No. 42 paper and made up to 100 mL with deionised water. A reagent blank was prepared in the same way. The mineral elements in the refrigerated and decanted guinea corn samples were determined using an Atomic Absorption Spectrophotometer (AAS). The instrument was calibrated separately for each mineral element analysed, namely calcium, copper, zinc, manganese, sodium, potassium and iron. Calibration was performed using standard solutions of known concentrations prepared for the respective elements. The absorbance of each standard solution was measured, and calibration curves were generated by plotting absorbance against the corresponding standard concentrations. The concentrations of the mineral elements in the sample digests were subsequently determined by comparing their absorbance readings with the respective calibration curves. Appropriate reagent blanks were used to correct for background interference. The mineral concentrations were calculated and expressed in milligrams per 100 grams (mg/100 g) of sample. All determinations were performed in triplicate, and the results were presented as mean ± standard deviation.

Antinutritional Factors

Phytate was determined by the method of Lolas and Markakis (1975): the sample was extracted with 2% hydrochloric acid, filtered, treated with ammonium thiocyanate and titrated with a standard iron solution. Oxalate was determined by acid digestion, precipitation and titration with 0.05 M potassium permanganate (Day & Underwood, 1986**)**. Phytate is expressed as a percentage and oxalate as mg/kg.

Vitamin C Analysis

Vitamin C was determined spectrophotometrically. One gram of sample was dissolved in 100 mL of distilled water and filtered, and an aliquot was treated with potassium dichromate, sulphuric acid and 1,5-diphenylcarbazide reagent. Absorbance was read at 560 nm against ascorbic acid standards of 0.01, 0.1, 1, 5 and 10 ppm. The calibration equation was y = 0.0212x + 0.0533 (R^2 = 0.9726). The vitamin C concentration was determined using the laboratory analytical procedure based on absorbance measurement and calibration against ascorbic acid standards. The absorbance readings were used to estimate vitamin C concentration, and the results were expressed as mean ± standard deviation of triplicate laboratory determinations.

Statistical Analysis

Data obtained from the laboratory analyses were analysed using descriptive statistics. All determinations were performed in triplicate, and the results were expressed as mean ± standard deviation (SD). The mean and standard deviation were calculated for each proximate composition parameter to summarise the nutritional characteristics of the refrigerated and decanted guinea corn samples. The results were presented in tables to facilitate comparison between the two storage conditions. No inferential statistical test was performed because the triplicate measurements represented repeated laboratory determinations of the same samples rather than independent experimental replicates. All laboratory analyses were performed in triplicate to ensure analytical precision and reproducibility. Results were expressed as mean ± standard deviation (SD). Descriptive statistics were used to summarise the proximate composition of refrigerated and decanted guinea corn samples."

RESULTS AND DISCUSSION

Table 1: Proximate Composition of Refrigerated and Decanted Guinea Corn

Parameter (%)	RGC (Mean ± SD)	DGC (Mean ± SD)
Moisture	47.900 ± 0.436	56.000 ± 0.200
Lipid	2.090 ± 0.026	2.183 ± 0.074
Ash	0.960 ± 0.020	0.677 ± 0.015
Crude fibre	3.537 ± 0.051	1.420 ± 0.053
Crude protein	2.833 ± 0.064	2.843 ± 0.118
Carbohydrate	42.333 ± 0.304	37.137 ± 0.237

Table 1 shows variations in the proximate composition of refrigerated guinea corn (RGC) and decanted guinea corn (DGC). DGC recorded higher moisture (56.00 ± 0.20%), lipid (2.18 ± 0.07%) and crude protein (2.84 ± 0.12%) contents than RGC. In contrast, RGC had higher ash (0.96 ± 0.02%), crude fibre (3.54 ± 0.05%) and carbohydrate (42.33 ± 0.30%) contents compared with DGC. The differences were more noticeable in moisture, crude fibre and carbohydrate contents, while lipid and protein values were relatively similar. Overall, the findings indicate variations in the nutritional composition of guinea corn under the two storage conditions, with RGC showing higher ash, fibre and carbohydrate contents, while DGC had higher moisture, lipid and protein contents. These observations are descriptive and do not establish statistical significance.

Table 2: Proximate Composition of Refrigerated and Decanted Guinea Corn on a Dry-Weight Basis

Parameter (%)	RGC (Mean ± SD)	DGC (Mean ± SD)
Lipid	4.012 ± 0.050	4.961 ± 0.168
Ash	1.843 ± 0.038	1.539 ± 0.034
Fibre	6.789 ± 0.098	3.227 ± 0.120
Protein	5.438 ± 0.123	6.461 ± 0.268
Carbohydrate	81.253 ± 0.583	84.402 ± 0.539

The dry-weight presentation provides a clearer basis for comparing the proximate composition of the two samples by accounting for their different moisture contents. On this basis, decanted guinea corn recorded higher calculated lipid (4.961%) and protein (6.461%) contents than refrigerated guinea corn (4.012% and 5.438%, respectively). Similarly, the calculated carbohydrate content was higher in the decanted sample (84.402%) than in the refrigerated sample (81.253%). In contrast, refrigerated guinea corn recorded higher ash (1.843%) and fibre (6.789%) contents compared with the decanted sample (1.539% and 3.227%, respectively).

Table 3: Report of Mineral Composition of Refrigerated and Decanted Guinea Corn

Mineral(mg/100 g)	RGC (Mean ± SD)	DGC (Mean ± SD)
Calcium (Ca)	1.200 ± 0.010	0.653 ± 0.015
Copper (Cu)	0.060 ± 0.001	0.030 ± 0.002
Zinc (Zn)	0.382 ± 0.002	0.400 ± 0.002
Manganese (Mn)	31.300 ± 0.265	33.297 ± 0.270
Sodium (Na)	4.507 ± 0.021	1.330 ± 0.036
Potassium (K)	12.463 ± 0.055	2.770 ± 0.044
Iron (Fe)	5.431 ± 0.075	2.869 ± 0.007

Table 3 shows variations in the mineral composition of refrigerated guinea corn (RGC) and decanted guinea corn (DGC). RGC recorded higher concentrations of calcium (1.200 ± 0.010 mg/100 g), copper (0.060 ± 0.001 mg/100 g), sodium (4.507 ± 0.021 mg/100 g), potassium (12.463 ± 0.055 mg/100 g) and iron (5.431 ± 0.075 mg/100 g) compared with DGC. In contrast, DGC had higher zinc (0.400 ± 0.002 mg/100 g) and manganese (33.297 ± 0.270 mg/100 g) contents than RGC. Refrigerated guinea corn had higher measured concentrations of five out of the seven minerals analysed, while decanted guinea corn contained higher zinc and manganese concentrations.

Table 4: Phytate and Oxalate Contents of Refrigerated and Decanted Guinea Corn

Sample	Phytate (%) (Mean ± SD)	Oxalate (mg/kg) (Mean ± SD)
RGC	0.303 ± 0.015	0.417 ± 0.021
DGC	0.263 ± 0.015	0.217 ± 0.015

Table 4 shows that refrigerated guinea corn (RGC) had higher phytate (0.303 ± 0.015%) and oxalate (0.417 ± 0.021 mg/kg) contents than decanted guinea corn (DGC), which recorded 0.263 ± 0.015% phytate and 0.217 ± 0.015 mg/kg oxalate. This indicates that decanted guinea corn contained lower levels of the two antinutritional factors. The lower phytate and oxalate contents in DGC may favour better mineral bioavailability because these compounds can bind essential minerals and reduce their absorption.

Table 5: Mean and Standard Deviation of Absorbance and Vitamin C Concentration

Sample	Absorbance (Mean ± SD)	Vitamin C Concentration (mg/100 g) (Mean ± SD)
RGC	0.092 ± 0.003	2.167 ± 0.208
DGC	0.116 ± 0.001	3.033 ± 0.153

Table 5 shows that decanted guinea corn (DGC) recorded higher absorbance (0.116 ± 0.001) and vitamin C concentration (3.033 ± 0.153 mg/100 g) than refrigerated guinea corn (RGC), which had 0.092 ± 0.003 absorbance and 2.167 ± 0.208 mg/100 g vitamin C. This indicates a higher measured vitamin C content in DGC. The difference may be associated with sample handling, processing and storage conditions, as vitamin C is sensitive to oxidation, temperature and light.

Discussion

The results showed variations in the proximate composition of refrigerated and decanted guinea corn. DGC recorded higher moisture, lipid and crude protein contents on the original as-is basis, while RGC recorded higher ash, crude fibre and carbohydrate values. The higher moisture content in DGC may be associated with water retention during soaking and daily water replacement. The moisture difference is important because the concentration of nutrients expressed on an as-is basis may be influenced by the amount of water present in the sample.

Following dry-matter standardisation using the reported values, RGC had higher ash and crude fibre concentrations, whereas DGC had higher lipid and crude protein concentrations. This demonstrates that differences in moisture content can influence the interpretation of proximate composition. The findings can be compared with Keyata et al. (2021), who investigated the effects of premilling treatments on the nutritional composition and antinutritional factors of sorghum. Their findings demonstrated that washing, soaking and malting could influence proximate composition and other nutritional characteristics.

Similarly, Li et al. (2022) discussed the influence of processing methods on the bioactive compounds and biological activities of sorghum grains. Their studies highlighted the importance of processing conditions in determining the nutritional and functional properties of sorghum. The differences observed in the present study may be associated with moisture variation, processing conditions and the possible removal of soluble constituents during daily water replacement.

The mineral composition of RGC and DGC. RGC recorded higher measured concentrations of calcium (1.200 ± 0.010 mg/100 g), copper (0.060 ± 0.001 mg/100 g), sodium (4.507 ± 0.021 mg/100 g), potassium (12.463 ± 0.055 mg/100 g) and iron (5.431 ± 0.075 mg/100 g) than DGC. In contrast, DGC contained higher zinc (0.400 ± 0.002 mg/100 g) and manganese (33.297 ± 0.270 mg/100 g).

The higher concentrations of several minerals in RGC may indicate greater retention of these elements in the refrigerated sample. Conversely, the lower measured concentrations of calcium, copper, sodium, potassium and iron in DGC may be associated with mineral losses into the soaking or decantation water. This possibility is supported by Asiri (2025), who reported losses of iron, phosphorus, zinc and calcium in sorghum grains during soaking. The study demonstrated that some minerals were released into the soaking medium during processing. Similarly, Keyata et al. (2021) observed that washing, soaking and malting influenced the mineral composition of sorghum. Their findings showed that mineral concentrations could either increase or decrease depending on the processing treatment. They suggested that mineral changes during soaking may be influenced by the release of bound minerals, solubility and possible mineral uptake from the soaking water. The higher zinc and manganese concentrations recorded in DGC suggest that mineral retention during processing may differ among individual elements.

The findings showed that RGC recorded higher phytate and oxalate concentrations than DGC. The lower measured concentrations of these antinutritional factors in DGC may be associated with the removal of soluble compounds during daily water replacement. This observation agrees with Keyata et al. (2021), who reported reductions in phytate and oxalate contents following washing, soaking and malting of sorghum grains. Their findings showed that processing could reduce antinutritional factors and improve in-vitro mineral bioavailability. Similarly, Asiri (2025) demonstrated that soaking sorghum grains in water and acidic solutions reduced phytate concentrations, with the extent of reduction depending on the soaking temperature, duration and pH.

The reduction in phytate and oxalate observed in DGC may be explained by their solubility and the possible activation of endogenous enzymes during soaking. Discarding the soaking water may remove some of these compounds from the grain. However, this process may also result in the loss of soluble minerals and other nutrients. Asiri (2025) specifically reported that phytate reduction during soaking was accompanied by losses of some minerals, including iron, zinc and calcium.

The results showed that DGC recorded higher absorbance and measured vitamin C concentration than RGC. The decanted sample had a vitamin C concentration of 3.033 ± 0.153 mg/100 g, compared with 2.167 ± 0.208 mg/100 g in the refrigerated sample. The observed variation may be associated with differences in sample preparation, processing and storage conditions. Vitamin C is water-soluble and susceptible to oxidation, particularly when exposed to oxygen, unsuitable temperatures and light. Consequently, its measured concentration may vary depending on the handling and storage conditions of food samples. A study by Alhashem et al. (2024) on processing effects in sorghum also noted that processing can influence the retention of water-soluble bioactive compounds and other nutritional constituents.

CONCLUSION

This study evaluated the nutritional composition of guinea corn stored under refrigeration and decantation conditions, focusing on proximate composition, mineral content, antinutritional factors and vitamin C. The findings revealed variations in the measured nutritional properties of the two samples. Refrigerated guinea corn recorded higher ash, crude fibre, calcium, copper, sodium, potassium and iron contents, whereas decanted guinea corn had higher lipid, crude protein, zinc, manganese and vitamin C contents. In addition, decanted guinea corn contained lower phytate and oxalate levels. Differences in moisture content may also influence nutrient concentrations, highlighting the importance of consistent dry-matter standardisation when comparing the samples. Furthermore, since microbial quality and safety were not investigated, the findings cannot establish the shelf life or suitability of either storage method for prolonged household

use. Therefore, further investigations involving independently prepared experimental replicates, dry-matter standardisation, nutrient-retention assessments and microbiological quality evaluation are necessary to establish the nutritional stability and safety of guinea corn under these storage conditions before either method can be recommended for long-term household storage.

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