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Nutrient composition, antioxidant properties, and sensory characteristics of instant *Kunu* from pearl millet supplemented with African locust bean pulp

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Abstract

Kunu is a millet-based, non-alcoholic, and non-carbonated energy beverage commonly consumed in the northern part of Nigeria. The nutrients composition, antioxidant properties, and sensory characteristics of instant *kunu* beverage made from pearl millet supplemented with African locus bean pulp (ALBP) were evaluated in this study. Instant *kunu* beverage was produced with 5–25% ALBP replacement for millet and freeze-dried. A control sample was produced from 100% millet. The chemical (proximate, vitamins, minerals) and phytochemical (total phenol, flavonoids, tannin, saponin, and phytates) contents and antioxidant activities, as well as the sensory properties of the beverage, were evaluated, using standard methods. The crude fiber (3.14–4.07%), total ash (1.77–3.40%), phosphorus (12.45–15.00 mg/100 g, potassium (12.00–12.55 mg/100 g), vitamin A (0.34–1.35%), and phytochemical contents (except phytate) increased significantly as the ALBP supplementation level increased in the beverage. The ranges of phenolic, flavonoid, saponin, tannin, and phytate were 0.71–0.90, 0.35–0.86, 0.02–0.34, 0.02–0.34, and 0.83–0.62 mg/g, respectively. The antioxidant activities of the beverage also increased as the ALBP level in the beverage increased. All the beverage samples were generally accepted by the panelists, with an overall acceptability of 5.17 to 6.73. Hence, the instant *kunu* beverage made from pearl millet supplemented with African locus bean pulp may serve as a dietary source of essential nutrients and antioxidants for human nutrition.

Keywords Antioxidant power, *Kunu* beverage, Millet, Sensory attribute, *Parkia biglobosa*

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Introduction

The maintenance of a good health is a function of adequate nutrition, through macronutrients and micronutrients consumption, together with phytochemicals, which are capable of scavenging free radicals [1, 2]. Thus, it is imperative to boost the intake of natural antioxidants, in order to arrest the free radicals and their associated degenerative diseases [1]. This is important, especially in developing nations, where a sole diet with an adequate nutrient composition is rare [3]; thus, food supplementation has been considered as a veritable option. Vitamins and minerals are essential micronutrients for human growth and well-being and should be adequately supplied in the diet for human needs. According to studies, over 2 billion people are deficient in essential vitamins and minerals such as vitamin A, C, zinc, iron, and iodine worldwide [4]. The most vulnerable population groups in this scourge are children and women [5]. Some of these micronutrients may also assist in the prevention and management of degenerative diseases associated with oxidative stress. Previous researches on micronutrient deficiencies intervention include Alake et al. [6], Olaniran et al. [7], and Olatoye et al. [4], and food supplementation was considered a versatile, veritable, and cost-effective strategy to manage these nutritional concerns. Food supplementation could be considered as a cost-effective strategy, suitable for the delivery of micronutrients to a large segment of the population, without traces of changes in food consumption patterns [8]. Energy-giving foods and beverages, such as *kunu*, that are marginally deficient in micronutrients are common staples in most developing nations [9, 10]. *Kunu-Zaki*, as it is often called by people in the northern part of Nigeria, is a widely consumed energy beverage that is readily available and affordable, with a thirst-quenching propensity. It is a millet-based beverage, which serves as complementary food beverage for infants and for thirst-quenching, especially during the dry season [11]. *Kunu* is a non-alcoholic, non-carbonated beverage produced by fermentation of malted cereal grains, such as millet, maize, guinea corn, sorghum, and rice [12]. It is quite enjoyed by all and sundry, without age, social–cultural, or ethnicity barriers. However, it is mainly a high caloric-beverage, apart from its high content of moisture. In an attempt to offer a convenient food and extend its shelf stability, Abulude et al. [13] developed *kunu* instant powder via dehydration. Various research works were also carried out on the fortification of *kunu* with protein sources, such as soybean [11, 14], *Vigna racemosa* [15], cowpea [14], and Ackee fruit [3]. However, scanty literature reports exist on the utilization of African locust bean pulp (ALBP) in *kunu* recipe, as a way of boosting its micronutrients profile and antioxidant power. According to Gernah et al. [16], ALBP was described as a rich source of total carotenoids, known to be a precursor of vitamin A, mineral elements, and phytochemicals, some of which are antioxidants in nature. The pulp can improve appetite and thus human growth performances. Its remarkable sour taste showcases its acidity (vitamin C) [17]. Additionally, it was reported that in rural Africa, during emergencies, when the grain stores are exhausted, the fruit pulp can be used in the preparation of stews, soups, and sauces for the consumption of cereals, or pressed into cakes or sometimes for the production of indigenous wine. This justifies its edibility and safety [18]. ALBP may improve the micronutrient content and natural antioxidants in human staples. Its propensity for preventing chronic diseases and cellular mutation, owing to the presence of these antioxidant properties cannot be ruled out. As part of interventions toward reducing the incidences of degenerative diseases in developing nations, the inclusion of natural antioxidants in human staples to scavenge the free radicals causing them has been adopted [1, 2]. Addition of ALBP in the recipe of beverages, such as *kunu*, in Nigeria may be a viable vehicle of nutrients for ameliorating micronutrient deficiencies and oxidative stress. Therefore, this study was designed to evaluate the nutrients composition, antioxidant properties, and sensory attributes of freeze-dried *kunu* beverage supplemented with ALBP.

Materials and methods

Samples collection and preparation

Samples of pearl millet (*Pennisetum glaucum*) grains and African locust bean (*Parkia biglobosa*) fruits were procured from a local market in Malete, Kwara State, Nigeria. The African locust bean fruits sample was manually extracted using the method of Gernah et al. [16], with a slight modification. The yellow pulp was dried in a cabinet drier at 60 °C for 4 h to a moisture content of 10%. The powder was pulverized with an electric blender (7-IN-1 ETKAL-868 blender TUV, Rheinland) and sieved through a 0.5-mm screen, to obtain a fine powder. The modified method of Sengev et al. [19] was used for the production of fermented millet (FM). Five hundred grams of dehulled pearl millet grains was cleaned, sorted, weighed, and steeped in 1000 ml of potable water for 16 h. The grains were drained and spread on a tray, covered with moistened cleaned jute bag, and allowed to sprout for 24 h. The sprouted grains were washed with potable water to remove the vegetative parts. It was milled, sieved using a clean muslin cloth, and allowed to sediment for 36 h at room temperature in a covered plastic container. The supernatant was decanted, and the sediment was used for the production of *kunu.* The fermented millet sediment was blended with measured amount of spices, including cloves, ginger, pepper, and ALPB as shown in Table 1 [16]. These were mixed with 20 ml of potable water (2:1 w/v) and then freeze-dried. The ALBP concentrations (5, 10, 15, 20, and 25%) chosen in this study were based on a preliminary experiment. The beverage was packaged in an air-tight container and stored at room temperature, prior to analysis.

Chemical analyses

Determination of proximate composition and metabolizable energy value

The proximate composition including crude protein, fat, moisture, fiber, ash, and carbohydrate (by difference)

Table 1 Ingredients formulation for production of millet-locust bean pulp-based *Kunu* beverage

Materials (g)	T1	T2	T3	T4	T5	T6
FM	200	190	180	170	160	150
ALBP	0	10	20	30	40	50
Ginger	2	2	2	2	2	2
Chili pepper	2	2	2	2	2	2
Clove	2	2	2	2	2	2

FM Fermented millet, *ALBP* African locus bean pulp. T1 = 100% FM; T2 = 95% FM:5% ALBP; T3 = 90% FM:10% ALBP; T4 = 85% FM:15% ALBP; T5 = 80% FM:20% ALBP; T6 = 75% FM:25% ALBP

contents of the formulated *kunu* samples was determined according to Horwitz and Latimer [20]. The energy value of the powder was calculated from the percentages of the major nutrients in kilojoules per 100 g, and the values were converted to kcal by dividing them by the conversion factor of 4.184 according to Maclean et al. [21] as shown in Eq. 1.

$$\text{Energy value (kcal)} = \frac{(\%\,\text{carbohydrate}\,x\,17 + \%\,\text{protein} \times 17 + \%\,\text{fat}\,x\,37)}{4.184} \quad (1)$$

Determination of vitamin content
The method described by Olatoye et al. [4] was used to determine the vitamin C concentration, while vitamin A concentration was determined according the method of Okwu [22].

Determination of mineral content
Five macrominerals (Ca, Mg, K, Na, P) and two microminerals (Fe and Zn) concentrations were determined in a 2-g digested sample of each *kunu* powder sample with the aid of an atomic absorption spectrophotometer (Buck 205 model; Buck Scientific Inc., USA). The outlined procedure of the Association of Official Analytical Chemists [20], approved method (968.08), was used.

Preparation of kunu extracts
A portion of 2 g of *kunu* sample was extracted by soaking in 20 mL of absolute (100%) methanol for 24 h. Thereafter, the mixture was centrifuged at 4000 rpm for 5 min, and the supernatant was collected by filtering through Whatman (No. 2) filter paper. The methanol in the filtrate was removed using a rotary evaporator at 45 °C, after which the dried extract was diluted to 6 mL with methanol [23].

Determination of phytochemical composition
The total phenolics content of the *kunu* sample was determined according to the Folin–Ciocalteu method as reported by Singleton et al. [24]; total flavonoids content was determined according to the aluminum chloride method described by Meda et al. [25]. Tannins content was quantified following the procedure of Amorim et al. [26]; total saponins level was determined as per the method described by Makkar et al. [27], and the method of Olatoye and Arueya [28] was employed to determine the phytate content.

Determination of antioxidant activity (DPPH*, ABTS^{*+} scavenging activity, and reducing power)
The determination of the DPPH* scavenging power of the sample extract was done according to the method described by Cervato et al. [29], where ascorbic acid was used as a positive control. The ability of DPPH* to scavenge radicals was expressed as the concentration of the extract that scavenged 50% of the DPPH* (SC_{50}). The method described by Re et al. [30] was used for the determination of the ABTS^{*+} scavenging ability of the *kunu* extracts and was expressed in micromole Trolox equivalent antioxidant capacity per gram sample (μmol TEAC/g). The method described by Oyaizu [31] was used for the determination of the reducing power and was expressed as gallic acid equivalent in mg/g sample (GAE mg/g).

Sensory evaluation of reconstituted kunu samples
The sensory evaluation conducted in this study was reviewed and approved by the Kwara State University IRB (Reference: KWASU/CR&D/REA/2023/0019), and informed consent was obtained from each panelist prior to their participation in the study. A total of 50 untrained panelists participated in the sensory evaluation. The samples were scored for appearance, taste, flavor, mouth-feel, and general acceptability using a 9-point hedonic scale, where “9” represents “like extremely” and “1” represents “dislike extremely” [32].

Statistical analysis of data

All generated data in triplicate were subjected to statistical analysis using Statistical Package for Social Sciences (SPSS, version 23). Separation of means was carried out at $p \leq 0.05$ using Duncan's multiple range test.

Results and discussion

Proximate composition and metabolizable energy content of instant *Kunu* supplemented with African locust bean pulp

The moisture content of *kunu* powder ranged between 8.13% and 8.60% and increased with the inclusion of ALBP (Table 2). This result was in accordance with the findings of Vincent et al. [33] in a related study. The effect of moisture on the stability and quality of foods cannot be overemphasized [34]. Foods with too much moisture content are subject to rapid deterioration due to mold growth, heating, insect damage, and sprouting [35]. However, in this study, the results showed that all the samples were within the safe (≤10%) moisture content recommended for flour [36]. Among the *kunu* samples, 75% FM:25% ALBP had the highest ash content (3.34%), which was higher than that of the control (1.77%). Ash is a measure of the inorganic residue remaining after either ignition or complete oxidation of organic matter in a food sample [34]. By inference, the increase in ash content with increased levels of ALBP may be an indication of their high mineral content [37]. Thus, the ALBP-enriched beverage may be a rich source of mineral to the consumers. The lipid content of the ALBP-supplemented *kunu* samples ranged from 0.81 to 1.03%. The value was lower than the 2.34% reported by Osanaiye et al. [38]. High-fat content could lead to rancidity, thereby causing deterioration of the product. Reduced fat contents are generally considered to improve the healthiness of the diet, help control weight, and benefit physical well-being. Generally, the higher the ALBP, the lower the protein content of the beverage. The ALBP flour, being obtained from a fruit, has been reported to be of lower protein content [38]. Proteins have a major role in the growth and maintenance of the human body. In addition, they have a wide range of other functions in the body, such as enzymatic activity and the transport of nutrients and other biochemical compounds across cellular membranes [39]. In order to maintain these important functions, it is essential to provide the body with good-quality proteins through diet. However, the *kunu* made from the various blends of millet and ALBP contained a sufficient protein level (7.24–9.90%) that could meet up the ≥8% recommended allowance by WHO/FAO [40]. In addition, the increased fiber content (3.14 to 4.70%) with the supplementation of millet with ALBP could be considered as an added advantage to the product. Fiber has been reported to add bulk to the feces, facilitating bowel movement and preventing many gastrointestinal diseases in man, including colon cancer [16]. The crude fiber value (3.14–4.07%) of the instant *kunu* in this study is lower than the range (5–15%) reported by Ogbonna et al. [41], but higher than the 0.25% reported by Adejuyitan et al. [42] in a similar study on *kunu* sample. Similarly, the carbohydrate content range (74.47 to 78.21%) is close to the values (71.54 and 71.53%) available in the literature [15]. Carbohydrates are long chains of sugar molecules that are mainly used for energy. The brain, nerve cells, and developing red blood cells can only use glucose for energy. The energy values of the blends also justified the energy beverage nature of the product, and this increased with an increase in the proportion of ALBP (Fig. 1).

Vitamins C and A contents of instant *Kunu* supplemented with African locust bean pulp

The vitamin C content of the instant *kunu* samples decreased with an increased addition of ALBP and ranged from 0.01 to 0.15 mg/100 g) as shown in Table 3. This implies that ALBP might not be regarded as an efficient source of Vitamin C. However, the vitamin A contents of the product improved with the incorporation of ALBP. The vitamin A content ranged from 0.34 to 1.35 mg/100 ml, with the control (100% millet *kunu*) having the lowest and 75% FM: 25% ALBP having the highest value of vitamin A. Vitamin A is an essential vitamin for the promotion of general growth, maintenance of visual function, regulation of differentiation of epithelial tissues, and embryonic development [43]. It can be

Table 2 Proximate composition (%) of instant *Kunu* supplemented with African locust bean pulp

Kunu samples	Moisture content	Crude protein	Crude fat	Crude ash	Crude fiber	Carbohydrate
100% FM	8.13 ± 0.43^a	9.90 ± 0.38^a	1.13 ± 0.01^a	1.77 ± 0.05e	3.70 ± 0.10^b	74.47 ± 0.87^c
95% FM:5% ALBP	6.76 ± 0.09^b	8.81 ± 0.20^b	1.12 ± 0.06^b	2.18 ± 0.02^d	3.14 ± 0.01e	78.21 ± 0.58^a
90% FM:10% ALBP	6.77 ± 0.46^b	8.52 ± 0.42^b	1.10 ± 0.02^b	2.28 ± 0.02^c	3.28 ± 0.06^d	75.85 ± 0.21^b
85% FM:15% ALBP	8.12 ± 0.10^b	8.29 ± 0.06^b	1.13 ± 0.01^a	2.49 ± 0.26^c	3.50 ± 0.02^c	76.45 ± 0.11^b
80% FM:20% ALBP	8.35 ± 0.32^a	7.24 ± 0.28	1.08 ± 0.01^b	2.60 ± 0.26^b	3.88 ± 0.01^b	76.29 ± 0.42^b
75% FM:25% ALBP	8.60 ± 0.15^a	7.23 ± 0.66^c	0.81 ± 0.02^c	3.34 ± 0.13^a	4.07 ± 0.87^a	75.78 ± 0.52^b

Means with different superscripts in the same column are significantly different ($p < 0.05$). *FM* Fermented millet; *ALBP* African locust bean pulp

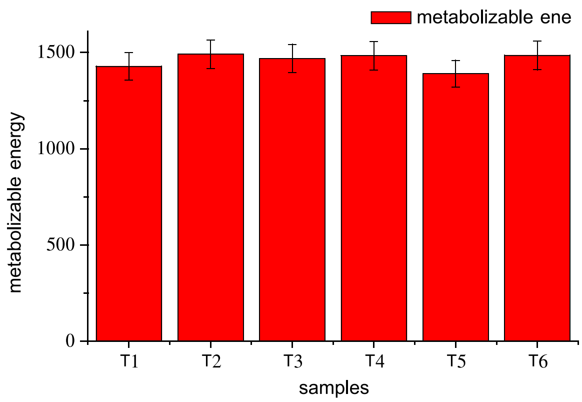

Fig. 1 Metabolizable energy contents of instant *Kunu* supplemented with African locust bean pulp. T1 = 100% FM; T2 = 95% FM:5% ALBP; T3 = 90% FM:10% ALBP; T4 = 85% FM:15% ALBP; T5 = 80% FM:20% ALBP; T6 = 75% FM:25% ALBP; FM = Fermented millet; ALBP = African locus bean pulp

Table 3 Vitamin contents of instant *Kunu* supplemented with African locust bean pulp

Kunu Samples	Vitamin C (mg/100 ml)	Vitamin A (mg/100 ml)
100% FM	0.15 ± 0.00^{a}	0.34 ± 0.06^{f}
95% FM:5% ALBP	0.09 ± 0.00^{b}	0.47 ± 0.03^{e}
90% FM:10% ALBP	0.07 ± 0.00^{c}	0.72 ± 0.03^{d}
85% FM:15% ALBP	0.05 ± 0.01^{d}	0.99 ± 0.02^{c}
80% FM:20% ALBP	0.08 ± 0.01^{c}	1.19 ± 0.02^{b}
75% FM:25% ALBP	0.01 ± 0.01^{e}	1.35 ± 0.03^{a}

Means with different superscripts in the same column are significantly different ($p < 0.05$). *FM* Fermented millet; *ALBP* African locust bean pulp

obtained from food, either as a preformed vitamin A in animal products, such as eggs and dairy products or as provitamin A carotenoids, mainly β-carotene in plant products, such as green leafy and yellow-colored vegetables and orange-colored fruit. Provitamin A carotenoids in vegetables and fruit provide 70% of daily vitamin A intakes. Epidemiologic data have shown that diets rich in carotenoid-containing foods are associated with decreased risk of certain types of chronic diseases, such as cancer, cardiovascular disease, age-related macular degeneration, and cataracts [44].

Mineral content of instant *Kunu* supplemented with African locust bean pulp

Generally, the minerals concentrations of the ALBP-supplemented *kunu* beverage were boosted, as their concentrations increased with an increasing proportion ALBP (Table 4). The minerals contents (mg/100 g) were in the following ranges: calcium (182.37–680.90), magnesium (145.90–544.72), potassium (12.00–12.55), sodium (10.50–11.20), phosphorus (12.45–15.00), iron (0.30–5.77), and zinc (0.50–1.85). The minerals levels recorded for the beverage samples in this study were slightly different from those reported by Makinde and Oyeleke [45] in *kunu* beverage. The report of Ogbonna et al. [46] also corroborates the values of potassium and phosphorus recorded in this study. The higher values of the minerals recorded in this study than those reported in other studies could obviously be attributed to the incorporation of ALBP into the *kunu* beverage. The increase in the mineral contents in the samples containing ALBP could, therefore, justify the need to enrich the beverage with sources that are rich in other nutrients lacking in cereals normally adopted in its production [28]. Minerals are essential for health and as such are part of all aspects of cellular function and structural components of human beings. Some minerals form an integral part of enzyme or protein structure. They are vital for normal growth, maintenance, an effective immune system, and the prevention of cell damage [28]. Calcium and magnesium play important roles in bone and teeth formation and development. Phosphorus makes up to 1% of the human

Table 4 Mineral content of instant *Kunu* supplemented with African locust bean pulp

Kunu Samples	Calcium (mg/100 g)	Magnesium (mg/100 g)	Potassium (mg/100 g)	Sodium (mg/100 g)	Phosphorus (mg/100 g)	Iron (mg/100 g)	Zinc (mg/100 g)
100% FM	182.37 ± 8.07^{f}	145.90 ± 6.46^{f}	12.00 ± 0.01^{c}	10.50 ± 0.10^{d}	12.45 ± 0.02^{d}	0.30 ± 0.10^{f}	0.50 ± 0.02^{f}
95% FM:5% ALBP	219.65 ± 21.35^{e}	175.72 ± 17.08^{e}	12.10 ± 0.04^{c}	10.55 ± 0.13^{c}	13.90 ± 0.05^{c}	0.42 ± 0.10^{ab}	0.60 ± 0.06^{e}
90% FM:10% ALBP	228.96 ± 13.98^{d}	183.17 ± 11.18^{d}	12.15 ± 0.09^{c}	10.65 ± 0.15^{bc}	14.00 ± 0.08^{c}	0.54 ± 0.18^{d}	0.62 ± 0.04^{d}
85% FM:15% ALBP	345.44 ± 21.35^{c}	276.35 ± 17.08^{c}	12.20 ± 0.10^{c}	10.75 ± 0.20^{b}	14.30 ± 0.10^{bc}	1.13 ± 0.10^{c}	0.94 ± 0.06^{c}
80% FM:20% ALBP	587.72 ± 8.07^{b}	470.17 ± 6.45^{b}	12.30 ± 0.15^{b}	10.80 ± 0.25^{a}	14.65 ± 0.20^{b}	2.70 ± 0.16^{b}	1.60 ± 0.02^{b}
75% FM:25% ALBP	680.90 ± 8.07^{a}	544.72 ± 6.45^{a}	12.55 ± 0.20^{a}	11.20 ± 0.32^{a}	15.00 ± 0.24^{a}	5.77 ± 0.10^{a}	1.85 ± 0.02^{a}

Means with different superscripts in the same column are significantly different ($p < 0.05$). *FM* Fermented millet; *ALBP* African locust bean pulp

total body weight. It plays an important role in metabolic pathways that produce and store energy in adenosine triphosphate (ATP). It is also vital for kidney function and serves as a structural component of teeth and bone [47]. Potassium, on the other hand, helps in the prevention of high blood pressure [48]. Similarly, potassium is essential for the synthesis of amino acids and proteins. It also plays fundamental roles in most reactions involving phosphate transfer and is believed to be essential in the structural stability of nucleic acid and intestinal absorption. Iron has been linked to hemoglobin production, which is significant for oxygen transportation in the body, and its deficiency results in anemia. Thus, the 75% FM:25% ALBP can be recommended as a beverage for iron-deficient individuals. Likewise, zinc has been reported to enhance immunity and fight infection [49]. The increase in the contents of the minerals recorded in the *kunu* samples containing ALBP could, therefore, be of nutritional advantage to the consumers of the products.

Phytochemical profile of instant *kunu* supplemented with African locust bean pulp

The supplementation of ALBP powder in the instant *kunu* beverage resulted in increased contents of phytochemicals except for phytate (Table 5). The ranges of phenolic, flavonoid, saponin, tannin, and phytate were 0.71–0.90, 0.35–0.86, 0.02–0.34, 0.02–0.34, and 0.83–0.62 mg/g, respectively. Although the presence of these phytochemicals could be associated with problems of nutrient bioavailability, they have been largely associated with diverse health benefits [28]. Most of these phytochemicals have the potential to reduce the risk of several chronic diseases in humans at their permitted levels [50]. For instance, phenolic compounds were reported to inhibit the activity of digestive as well as hydrolytic enzymes, such as amylase, trypsin, chymotrypsin, and lipase [51]. Studies have demonstrated the impacts of phenolics on health-related functional properties, such as anticarcinogenic, antiviral, antimicrobial, anti-inflammatory, antihypertensive, and antioxidant activities [52, 53]. Among the phytochemicals, flavonoid has been recognized for its ability to regulate gene expression and modulate enzymatic action [54] and anti-obesity effect [28, 55]. An increase in energy expenditure for digestion and absorption of protein, inhibitions of fat absorption, and promotion of thermogenic fat-burning were documented for flavonoids [56].

The result of tannin was similar to the tannin content reported by Abidoye et al. [57] in a similar study, tannins have been reported to affect the nutritive value of food products by binding metals, such as iron and zinc, reducing the absorption of nutrient, and also forming complexes with protein, thereby inhibiting their digestion and absorption [58]. The total saponin contents of the samples in this study also agreed with the findings of Makinde and Oyeleke [45] on the effect of sesame seeds on the anti-nutritional properties of *kunu* enriched with sesame seed flour. Saponins have been found to cause hemolytic activity by reacting with sterols of erythrocyte membrane. Similarly, phytate is known to adversely affect mineral bioavailability at a high level [59]. Its pharmacological benefits, such as reduction of blood glucose, plasma cholesterol, triglycerides levels, and cancer risks, have been documented [60].

Antioxidant activity of instant *kunu* supplemented with African locust bean pulp

The antioxidant activity of the *kunu* powder, examined using free radicals ($ABTS^{*+}$ and $DPPH^{*}$) scavenging assays and reducing power, revealed an increase with increasing levels of ALBP supplementation, with the control sample and 75% FM:25% ALBP being the lowest and highest, respectively (Table 6). This can be attributed to the observed increase in the contents of bioactive components (phenol, flavonoids, tannins, saponin, and phytate) with a higher supplementation level of ALBP in the *kunu*. As earlier stated, most of these phytochemicals have been largely associated with different health benefits [28] and the potential to reduce the risk of several chronic diseases in humans [50]. The enhanced antioxidant activity of the ALBP-supplemented *kunu* suggests that it may be useful for the prevention of oxidative stress and the diseases associated with it, when consumed. This is in line with earlier assertions by Arueya and Ugwu [1] and Irondi et al. [2] that boosting the antioxidant capacity

Table 5 Phytochemical contents of instant *Kunu* supplemented with African locust bean pulp

Kunu Samples	Phenolic (mg/g)	Flavonoid (mg/g)	Tannins (mg/g)	Saponin (mg/g)	Phytate (mg/g)
100% FM	0.71 ± 0.01^{c}	0.35 ± 0.00^{bc}	0.02 ± 0.01^{c}	0.02 ± 0.01^{c}	0.83 ± 0.01^{a}
95% FM:5% ALBP	0.75 ± 0.01^{d}	0.34 ± 0.01^{bc}	0.34 ± 0.05^{a}	0.16 ± 0.04^{b}	0.51 ± 0.03^{c}
90% FM:10% ALBP	0.80 ± 0.00^{c}	0.33 ± 0.02^{c}	0.20 ± 0.02^{b}	0.20 ± 0.03^{b}	0.77 ± 0.09^{a}
85% FM:15% ALBP	0.81 ± 0.00^{c}	0.35 ± 0.05^{bc}	0.16 ± 0.04^{b}	0.20 ± 0.02^{b}	0.67 ± 0.01^{a}
80% FM:20% ALBP	0.84 ± 0.01^{a}	0.40 ± 0.03^{b}	0.20 ± 0.03^{b}	0.33 ± 0.00^{a}	0.60 ± 0.02^{b}
75% FM:25% ALBP	0.90 ± 0.01^{a}	0.86 ± 0.03^{a}	0.34 ± 0.05^{a}	0.34 ± 0.05^{a}	0.62 ± 0.00^{b}

Means with different superscripts in the same column are significantly different ($p < 0.05$). *FM* Fermented millet; *ALBP* African locust bean pulp

Table 6 Antioxidant power of instant *Kunu* supplemented with African locust bean pulp

Kunu Samples	ABTS*$^{+}$ scavenging ability (µmol TEAC/g)	DPPH* SC_{50} (µg/mL)	Reducing power (mg GAE/g)
100% FM	172.63 ± 1.03^{f}	41.72 ± 0.20^{f}	6.85 ± 0.16^{f}
95% FM:5% ALBP	211.34 ± 1.10^{e}	49.21 ± 0.28^{e}	10.14 ± 0.28^{e}
90% FM:10% ALBP	229.81 ± 0.14^{d}	51.41 ± 0.2^{d}	17.12 ± 0.15^{d}
85% FM:15% ALBP	275.77 ± 3.34^{c}	60.12 ± 0.54^{c}	22.32 ± 0.21^{c}
80% FM:20% ALBP	312.34 ± 1.10^{b}	62.19 ± 0.35^{b}	37.41 ± 0.52^{b}
75% FM:25% ALBP	344.08 ± 2.10^{a}	65.13 ± 9.46^{a}	42.41 ± 0.01^{a}

Means with different superscripts in the same column are significantly different ($p < 0.05$). *FM* Fermented millet; *ALBP* African locust bean pulp

of the cell is essential for the management of metabolic diseases, such as obesity and type 2 diabetes.

Sensory attributes of instant *kunu* supplemented with African locust bean pulp

Supplementations of ALBP powder in instant *kunu* beverage resulted in an improvement in its appearance, taste, aroma, flavor, mouth-feel, and overall acceptability (Table 7). The ALBP was reported to be yellowish in appearance, due to the presence of carotenoids [17], and this may have contributed to a slight deviation from the usual color of the *kunu* beverage. Similarly, ALBP was reported to have a sweet taste, which was suggested to be an indication of the presence of natural sugars [17]. The sourness, as pointed out by the panelists, shows the presence of ascorbic acid (vitamin C), which is quite known to improve appetite and consequently growth performance in humans. Adejuyitan et al. [42] and Makinde and Oyeleke [45] reported a similar finding. The inclusion of between 5 and 10% ALBP in *kunu* beverage production was found to compare with the control sample according to the panelists results. Notwithstanding, the overall acceptability of all the samples was above 5.0 on a 9-point hedonic scale, showing no rejection of any of the samples [32]. This further confirms that up to 25% ALBP inclusion in millet-based *kunu* beverage recipe is potentially feasible from the organoleptic view point.

Conclusions

This study revealed that the 5–25% supplementation of African locust bean pulp (ALBP) in millet instant *kunu* improved the nutrients (ash, minerals, and vitamin A), phytochemical compositions (total phenolics, tannins, flavonoids, and saponin), and antioxidant activity of the *kunu* beverage. The levels of moisture, ash, crude fiber, vitamin A, minerals (Ca, Mg, K, Na, P, Fe, and Zn), phenolics, and antioxidant activity increased with increasing concentrations of ALBP in the instant *kunu*. However, there was a concomitant reduction in the crude protein, fat, carbohydrate, metabolisable energy value, vitamin C, and phytate contents of the *kunu*. Sensory panelists adjudged the *kunu* beverage to be acceptable at up to 25% ALBP supplementation. The study recommends the utilization of ALBP as a supplement in *kunu*-based beverages and similar foods with low nutrients and antioxidant profile. However, studies on the storage stability of this product are imperative.

Table 7 Sensory attributes of instant *Kunu* supplemented with African locust bean pulp

Kunu samples	Appearance	Taste	Aroma	Mouth feel	Overall acceptability
100% FM	7.30 ± 1.58^{a}	6.47 ± 1.91^{a}	7.23 ± 1.17^{a}	6.57 ± 1.61^{a}	6.73 ± 1.89^{a}
95% FM:5% ALBP	6.67 ± 1.52^{ab}	5.90 ± 1.77^{a}	6.60 ± 1.16^{ab}	6.17 ± 1.51^{ab}	6.67 ± 1.74^{a}
90% FM:10% ALBP	6.33 ± 2.06^{ab}	6.13 ± 1.50^{a}	6.47 ± 1.63^{ab}	6.20 ± 1.92^{ab}	6.43 ± 1.74^{a}
85% FM:15% ALBP	6.03 ± 2.02^{abc}	5.53 ± 1.93^{ab}	6.20 ± 1.86^{bc}	5.53 ± 1.80^{bc}	5.83 ± 1.82^{ab}
80% FM:20% ALBP	5.73 ± 1.95^{bc}	5.67 ± 1.69^{ab}	6.07 ± 1.51^{bc}	5.57 ± 1.91^{bc}	6.03 ± 1.83^{ab}
75% FM:25% ALBP	5.00 ± 1.89^{c}	4.83 ± 2.02^{b}	5.37 ± 1.96^{c}	4.63 ± 1.87^{c}	5.17 ± 2.12^{b}

Means with different superscripts in the same column are significantly different ($p < 0.05$). *FM* Fermented millet; *ALBP* African locust bean pulp

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Author contributions
KKO conceptualized and designed the research, sourced the funding, supervised the study, and drafted the manuscript. EAI sourced the funding, supervised the study, and reviewed and edited the final manuscript draft. WA sourced the funding, supervised data analysis and interpretation, and reviewed and edited the final manuscript draft. OIA analyzed the samples, collected, analyzed, and interpreted the data. All authors read and approved the final manuscript.

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Availability of data and materials
The raw data and materials for this study will be made available by the authors on request.

Declarations

Competing interests
The authors have no competing interest regarding this study.

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