



Enhancing the antioxidative capacity and acceptability of Kunnu beverage from gluten-free pearl millet (*Pennisetum glaucum*) through fortification with tigernut sedge (*Cyperus esculentus*) and coconut (*Cocos nucifera*) extracts

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Abstract

Kunnu is an infamous non-alcoholic beverage among the inhabitants of Sub-Saharan Africa. It is a fermented product commonly made from millet, sorghum or corn and relatively cheap when compared to carbonated beverages. This study targets value addition of kunnu by fortification with tigernut extracts and coconut milk to further boost the consumption and acceptance among people of all ages. The beverages were then evaluated for the physicochemical properties, phytochemical content and colour analyses. Folin-Ciocalteu method was used to measure the total phenolic content while the ferric reducing antioxidant potential (FRAP), 2,2-diphenyl-1-picrylhydrazyl (DPPH) and 2,2-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS) were used to determine the antioxidant capacity. The unfortified kunnu sample had the lowest pH of 3.24 which was significantly increased upon fortification with tigernut extract and coconut milk. Kunnu samples fortified with tigernut had the highest vitamin contents (28.07 mg/ml) and soluble fiber (8%) when compared to the other samples. The total phenol (0.85 mg GAE/ml) and flavonoids (4.59 mg RE/ml) were also highest when the kunnu beverages were fortified with tigernut extract. Fortification with tigernut and/or coconut milk result in elevated antioxidant potentials determined by ABTS, DPPH and FRAP. There was no significant difference in the taste, viscosity, colour and overall acceptability of the beverages when fortified with tigernut extract. The study revealed that fortification with tigernut and/or coconut milk improves the antioxidative potential of the beverages with very good acceptability. The beverage could serve as a healthy replacement for sugar-laden fizzy drinks.

Keywords Antioxidant · Functional beverage · Tigernut milk · Coconut milk

Introduction

The unraveling of the probiotic potentials and health benefits that locally fermented beverages confer has led to significant increase in the demand for these beverages as against the common carbonated fizzy drinks [1]. Most of the fermented beverages are made locally from cereals such as sorghum, millet and maize. The derived drinks range from fruit juices to milks and brews that are high in nutrient levels [2, 3].

Millets are a group of highly variable small-seeded grasses, widely grown around the world as cereal crops or grains for fodder and human food. They are a major food sources in the arid and semiarid regions of the world and are rich in minerals and certain vitamins. Gluten-free pearl millet is a rich source of energy and it plays a major role in the food security and economy of many developing nations of the world [4]. Millet is used in making alcoholic beverages and it serves as the main ingredient for preparation of traditional foods, sourdough and beverages [5, 6].

Tiger nut (*Cyperus esculentus*) is a crop of the sedge family with a brownish colour and a sweet flavor. The almond-like tuberous “nuts” are highly nutritious and used mainly to manufacture a milky beverage called “*horchata de chufa*” [7]. The milky extract is of great economic importance and has been used in the treatment of flatulence, indigestion,

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diarrhea, and dysentery while the starch composition has been found to provides prebiotic properties for colon bacteria [8]. Further value-addition has been carried out on the extract by combining with other plant extracts to produce beverages [9]. Tigernut has been described as a “health” food, as its consumption can help prevent heart-related diseases and it also activate blood circulation [10]. It is a convenient drink for both diabetic and celiac patients because of the low-glycemic index and gluten-free nature, respectively and it can also assist in reducing the risk of colon cancer [11].

Coconut is a member of the family *Arecaceae* known for their versatility ranging from food to cosmetics. Coconut milk, which is obtained by pressing grated coconut with or without water has found great use in the bakery and confectionery industries where it is used to enhance taste and flavor baked foods. It is also taken as a refreshing drink [12]. More than 50% of the coconut milk composition is water, the fat content is about 35% fat and 11% solid non-fat with the fat content playing an important role in the flow property [13]. Preheat treatment has been reported to have significant effect on the apparent viscosity of coconut milk [14].

Honey is a sweet, viscous food substance produced by bees and some related insects. Honey is acidic in nature with pH 3.5–4.0. It has anti-fungal and antimicrobial properties conferred by the presence of organic acids [15]. The major constituent of honey is fructose with 75–80% in composition. Fructose is sweeter than sucrose or glucose and thus honey has lower glycemic index than table sugar. It has been used over the years as an excellent substitute for sugar in bakery, confectionery and beverages.

Ginger (*Zingiber officinale*) is a plant that has been used as a spice in food preparation and, more recently, for its antimicrobial and antioxidant properties [16]. It has many health benefits which are credited to the presence of polyphenolic compounds, such as gingerols and shogaols [17]. Both gingerol and shogaols possess biological activities such as anticancer, antioxidant, antimicrobial, anti-inflammatory and anti-allergic to various central nervous systems activities [18], and these properties have been used over the years to relieve nausea and treat cold. In many places, it is mostly used in sweets and alcoholic beverages such as ginger beer and wine.

Kunnu is a non-alcoholic local beverage made from whole grains of millet, sorghum or corn. It is very common in the Northern part of Nigeria and rapidly spreading to the south and other African countries. It is cheap and highly affordable to the low- and middle-income earners who cannot afford the popular fizzy drinks. Kunnu-zaki produced from cereals is nutritionally poor and the taste encourages selective consumers. Beverages are fortified with other health promoting plant extracts to enhance the nutritional and health benefits while also encouraging

broad consumption among all age groups [19]. Tigernut extracts have been used to improve the quality and acceptability of beverage drinks from *Hibiscus sabdariffa* and *Digitaria exilis* [9, 20].

A larger number of the commercially available beverages in developing countries are laden with sugar (which is detrimental to health when consumed in excess) and only serves to quench thirst with little or no nutritional benefits. The need for value addition to the existing kunnu-zaki with locally sourced milky extracts that will improve the nutritional and functional qualities as well as improve acceptability of the product is highly imperative. This study seeks to evaluate the physicochemical properties, antioxidant capacity and consumer acceptability of kunnu beverages fortified with tigernut and/or coconut extracts sweetened with honey.

Materials and methods

Materials

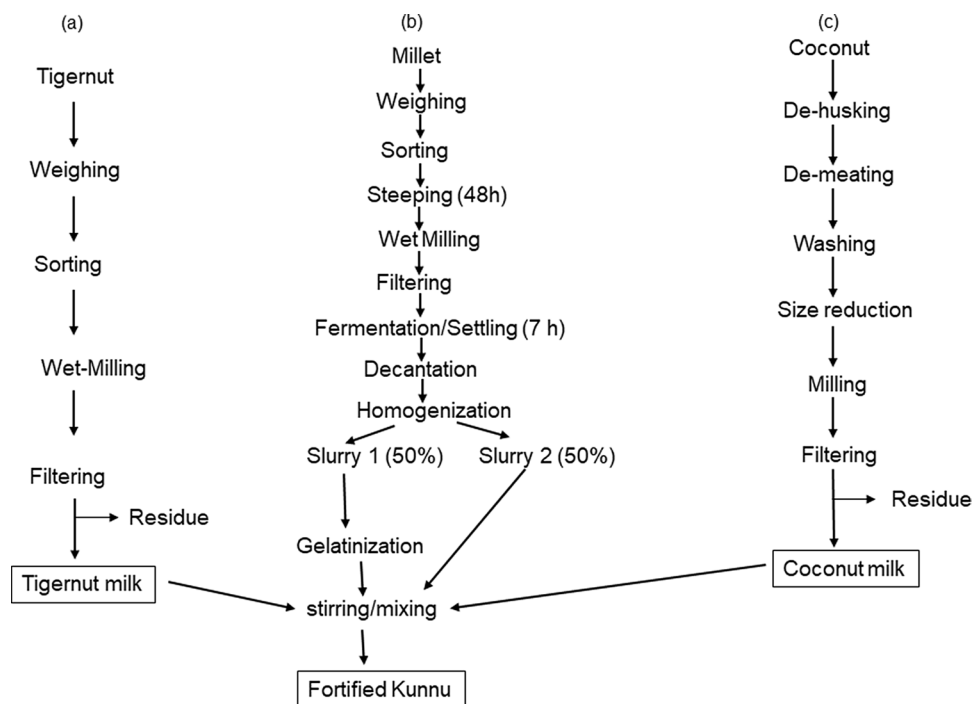
The millet, ginger, tigernut, and coconut were purchased from a major food market in Akure, Ondo State, Nigeria. The honey was obtained from Sunshine Floral Honey, Alagbaka, Akure, Ondo State, Nigeria. All the chemicals used were of analytical grade and purchased from reputable vendors.

Preparation of kunnu, tigernut milk and coconut milk

The millet was processed into kunnu following the method described by Belewu and Abodunrin [21]. The millets were sorted, weighed and steeped for 48 h to ferment. The steeping water was changed at intervals of 12 h. It was wet-milled into slurry together with peeled ginger. The slurry was filtered using a muslin cloth and the filtrate left to settle and ferment for 7 h, after which the liquid on top was decanted leaving a thick gel at the bottom. The gel was divided into two portions: the first part was gelatinized on heat and then mixed thoroughly with the other portion to give the kunnu (Fig. 1a). The tigernut milk was extracted as described by Badejo et al. [9]. Briefly, samples were sorted to remove stones and other foreign material and weighed. It was then wet milled and the slurry filtered using a muslin cloth to extract the milk (Fig. 1b).

The coconut milk was extracted by de-shelling to remove the meat before washing with water essentially as described by Belewu and Belewu [22]. It was cut into small billets for easy milling. The billets were milled and filtered to obtain the coconut milk (Fig. 1c).

Fig. 1 Flow chart for the production of tigernut milk (a), fortified kunnu beverages (b) and coconut milk (c)



Preparation of kunnu fortified with tigernut milk and/or coconut milk

The kunnu: tigernut milk: coconut milk beverages were prepared by combining them in the following ratios: 100:0:0; 40:60:0; 40:0:60 and 40:30:30 and labelled KUN, KTM, KCM and KTC, respectively. To 100 ml of each sample, 1 ml of honey was added and mixed thoroughly. The beverages were stored at refrigeration temperature and mixed vigorously before use for further analyses.

Determination of physicochemical parameters

Evaporation method was used to determine the total solid in the kunnu beverages as earlier described [23]. An aliquot of 25 ml of the sample was evaporated in a boiling water bath and further dried in an oven at 130 °C for 2–3 h until a constant weight is obtained. The total solid was then calculated as shown. The titration method was used to determine the titratable acidity of the beverages. The sample was titrated against 0.1 M NaOH with phenolphthalein indicator. The pH was measured with a Mettler Toledo MP220 pH meter (Mettler Toledo, Greifensee, Switzerland).

Determination of total phenolic content

The total phenolic content of the extracts was determined using the method of Singleton et al. [24]. One milliliter of the sample was dissolved in 10 ml of distilled water and filtered and 0.2 ml of the filtrate was mixed with 2 ml of 7.5%

Na₂CO₃ and 2.5 ml of 10% Folin Ciocalteu's reagent. The reaction mixture was incubated at 45 °C for 40 min, and the absorbance was measured at 700 nm using a spectrophotometer. Gallic acid was used as the standard. The total phenol was measured as mg gallic acid equivalent per ml sample.

Determination of total flavonoids

The total flavonoid content of the extract was determined using a spectrophotometry assay as described by Jia et al. [25]. An aliquot of 0.2 ml of the extract was added to 0.3 ml of 5% NaNO₃ followed by 0.6 ml of 10% AlCl₃ after 5 min. Finally, 2 ml of 1 M NaOH and 2.1 ml of distilled water were added to the reaction mixture. The absorbance was read at 510 nm against the reagent blank. Rutin was used as a standard for the calibration curve and flavonoid content was expressed as mg rutin equivalent per ml sample.

Determination of ferric reducing antioxidant potential (FRAP)

The ferric reducing property of the extract was determined as described by Pulido et al. [26]. An aliquot of 0.25 ml of the extract was mixed with 0.25 ml of 200 mM of sodium phosphate buffer (pH 6.6) and 0.25 ml of 1% Potassium Ferrocyanate (KFC). The mixture was incubated at 50 °C for 20 min, thereafter 0.25 ml of 10% Tricarboxylic acid (TCA) was also added and centrifuged (Eppendorf, USA) at 2000 rpm for 10 min, 1 ml of the supernatant was mixed with 1 ml of distilled water and 0.1% of FeCl₃ and the

absorbance was measured at 700 nm. The FRAP value was calculated and expressed as mmol of Fe^{2+} equivalents per ml of the sample.

Determination of free radical scavenging ability (DPPH)

The free radical scavenging ability of the extract against DPPH (1, 1-diphenyl-2-picrylhydrazyl) was determined using the method described by Gyamfi et al. [27]. An aliquot of 1 ml extract was mixed with 1 ml of 0.4 mM methanolic solution of the DPPH. The mixture was left in the dark for 30 min before measuring the absorbance at 516 nm. The percentage DPPH scavenged was calculated as shown below:

$$\% \text{ DPPH scavenged} = \frac{Abs_{control} - Abs_{test}}{Abs_{control}} \times 100$$

ABTS scavenging ability

The ABTS [2, 2-azino-bis(3-ethylbenthiazoline-6-sulphonic acid)] scavenging ability of the extract was determined according to the method of Re et al. [28]. The ABTS stock was generated by reacting 7 mM of ABTS aqueous solution with 2.45 mM $\text{K}_2\text{S}_2\text{O}_8$ in the dark for 16 h and adjusting the absorbance at 734 nm to 0.70 ± 0.02 with ethanol. Aliquot of 0.2 ml of the appropriate dilution of the extract was then added to 2.0 ml of ABTS solution and the absorbance was read at 734 nm after incubation for 15 min at room temperature. The trolox equivalent antioxidant capacity was subsequently calculated.

Determination of Vitamin C

An aliquot of 200 μl of the extract was pipetted and mixed with 300 μl of 13.3% of Trichloroacetic acid and 75 μl of 2,4 dinitrophenylhydrazine. The mixture was incubated at 37 °C for 3hrs and 500 μl of 65% H_2SO_4 was added alongside 500 μl of water. The vitamin C content was determined using the ascorbic acid as the reference and absorbance was read at 520 nm on a spectrophotometer.

Determination of extractable polyphenols, hydrolysable polyphenols and condensed tannins

Extraction was done by constant shaking at room temperature with acidic methanol (8 ml/L HCl)/ water (50:50 v/v, 50 ml/ml sample, 60 min) and acetone/water (70:30 v/v, 50 ml/ml sample) for 1 h. After centrifugation (3000 $\times$ g, 15 min, 25 °C), supernatants were combined and extractable polyphenols were quantified with Folin-Ciocalteu reagent using gallic acid as standard. Hydrolysable polyphenol was determined in residues of methanol/acetone/water extraction

by methanol/ H_2SO_4 (90:10 v/v) hydrolysis at 85 °C for 2 h. The samples were then centrifuged (3000 $\times$ g, 15 min, 25 °C) and hydrolyzing polyphenol were determined in the supernatants with Folin-Ciocalteu reagent using gallic acid as standard. Analysis of condensed tannin content was carried out according to the method of Broadhurst and Jones [29] with slight modification. To 50 ml of the extract 3 ml of 4% methanolic vanillin solution and 1.5 ml of HCl were added. The mixture was allowed to stand for 15 min, and the absorbance was measured at 500 nm against an ethanol as a blank. The amount of condensed tannins was then calculated and expressed as mg catechin equivalent.

Determination of soluble and insoluble fibre

An aliquot of 300 μl was impregnated with 10 ml of 72% H_2SO_4 and placed in the bath at 30 °C for 2 h, followed by the addition of 100 ml demineralized water and autoclaving at 125 °C for 1 h. The sample was then removed, cooled and filtered. The insoluble fiber (residue left) was washed with demineralized water until neutral pH of 7 was obtained and then oven dried at 105 °C until constant weight was obtained. The sample was allowed to cool to room temperature in a desiccator before being weighed. The fibre content was calculated by subtracting the final weight from the initial. The filtrate obtained was used to determine the soluble fibre content. For the soluble dietary fiber, to 5 ml of the filtrate, 5 ml of 3% sulphuric acid was added and the absorbance was measured at 205 nm with water and sulphuric acid as blank.

Determination of colour

The colour of the beverages was measured using a colour meter PCE-CSM (Deutschland GmbH) connected to a CQCS3 software (Shenzhen 3nh Technology, China). The spectrophotometer was calibrated against a white plate before the reading was taken. The aperture of the spectrophotometer was placed on top of the sample and measurement was taken. L represents lightness, “a” represents red to green ratio, “b” represents yellow to blue ratio.

Sensory evaluation

The beverages were evaluated for colour, taste, viscosity, flavor and overall acceptability using a nine-point hedonic scale. Each parameter was scored using numerical values with the following categories: (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 and (9) like extremely. Twenty panelists seated in a well-lighted room evaluated the samples that were randomly coded.

Statistical analysis

All determinations were carried out at least in triplicates except otherwise stated. The statistical difference between the means were analyzed by One-way ANOVA and the means were separated by Duncan's new multiple range technique with SPSS Statistics for Windows, Version 17.0. (Chicago SPSS Inc.).

Results and discussion

Physicochemical properties and Vitamin C content of the fortified kunnu

The pH of the kunnu samples ranged from 3.24 to 4.96 (Table 1). The kunnu with tigernut (KTM) had the highest pH, thus showing that tigernut is less acidic than millet. It had been earlier reported that the pH of tigernut extract is between 5.3–5.6 [9]. As acidic beverages are not desirable to consumers with ulcer and other related diseases, inclusion of tigernut extract in kunnu will reduce the acidity and increase preference for consumers with digestion problems. The low pH of 3.24 of the unfortified kunnu could be as a result of fermentation as the process leads to decrease in pH value [30].

The total titratable acidity which is a measure of the 'acid taste' of the samples ranged from 4.60 to 6.53. (Table 1). There were significant differences ($P < 0.05$) in the total titratable acidity between the four samples. The unfortified kunnu had the highest total titratable acidity value of 6.53 (mg/ml) when compared to the other samples. The kunnu with tigernut had the lowest titratable acidity value of 4.60 (mg/ml) probably due to concomitant highest pH value of 4.96 of the four samples. This fact indicates that extracts from tigernut has less 'acid taste' as similarly reported by Badejo et al. [9]. The presence of tigernut and/or coconut had significant effect on the total titratable acidity of the fortified kunnu beverages. Badejo et al. [20], reported however that increase in tigernut extracts had no noticeable effect on the titratable acidity of acha-tigernut beverages. The total

dissolved solids of the samples ranged from 19.11 to 27.31% (Table 1) with KCM having the highest value. The total dissolved solids values obtained for these kunnu were higher than the values reported by Olaoye et al. [23] and the disparity may be due to the fermentation duration and processing techniques.

The soluble and insoluble fibre content of the fortified kunnu are shown in Table 1. KTM had the highest soluble fibre content of 8.00% which could be as a result of tigernut being rich in fibre [7]. The unfortified kunnu had the highest insoluble fibre content of 85.01%. Millet generally are rich in insoluble fibre [31] making it a low-calorie ingredient that can help reduce blood glucose levels [32]. Coconut milk has been reported to have low soluble fibre content [33] and as a result all samples fortified with coconut milk also has significantly lower soluble fiber contents than those with tigernut (Table 1).

Vitamin C is found in food and used as dietary supplement. It is an essential nutrient involved in the repair of tissue and the enzymatic production of certain neurotransmitters. The kunnu sample that was not fortified was significantly lower in vitamin C content when compared to the fortified samples. The beverage fortified with tigernut had the highest vitamin C content of 28.07 mg/ml as compared to 6.61 mg/ml in the unfortified sample (Table 1). Tigernut has been reported as a rich source of vitamin C [8, 22]. This study shows kunnu beverage fortified with either coconut milk or tigernut extract can provide more than 30% of the daily requirement of vitamin C for children and adult [34].

Phytochemical content of fortified kunnu samples

The millet used for kunnu production is generally low in polyphenols and fibre content [35]. Fortification of kunnu with either coconut milk or tigernut extract resulted in significant increase in the extractable polyphenol content of the beverages (Table 2). This may be due to the high composition of phytochemicals (polyphenols) in tigernut such as alkaloids, cyanogenic glycosides, resins, tannins and saponins [10]. The hydrolysable polyphenol content ranged from 1.06 mg GAE/ml to 1.34 mg GAE/ml. However, no

Table 1 Physicochemical properties of the kunnu beverages fortified with tigernut and coconut extracts

Sample	pH	Total titratable acid (mg/ml)	Total dissolved solid (%)	Soluble fibre (%)	Insoluble fibre (%)	Vitamin C (mg/ml)
KUN	3.24 ^c	6.53 ± 0.06 ^a	23.08 ± 0.07 ^b	1.37 ± 0.02 ^d	85.01 ± 0.32 ^a	6.61 ± 0.53 ^c
KTM	4.96 ^a	4.60 ± 0.10 ^d	19.11 ± 0.43 ^d	8.00 ± 0.02 ^a	51.00 ± 1.00 ^d	28.07 ± 1.07 ^a
KCM	4.82 ^a	5.47 ± 0.15 ^c	27.31 ± 0.41 ^a	3.98 ± 0.04 ^c	66.17 ± 0.17 ^c	17.77 ± 0.56 ^b
KTC	4.06 ^b	5.90 ± 0.10 ^b	20.53 ± 0.66 ^c	6.05 ± 0.01 ^b	71.14 ± 0.20 ^b	17.71 ± 1.61 ^b

Values are mean ± SEM (n = 3). Values with the same superscript in the same column are not significantly different ($P < 0.05$)

KUN kunnu only, KTM kunnu with tigernut milk, KCM kunnu with coconut milk, KTC kunnu with tigernut and coconut milk

Table 2 Phytochemical content of kunnu beverages fortified with tigernut and coconut milk

Sample	Extractable poly-phenol (mg GAE/ml)	Hydrolysable Polyphenol (mg GAE/ml)	Condensed tannin (mg catechin eqv/ml)
KUN	0.79 ± 0.03 ^b	1.31 ± 0.10 ^a	0.38 ± 0.06 ^d
KTM	1.58 ± 0.00 ^a	1.12 ± 0.12 ^a	1.08 ± 0.08 ^c
KCM	1.40 ± 0.19 ^a	1.06 ± 0.83 ^a	1.79 ± 0.51 ^b
KTC	1.44 ± 0.15 ^a	1.34 ± 0.30 ^a	2.31 ± 0.08 ^a

Values are mean ± SEM (n=3). Values with the same superscript in the same column are not significantly different (P < 0.05)

KUN kunnu only, *KTM* kunnu with tigernut milk, *KCM* kunnu with coconut milk, *KTC* kunnu with tigernut and coconut milk

Table 3 Colour analysis of kunnu beverages fortified with tigernut and coconut milk

Sample	L*	a*	b*
KUN	58.79 ± 1.34 ^a	1.74 ± 0.06 ^c	6.60 ± 0.15 ^c
KTM	53.48 ± 0.44 ^c	4.68 ± 0.42 ^a	11.17 ± 0.58 ^a
KCM	57.62 ± 0.37 ^a	3.68 ± 0.13 ^b	8.89 ± 0.18 ^b
KTC	55.39 ± 0.78 ^b	4.85 ± 0.14 ^a	11.31 ± 0.17 ^a

Values are mean ± SEM (n=3). Values with the same superscript in the same column are not significantly different (P < 0.05)

KUN kunnu only, *KTM* kunnu with tigernut milk, *KCM* kunnu with coconut milk, *KTC* kunnu with tigernut and coconut milk

significant difference was observed in the hydrolysable polyphenol content of the beverages. Both tigernut extract and coconut milk have higher condensed tannin composition as reported by Chukwuma et al. [10] and Lima et al. [36] which might be responsible for the high level recorded in sample KTC.

Colour analysis of the kunnu samples

The CIE colour analyses showed that the lightness (L*) of the samples ranged from 53.48–58.79 (Table 3). The L* value for KUN was the highest with a value of 58.79. The milky brown colour of the tigernut extract led to a reduction in the L* value of KTM. Similarly, there were significant difference between the greenness to redness (a*) and blueness to yellowness (b*) of KUN and other kunnu samples having either coconut or tigernut extracts.

Antioxidant potentials of the fortified kunnu beverages

The reactivity of ABTS towards many antioxidants has led to its frequent use in assessing antioxidant potential [37]. The kunnu beverage fortified with coconut milk had the highest ABTS scavenging ability of 36.97 µmol TE/ml.

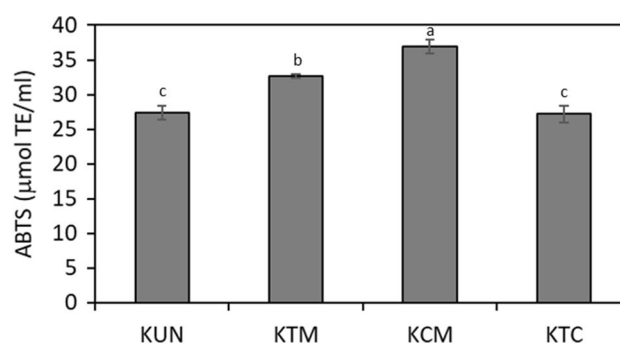


Fig. 2 The ABTS scavenging ability of kunnu beverages fortified with tigernut and coconut extracts. Values are mean ± SEM (n=3). Bars with the same alphabets are not significantly different (P < 0.05). KUN: Kunnu only, KTM: Kunnu with tigernut milk, KCM, Kunnu with coconut milk, KTC, Kunnu with tigernut and coconut milk

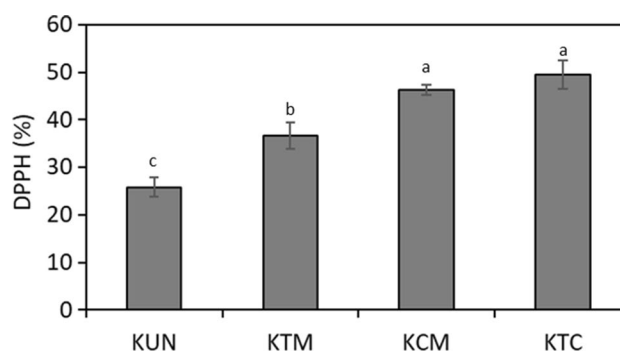


Fig. 3 The DPPH scavenging ability of kunnu beverages fortified with tigernut and coconut extracts. Values are mean ± SEM (n=3). Bars with the same alphabets are not significantly different (P < 0.05). KUN: Kunnu only, KTM: Kunnu with tigernut milk, KCM, Kunnu with coconut milk, KTC, Kunnu with tigernut and coconut milk

The sample fortified with tigernut was significantly higher than the unfortified sample (Fig. 2). Tigernut extract has been reported to enhance ABTS scavenging ability when used to fortify acha beverages [20].

The DPPH assay is a simple method frequently used to evaluate the ability of antioxidants to scavenge free radicals. Figure 3, showed that fortification of kunnu with either coconut milk and /or tigernut extracts resulted in significant increases in the DPPH scavenging ability of the beverages. The highest scavenging ability was recorded in the beverage fortified with both tiger nut and coconut milk. The inclusion of ginger extracts in the samples might have contributed to the observed increase in the scavenging abilities, as ginger has been reported to have high DPPH scavenging ability [38] and extract from steamed ginger has been found to have high anti-proliferative effect on cancer cell [39]. The DPPH scavenging ability of the KTM was lower than that of KCM. This fact agrees with findings of Badejo et al. [9] on lower DPPH inhibition

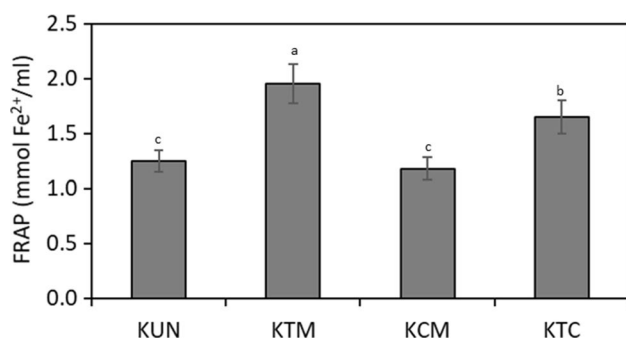


Fig. 4 The ferric reducing antioxidant potential of kunnu beverages fortified with tigernut and coconut extracts. Values are mean $\pm$ SEM ($n=3$). Bars with the same alphabets are not significantly different ($P<0.05$). KUN: Kunnu only, KTM: Kunnu with tigernut milk, KCM, Kunnu with coconut milk, KTC, Kunnu with tigernut and coconut milk

activity of beverages prepared with fresh tigernut extract than the roasted one.

The ability of an antioxidant to keep a transition metal in its reduced state is called the reducing potential. The reducing potentials of the four beverage samples showed that kunnu fortified with tigernut had the highest reducing potential of 1.95 mmol Fe²⁺ (Fig. 4). This could be due to the tigernut with rich antioxidant potential. When compared to other drinks, the ferric reducing potential of kunnu was only slightly higher than those of the palm drinks and lower than zobo and soybean drinks [35].

Total phenolic and flavonoid content of the kunnu samples

Phenolic compounds present in almost all foods of plant origin have beneficial effects which includes reducing the risk of diabetes, cancer, cardiovascular diseases and allergens [40]. The total phenolic content of the samples is presented in Fig. 5. There was no significant difference between the pure kunnu and the sample fortified with coconut milk. However, addition of tigernut extract resulted in 60% increase in the total phenolic content of the beverage. Antioxidants activities of plant-based foods have been reported to correlate positively with total phenolic content levels [41]. In a comparative study between plant based non-alcoholic beverages zobo drinks, soybean and kunnu drinks were found to be high in phenolic content [35].

Flavonoids are a group of phenolic compounds found in fruits, vegetables, grains, barks, stems and flowers and are well known for their beneficial effects on health [40, 42]. Fortifying kunnu beverage with tigernut extract resulted in over threefold increase in the flavonoid content of the beverage (Fig. 5). People following diet of flavonoid rich food and

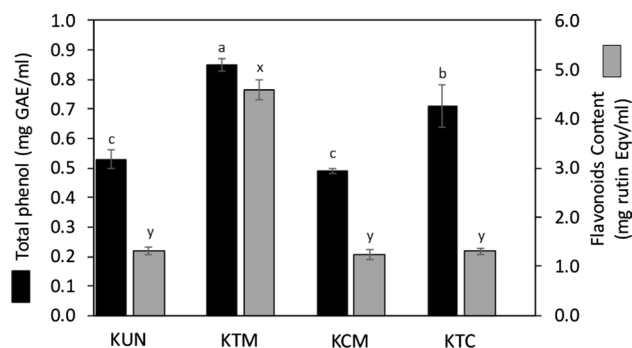


Fig. 5 The total phenolic and flavonoid contents of kunnu beverages fortified with tigernut and coconut extracts. Values are mean $\pm$ SEM ($n=3$). Bars with the same alphabets are not significantly different ($P<0.05$). KUN: Kunnu only, KTM: Kunnu with tigernut milk, KCM, Kunnu with coconut milk, KTC, Kunnu with tigernut and coconut milk

beverages have been reported to have lower risk of chronic diseases and they are used in the treatment of epilepsy [43].

Sensory evaluation of the kunnu samples

The organoleptic characteristics of the various beverage blends are shown in Table 4. The colour of kunnu that was not fortified was rated the highest. This may be probably due to the fact that the colour of the local commercially available kunnu has been registered in the mind of consumers over time. However, there was no significant difference ($P>0.05$) in the taste and viscosity of the four samples as opposed to what was observed by Ayo et al. [44] who reported significant difference in taste on addition of beniseed greater than 50%. The flavour of the kunnu beverage fortified with tigernut was the most preferred perhaps the milky feel of the tigernut extract in the beverage gave the appeal. Also, all the samples with tigernut extract were generally more acceptable to the consumer. Badejo et al. [20] reported that progressive increase in the proportion of tigernut extract in the beverages from acha and tigernut had significant ($P<0.05$) effect on the flavor, taste, mouthfeel, appearance and overall acceptability.

Conclusion

Kunnu beverage produced from millet was successfully fortified with coconut milk and tigernut extract. The fortified products were found to be higher in antioxidant capacity and vitamin C compared to the unfortified kunnu beverage. Consumer acceptability was not significantly different from the unfortified kunnu that the consumers were previously used to. The study has demonstrated value-addition chain to kunnu beverage that can bring about positive

Table 4 Sensory evaluation of the kunnu beverages fortified with tigernut and coconut milk

Sample	Colour	Taste	Viscosity	Flavour	Overall Acceptability
KUN	7.50 ± 1.05 ^a	6.40 ± 1.21 ^a	6.70 ± 0.45 ^a	5.95 ± 1.88 ^b	6.50 ± 1.32 ^a
KTM	6.70 ± 1.87 ^{ab}	6.75 ± 1.05 ^a	6.85 ± 0.63 ^a	6.55 ± 0.79 ^a	6.60 ± 1.54 ^a
KCM	5.90 ± 1.65 ^b	5.70 ± 0.84 ^a	6.90 ± 0.52 ^a	4.85 ± 0.30 ^c	5.10 ± 1.74 ^b
KTC	6.45 ± 1.43 ^b	6.20 ± 0.99 ^a	7.10 ± 0.17 ^a	5.60 ± 1.16 ^b	5.80 ± 1.91 ^{ab}

Values are mean ± SEM (n = 20). Values with the same superscript in the same column are not significantly different (P < 0.05)

KUN kunnu only, *KTM* kunnu with tigernut milk, *KCM* kunnu with coconut milk, *KTC* kunnu with tiger-nut and coconut milk

synergistic effect. Considering the health benefit that has been associated with the consumption of antioxidant-laden foods and beverages, the fortified kunnu beverage may be a good functional beverage for both adult and children.

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