

# Inclusion of Baobab (*Adansonia digitata* L.) Fruit Powder Enhances the Mineral Composition and Antioxidative Potential of Processed Tigernut (*Cyperus esculentus*) Beverages

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**ABSTRACT:** The functional beverage market has recently increased due to the health benefits in addition to their nutritional and thirst-quenching functions. Tigernut is an economic crop with reported health benefits. This study evaluates the antioxidative potential of processed tigernut extracts fortified with baobab fruit pulp powder. The ferric reducing antioxidant potential, 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid), and 1,1-diphenyl-2-picrylhydrazyl were used to determine the antioxidant capacity, while the Folin-Ciocalteu method was used to measure the total phenolic content of the beverages. The inclusion of baobab fruit significantly ( $P < 0.05$ ) increased the total phenolic content by 18% (from 31.06 to 36.83 mg gallic acid equivalent/100 mL) and the flavonoid content by 15~20%, while the vitamin C content peaked at 39.6 mg/100 mL. There was a significant correlation between the phenolic and vitamin C contents. Overall, the antioxidant potentials were elevated with the inclusion of baobab powder. All the beverages included in this study are good sources of Ca, P, and K; the contents of Ca, P, and K in the roasted tuber extracts with baobab peaked at 210.91, 8.70, and 93.35  $\mu\text{g}/\text{mL}$ , respectively. However, the K : Na ratio was greater than 5:1. Although, baobab increased the acidity of the beverages, it did not significantly diminish the consumer acceptability, with the values ranging from 7.62 to 8.40 on a 9-point Hedonic scale. The beverages have potential for use as natural antioxidants and could be recommended for consumers with diets deficient in Ca and K, particularly in food insecure communities. They could also be used as a replacement for sugar-sweetened carbonated beverages.

**Keywords:** antioxidant, baobab fruit, beverage, mineral, tigernut

## INTRODUCTION

Consumer awareness of the importance of nutrition in maintaining a healthy lifestyle and preventing the onset of diseases is increasing. This, alongside skyrocketing healthcare costs, has greatly contributed to a rapid growth in the number of functional foods and beverages, pharmaceuticals, and the nutraceutical market (Bigliardi and Galati, 2013; Corbo et al., 2014; Daliu et al., 2019; Nguyen and Chuyen, 2020). There is also a shift towards plant-based diets (with low frequency consumption of animal products) as they are associated with lower risk of cardiovascular diseases (Satija and Hu, 2018). Plant-based diets are considered healthy if they have among other components a low-energy density, low saturated fat, high fiber

content, high levels of antioxidants, and micronutrients composition.

Tigernut (*Cyperus esculentus*) is one of the widely distributed and underutilized plants in tropical and subtropical regions (Roselló-Soto et al., 2018; Badejo et al., 2020). The extract from the nut called “*horchata de chufa*”, and its other byproducts have generated over 3 million euro in the industry (Sánchez-Zapata et al., 2012). The tubers can be processed into flour or milky extracts, or can be consumed raw as snacks. Tigernut is laden with minerals and vitamins that are beneficial to the body. In recent years, the quest for an alternative to dairy milk, which will reduce the prevalence of hypercholesterolemia, cow milk allergy and lactose intolerance, has intensified, thus leading to development of new products and spe-

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cialty beverages (Sethi et al., 2016). Plant-based milk such as flax milk, oat milk, hazelnut milk, quinoa milk, and soymilk, are now marketed, and are gaining consumer confidence since they are lactose- and cholesterol-free, and are low in calories.

Baobab (*Adansonia digitata* L.) is a deciduous tree belonging to the plant family Bombacaceae. The trees are found in the savannas of Africa and India and known to be rich in phytochemicals and micronutrients (Rahul et al., 2015). Various parts of the tree are used as febrifuge, immune stimulants and for treating diarrhea, inflammation, and infections. The seeds can be fermented and used as flavoring agents or roasted and eaten as snacks; they can equally be used as thickening agents in soup (Bvenura and Sivakumar, 2017). The pulp is a rich source of polyphenolic compounds that could play a protective role against oxidative stress (Braca et al., 2018). It can be dissolved in milk and water, and the extract is used as a drink and a sauce for food, or as a fermentation agent in local brewing. The fruit pulp is laden with high amounts of vitamin C, minerals, and lipids, which make it suitable as a seasoning and appetizer, and in the production of juice.

A common status symbols in developing countries is the consumption of commercially available sugar-sweetened carbonated beverages. This has contributed to the recent growth in the burden of chronic non-communicable diseases, particularly diabetes mellitus (Foreman et al., 2018). It has been projected that more than 350 million people will be living with diabetes by 2030, increasing approximately 200% from 117 million in 2000 with sub-Saharan Africa accounting for the majority of this increase (Animaw and Seyoum, 2017). Sugar-sweetened beverages have also been attributed to high blood pressure and hypertension (Malik et al., 2014). Provision of an alternative healthy beverage is imperative. In recent years, supplementing diets with antioxidants as a strategy to improve health has gained popularity. The current study seeks to explore the antioxidative properties of extracts from tigernut fortified with the pulp of baobab fruit used as a beverage.

## MATERIALS AND METHODS

### Sample collections and source of chemicals

Tigernut and baobab fruits were obtained from a major market in Akure South Local Government, Ondo State, Nigeria (7° 15' 4" N, 5° 12' 12" E). Tigernut is predominantly cultivated in the Northern part of Nigeria and transported to the South, and was purchased in February 2019. However, baobab fruits are generally harvested when already dried on the tree. Folin-Ciocalteu's phenol reagent, 1,1-diphenyl-2-picrylhydrazyl (DPPH), 2,2'-azi-

no-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), 2,4-dinitrophenylhydrazine (DNPH), and gallic acid were purchased from Sigma-Aldrich Co. (St. Louis, MO, USA). Bromine water was purchased from Thermo Fisher Scientific (Waltham, MA, USA). All the other chemicals and solvents used were purchased from Sinopharm Chemical Reagent Co., Ltd. (Shanghai, China), and were all of standard analytical grade.

### Preparation of tigernut extracts and baobab fruit pulp

The tigernut tubers were sorted, cleaned, and washed to remove extraneous materials and then divided into two groups. One group (approximately 100 g of tubers) was roasted in a frying pan heated to about 70°C on a low-burning blue flame until they were 120°C for 60 s before extraction. Roasting was used to facilitate the release of roasting-induced antioxidants (Bekedam et al., 2008). The other group was extracted fresh as previously described (Badejo et al., 2014). The fresh or roasted tigernut (100 g) were blended into slurries with 100 mL water in a blender (QBL-18L40; Qasa, Taipei, Taiwan) and sieved using muslin cloth to extract the milk. The baobab fruits were washed to remove extraneous materials and cracked to separate the pulp from the seeds. Baobab pulp was later passed through a British sieve (size number 50) to obtain the pulverized powdery pulp.

### Preparation of tigernut-baobab beverages

Tigernut extracts and baobab pulp were combined to make the tigernut-baobab beverages. Soluble powdery pulp (2.5 g) was added to 97.5 mL of tigernut extract (fresh or roasted) and mixed. In order to understand the impact of the baobab on the tigernut extract, a control was set up containing 97.5 mL sterilized distilled water with 2.5 g of the soluble powdery pulp. Preliminary studies showed that a control sample containing  $\geq 3$  g of soluble powdery pulp created a solution with pH <2.5 and was scored extremely low by the panelists during sensory evaluation (data not shown). The beverages were pasteurized as previously described (Badejo et al., 2014), prepared fresh for all analyses.

### Determination of physicochemical parameters of the beverages

The refractive index of each beverage was carried out using refractometric method (soluble solids) with a handheld Refractometer (Atago Brix 0~32%, TM 1600; Gibertini Elettronica, Milan, Italy) and were recorded as °Brix. The titratable acidity (TTA) of the beverage was determined by titration with 0.1 M NaOH using phenolphthalein as the indicator. The pH of the beverages was determined using a MP220 pH meter (Mettler-Toledo, Greifensee, Switzerland).

### Determination of vitamin C content of the beverages

The vitamin C content of the beverage was determined by the spectrophotometric method described by Khan et al. (2016) with slight modifications. An aliquot of sample was mixed with 0.2% metaphosphoric acid and 5% acetic acid, diluted appropriately, and then filtered using a 0.22  $\mu\text{m}$  filter (Sigma-Aldrich Co.). The filtrate was treated with bromine water and DNPH solution. After 3 h of incubation at 37°C to form osazone, the vitamin C content was measured at 521 nm. A standard solution was prepared with L-ascorbic acid (1 mg/mL) and the vitamin C content was calculated by comparison with the standard, and expressed as mg/100 mL beverage.

### Determination of the mineral contents of the beverages

The mineral content of the beverages was determined using the method of AOAC (2012). Ca, Mn, and Na contents were determined using atomic absorption spectrophotometry (Buck Scientific Inc., Norwalk, CT, USA), and K and P contents were determined using Jenway flame photometers and Jenway colorimeters (Jenway Scientific Instruments, Stone, UK).

### Determination of the total phenolic content of the beverages

The total phenolic content of the beverages was determined as described by Singleton et al. (1999). Briefly, 0.5 mL of 10% Folin-Ciocalteu's reagent and 2 mL of 7.5% sodium carbonate were added to 0.2 mL of the beverage. The reaction mixture was subsequently incubated at 45°C for 40 min, and the absorbance was measured at 700 nm. Gallic acid was used as the standard, and the result was expressed as mg gallic acid equivalent (GAE) per 100 mL of the beverage.

### Determination of the total flavonoid content of the beverages

The total flavonoid content of the beverages was determined using the colorimetric assay developed by Bao et al. (2005). To 0.2 mL of the beverage, 0.3 mL of 5%  $\text{NaNO}_3$  was added followed by 0.6 mL of 10%  $\text{AlCl}_3$  after 5 min, and 2 mL of 1 M NaOH after a further 5 min. Finally, 2.1 mL of distilled water was added to the mixture and the absorbance was recorded at 510 nm. The flavonoid content was expressed as mg rutin equivalent (RE) per 100 mL of the beverage.

### Determination of free radical scavenging ability (DPPH)

The free radical scavenging ability of the beverages against DPPH was determined by the method of Gyamfi et al. (1999). Briefly, 1 mL of the beverage was added to 1 mL of 0.4 mM methanolic solution of DPPH. The mixture was incubated in the dark for 30 min before the absorbance was measured at 516 nm. The DPPH free-radical

scavenging activity was calculated as follows:

$$\text{DPPH scavenging ability (\%)} = \frac{\text{Abs}_{\text{control}} - \text{Abs}_{\text{test}}}{\text{Abs}_{\text{control}}}$$

### Determination of ABTS scavenging ability

The ABTS scavenging ability of the beverages was determined as described by Re et al. (1999). A stock solution was made by reacting 7 mM of ABTS aqueous solution with 2.45 mM  $\text{K}_2\text{S}_2\text{O}_8$ . After 16 h incubation in the dark, the absorbance was adjusted with ethanol to  $0.70 \pm 0.02$  at 734 nm. Then, 0.2 mL of the diluted beverage was added to 2.0 mL of ABTS solution, and the solution was incubated for 15 min at room temperature. The absorbance was then read at 734 nm and the ABTS scavenging ability was subsequently calculated as mmol Trolox per 100 mL of the beverage.

### Determination of ferric reducing antioxidant potential (FRAP)

The ferric reducing antioxidant potential of the beverages was determined by the method described by Pulido et al. (2000). FRAP reagent containing 2.5 mL of 10 mmol/L 2,4,6-Tris(2-pyridyl)-S-triazine solution in 40 mmol/L HCl, 2.5 mL of 20 mmol/L  $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ , and 25 mL of 0.3 mol/L acetate buffer (pH 3.6) was freshly prepared. Diluted sample (0.1 mL) was added to 0.9 mL of FRAP reagent. The mixture was incubated at 37°C for 30 min, and the absorbance measured at 595 nm. Solutions of  $\text{Fe}^{2+}$  of known concentrations were used for calibration, and FRAP was calculated as mmol  $\text{Fe}^{2+}$  per 100 mL of beverage.

### Commission Internationale de l'Éclairage (CIE) colour analysis

Colour analyses was carried out using a Colorimeter PCE-CSM (PCE Deutschland GmbH, Southampton, UK) with CQCS3 software (Shenzhen 3nh Technology Co., Ltd., Shenzhen, China). Readings were taken after prior calibration of the spectrophotometer against a standard white plate (CIE  $L^* = 96.63$ ,  $a^* = 0.22$ , and  $b^* = 2.28$ ). The aperture of the spectrophotometer was placed on top of the sample for measurements. Values were expressed on the  $L^*$ ,  $a^*$ , and  $b^*$  tristimulus scale, where  $L^*$  represents the colour lightness, and  $a^*$  and  $b^*$  represent the degrees of redness/greenness and yellowness/blueness, respectively.

### Sensory evaluation

Thirty male and female panelists were recruited with informed consent. Panelists included students and staff (17~55 years of age) familiar with consumption of tiger-nut milk. Panelists were seated in booths with proper illumination, where they evaluated randomly coded beverage

age samples on the nine-point hedonic scale for colour, taste, appearance, and overall acceptability. The following numerical values were used for the scoring: dislike extremely, 1; dislike very much, 2; dislike moderately, 3; dislike slightly, 4; neither like nor dislike, 5; like slightly, 6; like moderately, 7; like very much, 8; and like extremely much, 9.

### Ethical approval

The research was considered and approved by the ethical committee of School of Agriculture and Agricultural Technology, Federal University of Technology Akure, Nigeria (reference number: FUTA/SAAT/2019/015).

### Statistical analysis

All samples were analyzed in triplicates, unless stated otherwise. Data were analyzed by one-way analysis of variance (ANOVA) and Duncan's multiple range post hoc test, using the Statistical Package for the Social Sciences (SPSS) version 17.0 software (SPSS Inc., Chicago, IL, USA).  $P$ -value < 0.05 was considered statistically significant. Pearson correlation was performed using Microsoft Excel (Microsoft, Redmond, WA, USA) and was used to determine the relationship between TTA and pH, and antioxidant capacities.

## RESULTS AND DISCUSSION

### Physicochemical properties of the tigernut-baobab beverages

The Brix values of the tigernut-baobab beverages ranged from 7.50 to 13.50 (Table 1). The roasted extract had a significantly ( $P < 0.05$ ) higher °Brix content than fresh tubers, which may be due to partial removal of moisture by heat during roasting, thus concentrating the extract. The baobab-water solution had a very low °Brix value, and addition of the baobab to the tigernut extracts both fresh or roasted tubers reduced their °Brix values. The total TTA, a measure of 'acid-taste' of the formulated beverage, ranged from 0.19 to 0.57, which is similar to previous reports of tigernut beverages (Badejo et al., 2014;

**Table 1.** The physicochemical parameters of tigernut-baobab beverages

Sample	°Brix	TTA	pH
BAO	7.50±0.71 <sup>d</sup>	0.57±0.03 <sup>a</sup>	3.04±0.01 <sup>c</sup>
FRS	11.00±0.00 <sup>b</sup>	0.20±0.02 <sup>d</sup>	6.75±0.01 <sup>a</sup>
FSS	9.00±0.00 <sup>c</sup>	0.39±0.05 <sup>c</sup>	4.79±0.01 <sup>b</sup>
ROA	13.50±0.00 <sup>a</sup>	0.19±0.02 <sup>d</sup>	6.78±0.01 <sup>a</sup>
RSS	11.00±0.00 <sup>b</sup>	0.45±0.01 <sup>b</sup>	4.67±0.01 <sup>b</sup>

Data are mean±SD (n=3).

Values within the column with the different letters (a-d) are significantly different ( $P < 0.05$ ) by Duncan's multiple range test. TTA: titratable acidity (g/100 mL).

BAO, 97.5% water and 2.5% baobab fruit powder; FRS, 100% fresh tigernut extract; FSS, 97.5% fresh tigernut extract and 2.5% baobab fruit powder; ROA, 100% roasted tigernut extract; RSS, 97.5% roasted tigernut extract and 2.5% baobab fruit powder.

Adebayo-Oyetero et al., 2019). The TTA values were inversely proportional to the pH of the beverages, with a Pearson's correlation coefficient ( $r$ ) of  $-0.9925$  (data not shown). The baobab pulp in water had the lowest pH and highest TTA value. The addition of baobab fruit pulp powder to extracts both fresh and roasted tubers decreased the pH. The very low pH of carbonated soda and energy drink (pH 2.6 to 2.98) have been reported as one of the major causes of dental erosion (Ehlen et al., 2008). The pH of the tigernut beverages ranged from 4.67 to 6.78, and were higher than the values reported for carbonated beverages.

### Mineral composition of beverage blends from tigernut extract and baobab fruit pulp powder

Mineral composition analysis showed that Ca was the most abundant in all the beverages, with values ranging from 169.09 to 210.91 µg/mL (Table 2). The second most abundant mineral was K, with values ranging from 48.52 to 93.35 µg/mL. Roasting the tigernut increased the Ca content of the beverage by 5%, whereas inclusion of baobab powder increased the Ca contents by 10 to 14% (Table 2). The Ca : P ratio for all the beverages was very high. Low Ca : P ratios have been reported to have adverse effect on bone health, and higher ratios are reported to contribute to a lower prevalence of obesity (de

**Table 2.** The mineral composition of tigernut-baobab beverages

(unit: µg/mL)

Sample	Ca	Mn	K	Na	P	K/Na	Ca/P
BAO	169.09±2.12 <sup>c</sup>	0.07±0.03 <sup>d</sup>	48.52±0.11 <sup>d</sup>	2.31±0.04 <sup>e</sup>	5.66±0.06 <sup>c</sup>	21.0	29.9
FRS	175.11±3.15 <sup>c</sup>	1.31±0.04 <sup>b</sup>	83.90±0.29 <sup>c</sup>	3.10±0.04 <sup>b</sup>	5.74±0.13 <sup>c</sup>	27.1	30.5
FSS	192.24±3.37 <sup>b</sup>	1.02±0.06 <sup>c</sup>	86.26±0.06 <sup>b</sup>	2.69±0.05 <sup>d</sup>	7.87±0.01 <sup>b</sup>	28.3	24.4
ROA	184.24±2.37 <sup>b</sup>	1.98±0.07 <sup>a</sup>	88.24±0.09 <sup>b</sup>	3.36±0.06 <sup>a</sup>	4.62±0.05 <sup>d</sup>	26.3	39.9
RSS	210.91±3.13 <sup>a</sup>	1.20±0.03 <sup>b</sup>	93.35±0.08 <sup>a</sup>	3.02±0.04 <sup>c</sup>	8.70±0.07 <sup>a</sup>	30.9	24.2

Data are mean±SD (n=3).

Values within the column with the different letters (a-e) are significantly different ( $P < 0.05$ ) by Duncan's multiple range test. BAO, 97.5% water and 2.5% baobab fruit powder; FRS, 100% fresh tigernut extract; FSS, 97.5% fresh tigernut extract and 2.5% baobab fruit powder; ROA, 100% roasted tigernut extract; RSS, 97.5% roasted tigernut extract and 2.5% baobab fruit powder.

Carvalho Pereira et al., 2013). The K : Na ratio of the beverages were greater than the minimum recommended 5:1 ratio for healthy living (Konner and Eaton, 2010). A high intake of Na is attributed to high blood pressure and hypertension; therefore, fruit and vegetables and beverages from fruits and vegetables that are low in sodium but high in potassium are highly preferred for their health benefit (Houston and Harper, 2008).

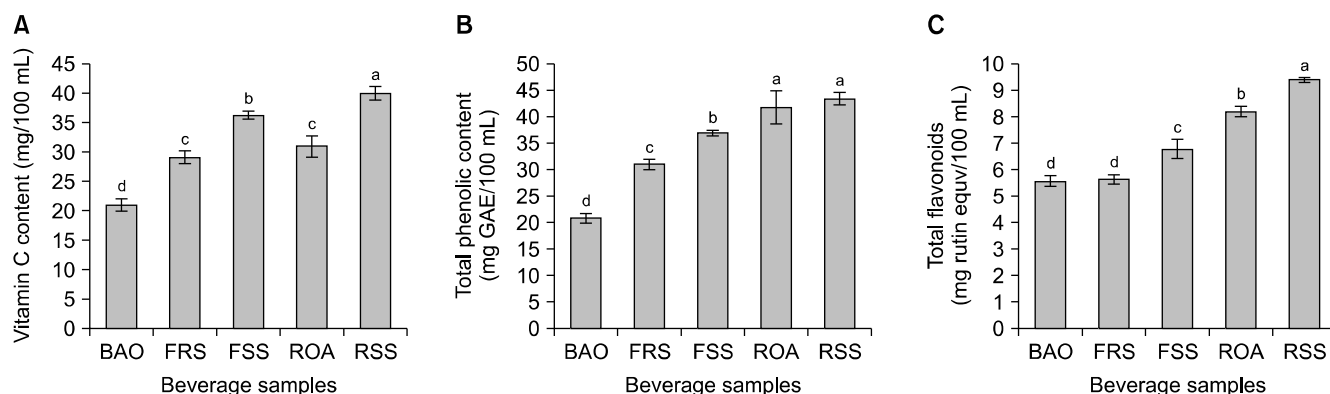
#### Vitamin C, total phenolic, and total flavonoid contents of tigernut-baobab beverage blends

The vitamin C contents of the beverage blends ranged from 20.7 to 39.6 mg/100 mL (Fig. 1A). Sample roasted tigernut extract and baobab fruit powder (RSS) had the highest vitamin C content, whereas the baobab fruit pulp in water (BAO) had the lowest content, which might be due to dilution during formulation. Roasting did not result in any significant difference in the vitamin C content of tigernut extracts from either the fresh and roasted tubers [fresh tigernut extract (FRS) and roasted tigernut extract (ROA)]. However, the inclusion of baobab in the beverages increased the vitamin C contents by >25% in sample RSS compared with sample fresh tigernut extract and baobab fruit powder (FSS). Baobab fruit is noted for its high vitamin C content of up to 400 mg/100 g, which is approximately 5-fold higher than that in orange (Rahul et al., 2015; Tembo et al., 2017).

The total phenolic content of the beverages ranged from 20.9 to 43.3 mg GAE/100 mL. Roasting significantly ( $P < 0.05$ ) increased the total phenolic content of the beverages. Roasting can result in breakdown of cellular structures of tuber, which could influence the solubility of previously insoluble or bound phenolics leading to formation of water-soluble products that can easily be captured by the Folin-Ciocalteu's assays (Şahin et al., 2009). Also, the assay detects both naturally occurring phenolics and newly formed phenolic compounds, which may in-

clude Maillard reaction products (MRPs) developed during roasting. MRPs are formed in a thermal processes when amino acids react with reducing sugars to form melanoidins with biological activities, including antioxidant activity, increases in concentration with the degree of roasting (Yen et al., 2005; Bekedam et al., 2008). The phenolic content of sample ROA (41.16 mg GAE/100 mL) was significantly ( $P < 0.05$ ) higher than that of FRS (31.06 mg GAE/100 mL). Badejo et al. (2014) reported similar results for tigernut beverages fortified with *Hibiscus sabdariffa* extract. Addition of baobab fruit powder to tigernut extract resulted in an increase in the phenolic contents of the fresh extract, but there was no significant difference in the total phenolic content of the extract from roasted tigernut even with addition of baobab (Fig. 1B). Polyphenols are secondary metabolites from plants, which are found in abundance in plant extracts. Polyphenols are laden with antioxidative potentials that can protect against several degenerative diseases. Phenolics can act as free radical scavengers and can inhibit radical mediated processes (e.g., lipid peroxidation) that would otherwise build up due to an imbalance between the antioxidant system and formation of reactive oxygen species (Khan et al., 2016).

The flavonoid contents of the beverages ranged from 5.57 to 9.40 mg RE/100 mL (Fig. 1C). There was no significant difference ( $P > 0.05$ ) between the flavonoid contents of the control and the fresh tigernut extracts. Roasting the tigernut before extraction led to a significant increase (approximately 46%) in the flavonoid content. Similar findings were reported for coffee beans and cashew nuts, whereby roasting effectively increased the phenolic and flavonoid contents (Yen et al., 2005; Chandrasekara and Shahidi, 2011). Inclusion of FSS also increased the flavonoid contents of the beverages by more than 20%. In the sample roasted before extraction, inclusion of baobab significant increased ( $P < 0.05$ ) the flavonoid content



**Fig. 1.** Vitamin C (A), total phenolic (B), and total flavonoids (C) contents of tigernut-baobab beverages. Data are mean±SD (n=3). Bars with the different letters (a-d) were significantly different ( $P < 0.05$ ) by Duncan's multiple range test. BAO, 97.5% water and 2.5% baobab fruit powder; FRS, 100% fresh tigernut extract; FSS, 97.5% fresh tigernut extract and 2.5% baobab fruit powder; ROA, 100% roasted tigernut extract; RSS, 97.5% roasted tigernut extract and 2.5% baobab fruit powder; GAE, gallic acid equivalent; RE, rutin equivalent.

**Table 3.** Pearson's correlation coefficients (r) for DPPH, ABTS, and FRAP assay results, and phenolics and flavonoid contents of tigernut-baobab beverages

	ABTS	FRAP	Phenolics	Flavonoids	Vitamin C
DPPH	0.936*	0.847	0.841	0.772	0.960*
ABTS		0.843	0.899*	0.893*	0.967*
FRAP			0.947*	0.900*	0.802
Phenolics				0.881*	0.884*
Flavonoids					0.768

\*Correlation is significant at 0.05 level.

by about 15%. Baobab fruits have been reported to be excellent source of flavonoids (Ismail et al., 2019). Statistically significant correlation was found between the flavonoid and phenolic contents ( $r=0.881$ ;  $P<0.05$ ) and phenolic and vitamin C contents ( $r=0.884$ ;  $P<0.05$ ) of the formulated beverages (calculated using Pearson's correlation coefficient; Table 3).

#### Antioxidant capacities of the tigernut-baobab beverages

Various assays have been used to determine and monitor antioxidant activities of food products, which give different results. In the current study, three different assays were used to analyze the antioxidant capacity of the tigernut-baobab beverages: DPPH, ABTS, and FRAP assays. DPPH is a stable free radical with a characteristic absorption that decreases significantly upon exposure to a radical scavenger. De-colorization of DPPH from purple to yellow occurred upon reacting with the food products, indicating that the food sample contained proton radical scavengers. The DPPH radical scavenging activity of the beverage ranged from 40% and 55% (Fig. 2A). However, roasting did not have significant effect on the radical scavenging ability of the beverage samples. Whereas addition of baobab resulted in 14% to 25% increase in the DPPH scavenging ability, since baobab has a very high

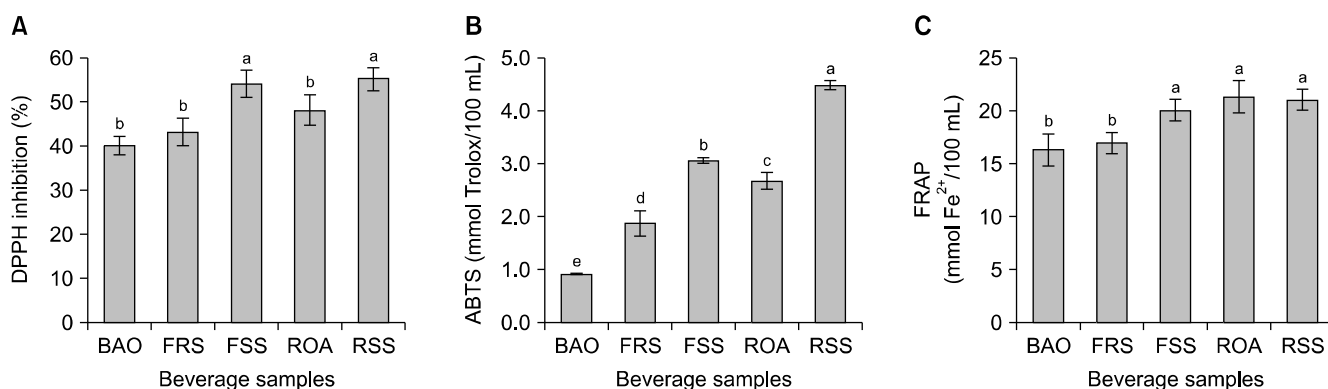
DPPH scavenging ability (Tembo et al., 2017).

ABTS assays are based on generation of a bluish-green radical that can react with both hydrophilic and hydrophobic antioxidant systems to turn colourless (Re et al., 1999). The ABTS radical scavenging capacities of the beverages ranged from 0.92 to 4.48 mmol Trolox/100 mL (Fig. 2B). Roasting significantly ( $P<0.05$ ) increased the ABTS scavenging ability of the beverages. Consistent with our results, a previous study showed that roasting increases the antioxidant activity of coffee (Bekedam et al., 2008). The antioxidant activity of plant extracts containing polyphenol components is due to their capacity to donate hydrogen atoms or electrons and capture the free radicals. In the present study, all the blends were able to decolorize ABTS radical cations, although in different proportions, demonstrating that all the blends possessed very good antioxidant properties. Inclusion of baobab in the beverages increased the ABTS radical scavenging by up to 90% in the roasted tigernut beverages. A high ABTS radical scavenging has been previously reported for baobab (Tembo et al., 2017). Results from Pearson's correlation coefficient showed that there is strong correlation between DPPH and ABTS ( $r=0.936$ ;  $P<0.05$ ) (Table 3).

The antioxidant capacity of the beverages was also demonstrated by their ferric reducing antioxidant power. The beverages reduced  $Fe^{3+}$  to  $Fe^{2+}$ , with FRAP values ranging from 16.3 to 21.3 mmol  $Fe^{2+}$ /100 mL. Both roasting and addition of baobab increased the FRAP of the beverages (Fig. 2C). When combined, the formulated beverages were able to react with free radicals to form a stable product.

#### Colour of tigernut-baobab beverages

One of the major quality parameters that influence consumers acceptability of a product is the colour (Adeola and Aworh, 2010). The colour analyses of the beverages blends from tigernut extract and baobab fruit powder are shown in Table 4. The value of  $L^*$ , which indicates



**Fig. 2.** Antioxidant capacities of the tigernut-baobab beverages, as shown by (A) DPPH, (B) ABTS, and (C) FRAP assays. Values are mean  $\pm$  SD ( $n=3$ ). Bars with the same letters (a-e) are not significantly different ( $P>0.05$ ) by Duncan's multiple range test. BAO, 97.5% water and 2.5% baobab fruit powder; FRS, 100% fresh tigernut extract; FSS, 97.5% fresh tigernut extract and 2.5% baobab fruit powder; ROA, 100% roasted tigernut extract; RSS, 97.5% roasted tigernut extract and 2.5% baobab fruit powder.

**Table 4.** CIE colour analysis of the tigernut-baobab beverages

Sample	L*	a*	b*	c*	h*
BAO	23.64±0.06 <sup>e</sup>	3.40±0.02 <sup>a</sup>	9.72±0.03 <sup>c</sup>	10.29±0.03 <sup>b</sup>	70.75±0.06 <sup>c</sup>
FRS	78.65±0.05 <sup>a</sup>	1.01±0.00 <sup>e</sup>	10.11±0.01 <sup>b</sup>	10.16±0.01 <sup>b</sup>	84.30±0.02 <sup>a</sup>
FSS	73.62±0.03 <sup>c</sup>	2.22±0.02 <sup>d</sup>	13.05±0.03 <sup>a</sup>	13.75±0.02 <sup>a</sup>	80.28±0.07 <sup>b</sup>
ROA	76.14±0.03 <sup>b</sup>	2.69±0.01 <sup>c</sup>	9.80±0.01 <sup>c</sup>	13.62±0.01 <sup>a</sup>	86.24±0.57 <sup>a</sup>
RSS	70.63±0.03 <sup>d</sup>	3.11±0.01 <sup>b</sup>	13.40±0.02 <sup>a</sup>	13.75±0.02 <sup>a</sup>	85.31±0.36 <sup>a</sup>

Data are mean±SD (n=3).

Values within the column with the different letters (a-e) are significantly different ( $P<0.05$ ) by Duncan's multiple range test. BAO, 97.5% water and 2.5% baobab fruit powder; FRS, 100% fresh tigernut extract; FSS, 97.5% fresh tigernut extract and 2.5% baobab fruit powder; ROA, 100% roasted tigernut extract; RSS, 97.5% roasted tigernut extract and 2.5% baobab fruit powder.

lightness of the product, ranged from 23.64 (control) to 78.65 (sample FRS). Addition of baobab reduced the L\* values. Furthermore, the a\* values, which indicate redness to greenness, ranged from 1.01 to 3.40, and increased with addition of baobab powder (Table 4). Also, roasting significantly ( $P<0.05$ ) increased the a\* values. In general, all the blends had low a\* values, however, the a\* values were significantly lower for FRS than the other samples. Similarly, the b\* values, which indicate blueness to yellowness, ranged from 9.72 to 13.40. The b\* values increased by incorporation of the baobab powdery pulp. The chroma (c\*) values, which were used to determine the degree of difference in hue, ranged from 10.16 to 13.75. The roasted samples and the samples containing baobab had significantly higher c\* values, which correlate with higher colour intensities perceived by humans. In addition, the hue (h\*) values for all the beverage blends were similar, ranging from 70.75 to 86.24.

#### Consumer preference of the tigernut-baobab beverages

The nine-point hedonic scale was used to evaluate the sensory attributes of the beverage blends (Table 5). Sample BAO was rated the lowest out of all the beverages.

**Table 5.** The sensory parameters of tigernut-baobab beverages

Samples	Colour	Appearance	Taste	Overall acceptability
BAO	6.20±0.47 <sup>c</sup>	6.40±0.68 <sup>c</sup>	5.52±0.68 <sup>c</sup>	5.88±0.36 <sup>c</sup>
FRS	7.61±0.44 <sup>b</sup>	7.85±0.37 <sup>b</sup>	7.42±0.98 <sup>b</sup>	7.62±0.24 <sup>b</sup>
FSS	8.12±0.82 <sup>a</sup>	7.73±0.08 <sup>b</sup>	7.46±0.06 <sup>b</sup>	8.19±0.30 <sup>a</sup>
ROA	8.52±0.50 <sup>a</sup>	8.88±0.21 <sup>a</sup>	8.84±0.40 <sup>a</sup>	8.20±0.26 <sup>a</sup>
RSS	8.52±0.34 <sup>a</sup>	8.70±0.28 <sup>a</sup>	8.68±0.37 <sup>a</sup>	8.40±0.47 <sup>a</sup>

Data are mean±SD (n=30).

Values within the column with the different letters (a-c) are significantly different ( $P<0.05$ ) by Duncan's multiple range test. BAO, 97.5% water and 2.5% baobab fruit powder; FRS, 100% fresh tigernut extract; FSS, 97.5% fresh tigernut extract and 2.5% baobab fruit powder; ROA, 100% roasted tigernut extract; RSS, 97.5% roasted tigernut extract and 2.5% baobab fruit powder.

Measured by nine-point hedonic scale: 1, dislike extremely; 2, dislike very much; 3, dislike moderately; 4, dislike slightly; 5, neither like nor dislike; 6, like slightly; 7, like moderately; 8, like very much; 9, like extremely much.

This may be due to its sour taste since the beverage had a very low pH. The beverages containing roasted tigernut had the most preferred tastes, scored significantly higher than the other beverages. In previous studies, Sanful (2009) and Badejo et al. (2014) reported that roasting improves the taste of tigernut extracts. This may be perceived as better compared with sugar-sweetened beverages that can cause high blood pressure and hypertension (Malik et al., 2014). Improved taste and overall acceptance was also significantly ( $P<0.05$ ) higher for roasted tigernuts with baobab than the other beverages.

The results of the current study show that tigernut-baobab beverages are a rich source of minerals, especially Ca, P, and K, and are high in vitamin C. The beverages have good radical scavenging abilities, the highest observed for roasted tigernut fortified with baobab fruit powder. The consumer acceptability results tigernut-baobab beverages could be a good replacement for sugar-sweetened beverages. Therefore, consumption of tigernut-baobab beverages should be encouraged, especially among rural dwellers and in areas with food insecurity, to improve health and food security.

#### AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

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