

Physiochemical and anti -oxidant properties of wheat flour and baobab leaf flour (*Adansonia digitata* L.) composite bread

Abstract

Composite bread was produced using baobab leaf flour at a substitution ration of (0) %BLF with 100% WF, (5) % BLF with 95% WF, (10) % BLF with 90% WF, (15) % BLF with 85% WF and (20) % BLF with 80% WF (w/w) using the straight dough method of making bread using the manual process. The composite breads obtained from the straight dough methods were evaluated for physical, nutritional, anti -oxidant and sensory properties using standard methods. The aim is to improve physical properties, nutritional anti -oxidant and acceptability quality of bread produced by replacing wheat flour (WF) with different proportions of baobab leaf flour (BLF). The results obtained show that baobab leaf flour bread (BLFB) has good physical attributes; Height (6.2 ± 0.02 - 8.3 ± 0.02) cm³ /100g volume; (62.01 ± 0.23 - 74.70 ± 0.32) cm³/100g, elasticity (60.24 ± 0.02 - 83.87 ± 0.02) % and H/D was between (31.0 ± 0.12 - 43.6 ± 0.18). The 20% BLF (sample E) presented a good loaves height, weight and H/D. Also, a rich source of minerals (Ca: 27.840 ± 0.05 - 30.80 ± 0.19) mg/L; Mg: (13.01 ± 0.35 - 15.93 ± 0.21) mg/L Na: (13.13 ± 0.75 - 13.47 ± 2.55) mg/L K: (19.32 ± 0.95 - 21.14 ± 0.85) mg/L; Zn: ($0.03.14 \pm 0.19$ - 0.33 ± 0.45) mg/L and Fe: (0.58 ± 2.15 - 2.19 ± 0.10) mg/L. The bread product with baobab leaf flour (BLF) had vitamin A and E content range of (0.08 ± 0.17 - 0.435 ± 0.15 0.002) ug/g, and (4.370 ± 0.15 - 5.735 ± 0.15) mg/100g while DPPH value of (65-85) % was the result for DPPH antioxidant activity range. Regarding the physical attributes, the bread sample with 20% BLF (sample E) was the best among the samples with different proportions of BLF. The scores obtained for taste and crust texture from BLFB on organoleptic test were the best from sample B in comparison with the control sample: This study shows that BLF improved the physiochemical, anti -oxidant and organoleptic properties, resulting in composite flour suitable for the production of functional bread.

Keywords: baobab leaf flour, bread property, nutritional, antioxidant activity, sensory property

Volume 14 Issue 3 - 2026

Ogori AF, Vala J, Fadipe E

Department of Home Science and Management, Faculty of Agriculture, Federal University, Nigeria

Correspondence: Ogori Akama Friday, Department of Home Science and Management, Faculty of Agriculture, Federal University, P.M.B. 1005 Gashua, Nigeria, Tel +2349038600586

Received: September 18, 2026 | **Published:** October 01, 2026

Introduction

Consumers' expectations concerning baked food is geared towards satisfying hunger, nutritional, medicinal, deliciousness of the product. A global recognized food with nutritional impact is baked food from wheat flour, a product that meets hunger expectations chemically engineered by gluten. The rheology in bakery enhanced by the gluten network help wheat flour bread to be good for consumption, ease production and equally suitable for enrichment.^{1,2} The enrichment of bread with plant materials with high health-promoting ingredient could increase the supply of bioactive ingredients in the diet³ however, Ogu Vegetable, scientifically known as *Telfairia occidentalis* and nuts as plant material has fulfilled this role.^{4,5} Baobab leaf flour is derived from the dried leaves of baobab tree (*Adansonia digitata*), a tree widely distributed in sub-Saharan Africa, including Northern Nigeria. The baobab tree belongs to the family *Malvaceae* and is often referred to as the "tree of life" due to its nutritional and medicinal importance. The leaves are traditionally dried and ground into powder (locally called "kuka"), which is commonly used in preparing soups and soup delicacies. Kuka flour is known for its high content of dietary fiber, calcium, potassium, iron, vitamin C, and bioactive substances like flavonoids and phenolic materials that has antioxidant functions.^{6,7}

In recent years, World Health Organization in the year 2020 argued that there has been increasing interest in composite flour

technology, which involves blending wheat flour with flours from other plant sources to improve nutritional quality and functional properties. The blending of wheat and baobab leaf flour may enhance the chemical composition of bread by increasing fiber, mineral, pro-vitamin A content and antioxidant activity. This approach can also reduce dependency, promote utilization of indigenous crops, and improve food security.³ Free radicals are unstable molecules that could cause damage cells, leading to chronic diseases such as cancer, cardiovascular diseases, and diabetes.⁸

Wheat contains some antioxidant compounds, mainly in the bran layer, while baobab leaves are particularly rich in natural antioxidants such as polyphenols and vitamin A and C. Incorporating baobab leaf flour into wheat flour may significantly improve pro-vitamin A content battled over the years by food authorities on bread flour and products and the antioxidant potentials of bread, making it a functional food with health-promoting properties.⁹ By enriching wheat bread with antioxidant-rich baobab leaf flour, it may be possible to produce bread that supports immune function, reduces oxidative stress, and improves digestive health due to increased fiber content.¹⁰ In Northern regions, baobab leaves are readily available and affordable, utilizing baobab flour in bread production could promote local agriculture, reduce import costs of whole wheat, vitamin A premix and encourage value addition to indigenous plant resources. This aligns with national strategy aimed at improving food security and economic sustainability.

Refined wheat flour is widely used in bread production but is limited in dietary fiber, certain minerals, and antioxidant compounds. The prevalence of non-communicable diseases such as cardiovascular diseases and diabetes has created a demand for healthier food alternatives. There is a need to fortify wheat-based products with nutrient-rich, locally available plant materials such as baobab flour. However, the incorporation of non-wheat flours may negatively affect dough structure and bread quality due to gluten dilution. There is insufficient data on the optimal blending ratio of wheat and baobab leaf flour that balances improved nutritional value with acceptable bread quality. Therefore, it is important to investigate the physical characteristics, nutritional composition, and antioxidant potentials of wheat–baobab leaf flour blends and evaluate their suitability for bread production. The findings will contribute to understanding composite flour technology and promote the use of locally available plant resources in bakery products. This will support the development of functional bakery product that could be beneficial to food processors, nutritionists, researchers, and policymakers in promoting healthier bread alternatives.

Materials and methods

Kuka leaves flour was processed in Gashua and the study conducted at the Federal University Gashua, biochemistry and chemistry Laboratories. Commercially available golden penny wheat flour was purchased from reputable suppliers in Gashua. The flour was sieved to remove impurities and before they were stored in airtight containers at room temperature until use. Dried baobab leaf flour were obtained from fresh baobab leaf (kuka tree) by cleaning, dried at 60°C under the sun for two 72 hours, and milled into fine flour using a hammer mill. The flour was sieved (mesh size 250 µm) to ensure uniform particle size and stored in airtight containers in a cool, dry environment (Figure 1).

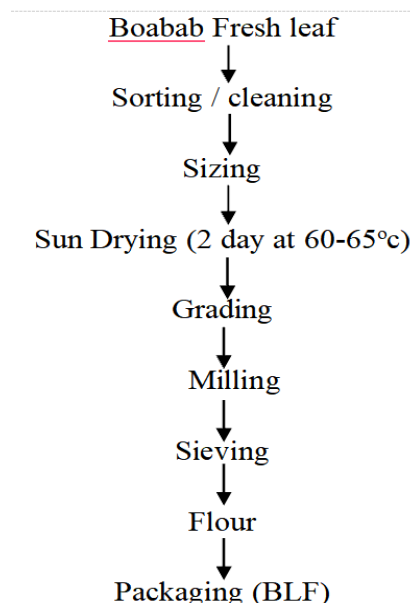


Figure 1 Flow chart for baobab leaf flour production.

Flour blending

Formulation of wheat–baobab leaf composite flour blends used for the study. Wheat flour and baobab leaf or Kuka flour were blend at different percentage levels of (0) %, (5) %, (10) %, (15) % and (20) % (w/w). Each blend was thoroughly homogenized to ensure uniform distribution of the flour components before subsequent baking. The physical, chemical and anti-oxidant analyses were conducted. See Table 1.

Table 1 Recipe for wheat Bread with Composite Boabab (*Andosonia digitata*) leaf flour

Characteristics Samples	Baobab leaf flour (g)	WF (g)	Butter (g)	Yeast(g)	Salt (g)	Sugar (g)	Water(ml)
Control A	—	500	4.0	5.0	2.0	25.0	250
Sample B.5gBLF	5.0	495	4.0	5.0	2.0	25.0	250
Sample C.10gBLF	10	490	4.0	5.0	2.0	25.0	250
Sample D.15gBLF	15	485	4.0	5.0	2.0	25.0	250
Sample E 20gBLF	20	480	4.0	5.0	2.0	25.0	250

Values are means ± standard deviation of triplicate determinations. Means values along columns followed with the same superscripts are not significantly ($p < 0.05$) different.

Keys:

A. 500% Wheat, 0% boaba leaf flour BLF

B. 495% Wheat, 5% boaba leaf flour BLF

C. 490% Wheat, 10% boaba leaf flour BLF

D. 485% Wheat, 15% boaba leaf flour BLF

E. 480% Wheat, 20% boaba leaf flour BLF

BLFB= baobab leaf flour bread

Production of bread

The straight dough method of bread making was adopted. The dry ingredients were sugar, flour ssyeast. The weight ingredient was water. Measurements were made in right quantity and then mixed with water

to make dough using a mixer. The dough were kneaded to smoothness and air space ascertain by hand elasticity test. The respective dough were pan and allowed to proof in a chamber at room temperature for 45 minutes and thereafter baked in hot oven at 230°C until golden brown colours were seen Figure 2 below and Plate 1.

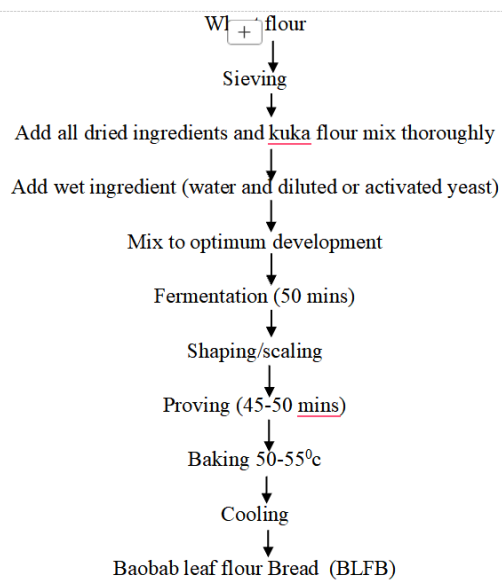


Figure 2 Flow chart for the production of baobab leaf flour bread.



Plate 1 Wheat flour and baobab flour bread at different flour inclusions.

Physical properties of the bread

Bread production and evaluation: The baobab bread was prepared using a no dough time method. Table 1, the standard procedure involved mixing the flour blends with yeast, sugar, salt, water, and fat, followed by proofing, baking, and cooling.

Determination of physical characteristic

Loaf volume: The Loaf Volume was measured using the rapeseed displacement method as described by American Association of cereal chemists.¹²

Loaf height (m): The Loaf Heights were calculated by using the rapeseed displacement apparatus that were graduated in meters.

Loaf weight (g): The method, each loaves of bread were weighted using digital weighing balance and each reading reported in grams (g). The reading were done three times to arrive at a mean value.

Elasticity (%): The elasticity method was by Dossa S, et al.,¹³ which consist of pressing the core piece of the bread for a minute and measuring the return to shape after the stop pressing.

$$\text{Elasticity (E)} = (B/A) \times 100 \quad (4)$$

Where (A—height of the core bread before pressing;

B—height of the core bread after pressing and to the initial position).

Height /diameter ratio HD: The bread height and diameter were measured using the method by Dossa S, et al.¹³ The ratio was calculated applying the formula:

$$\text{Height/diameter ratio} = H / D$$

H—maximum height of the bread sample

D—arithmetic mean of two perpendicular diameters, in centimeters of the bread.

Determination of chemical composition

Macro and micro elements

The macro-and micro elements content were examined using the atomic absorption spectroscopy (AAS) approach described by Plustea L, et al.¹⁴

Vitamin analysis

Pro -vitamin –A- determination in the bread sample

Pro-vitamin A content determination was done using the method by Association of Official Analytical Chemists¹⁵ procedures. Vitamin A in bread sample was determined using HPLC, were three grams 3g of ground sample was mixed with 5ml normal -hexane and 200ml HPLC grade water. The mixtures were homogenized using an ultra-macerator at 12.00 rpm and then centrifuged at 3500g for 30 minutes. The aqueous phases were filter through Whatman filter paper and 0.45m membrane filter sequentially, before 15 μm of supernatants was injected into HPLC system equipped with a UV detector which was set to 254 nm in absorbance mode. The vitamin standards were prepared in mobile phase. Peaks vitamins to some sample and each peak area were calculated in relation to the standard vitamin A peak.

Vitamin E analysis

Vitamin A was analyzed using the procedure outline by method of Abraham ISI.¹⁶ Bread samples were made into powder and extracted twice with 5.0 mL methanol. In case of liquid samples, samples were taken in glass tubes protected from light and saponified with addition of 1.0 mL of KOH, 50% and 2.0 mL of ethanol and incubated in a water bath at 45°C for 2 hours with intermittent mixing and purging by nitrogen gas. After incubation, 1.0 mL of water was added and extracted five times with 5.0 mL ether. The organic layers were recovered and evaporated to dryness in a water bath at 37°C under a stream of nitrogen. The residue then was re-dissolved by vortex-mixing in 5.0 mL methanol and diluted appropriately with carrier solution having methanol 5% solution containing triton X-100. Standard solutions were prepared from each sample and stock solutions of tocopheryl acetate in a 20 mL brown glass bottle; 25 mL of concentrated sulfuric acid and 10 mL of methanol were added to each bottle. The bottles were covered with aluminum foil by leaving a space for evaporation; after that the bottles were then heated between 70–80 °C in a water bath for 80–120 min by intermittent purging using nitrogen gas. During this periods, the contents of the bottles were evaporated to almost dryness. The end product of trans esterification was dissolved in 10 mL of ethanol and analyzed accordingly. The absorbance of the complex was monitored at 562 nm using a spectrophotometer (Jenway, 6505, UK) equipped with quartz (suprasil, Hellma, UK) sample holder, the output of the spectrophotometer is obtained by connecting it to a chart recorder (Kipp and Zonen BD40, Holland). The temperature of solution was also maintained using a water bath. All the solutions were mixed using sonicator and transferred in to the 3 mL quartz cuvette for reference (blank) and samples (carrying

vit. E) readings. The detector output from spectrophotometer was recorded using a chart recorder.

Determination of antioxidant DPPH property

Sample extractions: 10 grams of each powdered samples were weighed and dissolved in 100ml of organic Solvent (Ethanol) in a conical flask. The flask contents were plugged with foil paper and stirred intermittently and kept for 24 hours. After 24 hours, it was filtered through No 1 Whitman filter paper. The filtrate was collected, and the solvent was evaporated to reduce the final volume to one-fourth of the original volume, which was then kept in airtight bottles at 4 °C.¹⁷

The free radical scavenging effect of the baobab bread extract was determined using the DPPH free radical method as described by Oyesola O, et al.¹⁸ The activity of the test sample was determined by the level of reduction of DPPH radical which indicated levels of inhibition which increased with an increasing percentage of the free radical inhibition. DPPH free radical scavenging activity was expressed as the percentage of scavenging activity and studied at five different concentrations (20 µg/ml, 60 µg/ml and 90 µg/ml) respectively. The scavenging effect was calculated using the expression formula:

$$(\%) \text{ Inhibition} = \frac{\text{Absorbance}_{(\text{control})} - \text{Absorbance}_{(\text{sample})}}{\text{Absorbance}_{(\text{control})}}$$

Sensory evaluation

A panel of 20 semi-trained judges evaluated the baobab bread samples for Appearance, Taste, Aroma, Crumb texture and General acceptability. A 9-point hedonic scale was used, where 1 = dislike extremely and 9 = like extremely were used for the scoring.

Statistical analyses

Three replicates of each test samples were performed. Data were computed using SPSS (version 23.0) statistical software packages. To establish the level of significance within means, Duncan's Multiple Range test was used. Statistical significance was defined at $p < 0.05$ and the results expressed as means and standard deviations (SDS).

Results and discussion

Physical proprieties of baobab leave flour bread (BLFB)

Different samples of bread obtained were subjected to various physical analyses. These were; Height of loaves, volume of loaves, elasticity and height/diameter (H/D) ratio. The results obtained were presented in Table 2. An analysis of the data obtained from this table indicates that sample E with 20% addition of baobab leave flour (BLF) to the wheat flour (WF), bread product recorded the highest values in terms of the volume (8.3 ± 0.15 cm³/100 g) and bread loaves weight 83.0 ± 0.15 compared to the other samples under study. We also noted that the volume of the bread in sample E did not match with the sample elasticity. The elasticity of the bread decreased as baobab leaf flour addition increased however, high in the control samples which had a better physical properties in volume, elasticity and head / diameter ratio compared to the other samples under study. It was observed that as the percentage of baobab leaf flour (BLF) were increased; the physical properties of the baobab leaf flour bread (BLFB) were not drastically affected therefore, baobab leave flour did not significantly influence some physical quality of the baobab leaf flour bread (BLFB) baked product such as loaf weigh and volume. It was observed that the volume of sample C and D were not significantly higher compared to that of the control samples A of the baobab bread.

Table 2 Physical characteristic of bread with composite baobab (*Adansonia digitata*) leaf flour

Characteristics samples	Height (cm ³ /100g)	Volume (cm ³ /100g)	Loaf weight (g)	Elasticity (%)	Height /diameter ratio HD
Control A	8.0 ^a ±0.20	76 ^a ±0.0	37.0 ^a ±0.20	92.5 ^a ±0.02	45.0 ^a ±0.01
Sample B.5gBLF	6.2 ^a ±0.12	62 ^a ±0.23	34.5 ^a ±0.10	83.87 ^b ±0.02	31.0 ^a ±0.12
Sample C.10gBLF	8.0 ^b ±0.10	76 ^a ±0.54	38.5 ^a ±0.04	68.75 ^c ±0.02	42.0 ^a ±0.22
Sample D.15gBLF	8.0 ^b ±0.14	76.8 ^a ±0.90	35.5 ^a ±0.02	56.25 ^c ±0.02	44.0 ^a ±0.23
Sample E 20gBLF	8.3 ^a ±0.15	74.7 ^a ±0.32	38.0 ^a ±0.16	60.24 ^d ±0.02	43.6 ^a ±0.18

Values are means ± standard deviation of triplicate determinations. Means values along columns followed with the same superscripts are not significantly ($p < 0.05$) different.

Keys:

A. 500% Wheat, 0% baobab leave flour BLF

B. 495% Wheat, 5% baobab leave flour BLF

C. 490% Wheat, 10% baobab leave flour BLF

D. 485% Wheat, 15% baobab leave flour BLF

E. 480% Wheat, 20% baobab leave flour BLF

BLFB= baobab leaf flour bread

This observations maybe that baobab leaf flour would have added to the elasticity of the dough resulting from the characteristic pseudo plastic nature of the baobab leaf flour during hydration. The loaf volume recorded varied between 76.04 ± 0.54 and $78. \pm 0.9$ cm³/100 g. Under study. Regarding the H/D ratio, baobab leaf flour bread (BLFB) samples with different proportions of baobab leave flour recorded the following; 43 ± 0.02 , 42 ± 0.01 , and 45 ± 0.03

for sample B, C and D respectively. The values of the H/D ratio between 44 and 43, reflects that the bread is considered to be suitable in volume and height. See table 1. With the elasticity result in table 1, sample A, B and C baobab leaf flour bread were better domed. We can therefore conclude that an appropriate height, volume, loaf weight and H/D values were obtain when baobab leaf flour were used to make bread. Following the research, it was observed that bread with 10%

baobab leaf flour (BLF), sample C has the best balanced physical characteristics compared to sample A. However, from dough rheology sample B and E were pinned down as the bests.

Macro and micro elements content of bread with composite kuka (*Adansonia digitata*) leaf flour. (mg/L)

In Table 3, the content of the following macro elements are presented: calcium (Ca), magnesium (Mg), and sodium (Na), and potassium (K), along with selected microelements: iron (Fe) and zinc (Zn), in the composite bread samples. The results revealed that calcium (Ca) and potassium (K) were the most abundant macro nutrient in baobab leave flour bread BLFB Ca (30.80 ± 0.19 mg/L) and K (20.99 ± 0.95 mg/L) respectively. This result is in agreement with those results reported by Barakat H, et al.,¹⁹⁻²² where potassium (K) was the most abundant macronutrient. These values in calcium and potassium obtained under this study were above the range obtained as reported by Barakat H, et al.,¹⁹⁻²² 9.875 and 23.90 mg/g, and were also above 13.276 mg/g in Baobab seed flour and bread made from their composition.¹³ According to the results, calcium (Ca) and

potassium (K) are the abundant macro nutrients in composite flours bread samples under this study, but also increased in bread samples with increase in proportions of baba leaf flour. Furthermore, there is a significant difference in the potassium (K) content between sample B and C and also at the other end between sample A and sample E. It was observed that the higher the amount of BLF in the composite mix, the more abundant K was in the bread product. All these findings were in agreement with values reported by Barakat H, et al.^{19,23} Both Potassium (K) and sodium (Na), helps to maintain the osmotic fluid balance within the cells as well as the cellular pH, these greatly do contributes to stability of blood pressure and good nutrient for the heart muscle contractions and for the passage of messages through nerve impulses or axons.²⁴ The World Health Organization (WHO), had recommended an allowance of 35.10 mg/day intake for potassium in adults however, this differ in children population,²⁵ to help lower blood pressure which could result to cardiovascular disease, stroke, and coronary heart disease in adults. Therefore, the consumption of 100 g of BLFB bread with 15% baobab leave flour (BLFB – sample C) alone would meet above 60% of the daily potassium requirement by WHO.

Table 3 Mineral content of bread with composite baobab (*Adansonia digitata*) leaf flour

Samples	Ca mg/L	Mg mg/L	Fe mg/L	Na mg/L	Zn mg/L	K mg/L
Control A	24.65 ^a ±0.15	12.16 ^c ±0.11	0.76 ^c ±1.15	13.54 ^a ±0.95	ND	20.24 ^b ±0.75
Sample B5g	27.80 ^c ±0.05	14.96 ^a ±0.16	0.58 ^a ±2.15	13.13 ^c ±0.75	0.03 ^c ±0.19	19.32 ^c ±0.95
Sample C10g	28.32 ^b ±0.55	13.14 ^b ±0.18	0.59 ^a ±0.85	13.26 ^c ±0.05	0.03 ^c ±0.85	19.94 ^c ±0.85
Sample D15g	28.72 ^b ±0.17	13.01 ^b ±0.35	0.91 ^b ±0.94	13.47 ^a ±2.15	0.04 ^b ±0.95	21.14 ^a ±0.55
Sample E 20g	30.80 ^a ±0.19	15.93 ^a ±0.21	2.19 ^a ±0.10	13.41 ^b ±1.15	0.33 ^a ±0.45	20.99 ^b ±0.95

Values are means ± standard deviation of triplicate determinations. Means values along columns followed with the same superscripts are not significantly (p<0.05) different.

Keys:

- A. 500% Wheat, 0% baobab leave flour BLF
 - B. 495% Wheat, 5% baobab leave flour BLF
 - C. 490% Wheat, 10% baobab leave flour BLF
 - D. 485% Wheat, 15% baobab leave flour BLF
 - E. 480% Wheat, 20% baobab leave flour BLF
- BLFB= baobab leaf flour bread

Calcium is one macro-element for healthy bones and teeth. It is an important neuronal transmitters, blood coagulation, muscle contraction and relaxation as well as cell signaling, and many other functions. When in excess, it may leads to serious consequences such as nephron issues and renal impairment.²⁶

There is a significant difference in the values of calcium contents between sample E and the other breads sample under this study. There exist no significant difference between sample B and C types of bread. Calcium is more abundant in sample E (38.0 ± 0.19 mg/kg) than in the control sample A (24.65 ± 0.15 mg/L). The calcium (Ca) level in BLFB in our study is slightly above (23.703 to 37.0 mg/L) than in other studies by Barakat H, et al.¹⁹⁻²² Furthermore, 27.80 ± 0.05 mg/L, 28.32 ± 0.55 mg/L, 28.72 ± 0.17 mg/L, and 30.80 ± 0.19 mg/kg are the values for sample B, C, D and E of baobab breads obtained respectively. It can be observed that the more baobab leave flour in the inclusion, the more calcium (Ca) contents in bread products. With the same remark being made for potassium K, we can conclude that percentage substitution of WF with BLF would improve the calcium (Ca) and potassium (K) in its bread products.^{19,23} According to the

European Food Safety Authority, had recommended a daily calcium intake not exceeding 2500 mg/day for adults in which these samples under study could provide above 30%.

Magnesium (Mg), like calcium, is an essential macro-element for the functioning of about 300 metabolic reactions in the body, its contributes to nerve information passages and relaxation of muscles after contraction, fat metabolism, and for regulating diabetism and hypertension Magnesium (Mg) also contributes to the relaxation of menstrual complaints in women through its soothing or relaxing effect on the vessels.^{27,28} The Nutrition, and Allergies (NDA Panel) has established an intake for magnesium (Mg) of 350 mg/day for men and 300 mg/day for women. For children, it's varied from 170 to 300 mg/day, depending on age. Our results showed that sample A (12.16 ± 0.11 mg/L) is less in magnesium (Mg) than sample C and D (13.14 ± 0.18 mg/L and 13.09 ± 0.35 mg/L) respectively. Increase percentage addition of baobab leave flour to wheat flour for bread production results in bread with higher magnesium (Mg) contents Thus, increase in Mg content in BLF with wheat flour for bread making was obvious. Studies by Mounjouenpou P, et al.,^{23,29} reflected that the higher the

percentage of BLF, the more the Mg content in the finished bread products. It should be noted that the consumption of 100 g of BLFB of sample B and E provides 14.96 mg/L, 15.93 mg/L that is 4.274.% and 4.55% of the adequate intake recommended by the EFSA and NDA for men, 4.98% and 5.31% respectively.

Iron (Fe) deficiency causes anemia in the body now, a public health problem in both developed and developing countries.^{30,31} From our study, the (Fe) composition (0.58-2.19 mg/L) in the composite bread made from baobab leave flour samples were lower than its sodium (Na) composition (13.13 to 13.54mg/L). Each of these two elements (Fe and Na) are more abundant in BLF than in WF. Furthermore, 2.19 ± 0.03 mg/kg and 13.54 ± 0.76 mg/L are, respectively, the iron (Fe) and sodium (Na) compositions of the bread products. Also, as for the case of most of the other micro- and macronutrients, BF would have had an effect on the abundance of iron (Fe) and sodium (Na) in the compound flours and the bread obtained. These results are similar to those by Barakat H, et al.¹⁹ Except zinc (Zn), the least abundant elements in the bread product however thus increased with substitution. For BLFB, we obtained zero mg/L for sample A (0.03 ± 0.19) mg/L, for sample B (0.03 ± 0.85) mg/L, for sample C (0.04 ± 0.95) mg/L for sample D, and (0.3 ± 0.45) mg/L for sample E, respectively. These values are close to those reported by Barakat H, et al.,^{19,22,32,33} for bread composited products. It is important to note that the percentage substitution of BLF with wheat flour increase the macro and micro nutrients of baobab leaf flour bread.

Vitamin content of bread with composite baobab (*Andosonia digitata*) leaf flour (mg/100g)

The vitamin A- composition of bread samples made from wheat flour and baobab leaf flour are shown in table 3 below. As incorporation of BLF into wheat flour, the vitamin- A in the bread product significantly increased in content between (0.0402-0.435) mg/100g. This observed increase was in agreement with the report by Dossa S, et al.¹³ on the influence of baobab pulp flour supplement on quality of wheat based bread. This increase and the stability of vitamin A may be due to natural state of pro-vitamin used from baobab leave flour which might have resisted denature to heat during bread baking process. Vitamin A has been recognises worldwide as a versatile vitamin with roles springing from gene expression, vision,

maintenance of body cells, lungs, skin, immune defence, growth of bone and body development to reproductive health.^{33,34}

The deficiency of vitamin A place burden on millions of society across the globe because of its importance in our diets. The lack of vitamin A in our cell system could lead to long devastating illness like lung diseases, HIV and AIDS and others. Basic reasons why the WHO encourages its supplementations.³⁴ Vitamin A increases as percentage BLF increased in the bread product. But decreased was observed at 0% inclusion of the BLF. The highest value was observed in sample E with 0.435(mg/100g). It is therefore observed from this study that consumption of baobab bread made from baobab leave flour and wheat flour can improve especially our vision health and reproductive health.

Vitamin E called alpha tocopherol is an anti -oxidant and helps in a great deal to support the body against free radicals build ups during normal cellular activities as well as in the DNA molecules. Free radical have been known to mitigate against normal cell functioning, thus triggering myriads of metabolic diseases. The effect of vitamin E anti-oxidant effect has been felt in the lung organs and cell when blood concentration are being work such as in the erythrocytes.³³

Deficiency of vitamin E are much in developing fetus and new born because they do not have reserves of vitamin E like the adults. However, adult do have deficiency of vitamin E resulting in erythrocyte hemolysis, loss of muscle contractions and reflex as well as speech impairment.³³

From the result on this study. It has been discovered that lack of vitamin E and selenium spikes viruse load. Major sources of vitamin E are from oils and this element are natural which somehow protect the oil from peroxidation damages, however frying destroys vitamin E . The recommended DRI for women and men are 11.5 mg/day and 9.5 mg/day respectively. Vitamin E increases as percentage BLF increased in the bread product. But decreased was observed at 20% inclusion of the BLF but lower than the control with 4.001(mg/100g). The highest value was observed in sample D with 9.199 ± 0.15 (mg/100g which could give about 25% for every 100g of sample of BLFB. The consumption of bread made from baobab leaf flour can reduce neonatal death and blood hemolysis in our aging population (Table 4).

Table 4 Vitamin content of bread with composite kuka (*Andosonia digitata*) leaf flour (mg/100g)

Vitamins	SampleA.Contr	Sample B.5g	SampleB.10g	Sample B.15g	SampleB.20g
Vitamin A ($\mu\text{g/g}$)	0.0462 ± 0.15	0.08 ± 0.17	0.157 ± 0.05	0.419 ± 0.23	0.435 ± 0.15
Vitamin E (mg/100g)	4.001 ± 0.15	5.735 ± 0.15	7.101 ± 0.15	9.199 ± 0.15	4.370 ± 0.15

Values are Means $\pm$ standard deviation of triplicate determinations. Means values along rows followed with the same superscripts are not significantly ($p < 0.05$) different.

Keys:

A. 500% Wheat, 0% baobab leave flour BLF

B. 495% Wheat, 5% baobab leave flour BLF

C. 490% Wheat, 10% baobab leave flour BLF

D. 485% Wheat, 15% baobab leave flour BLF

E. 480% Wheat, 20% baobab leave flour BLF

BLFB= baobab leaf flour bread

DPPH of bread with composite baobab (*Andosonia digitata*) leaf flour

The DPPH of baobab composite wheat breads are presented in Figure 1. DPPH is a radical scavenging assay targeted at scavenging free radicals from cell or biomolecules. The antioxidant capacity of bioactive ingredient is crucial in mitigating oxidative stress, a key contributor to modern nutritional diseases. The bread DPPH increased linearly with increase in percentage increase of baobab leaf flour, except at 5g in sample B where a better DPPH activity was observed. At high concentration of 60 and 90 mg/mL, a significant increases were observed. The results further revealed that all bread samples under study significantly exhibited strong DPPH radical scavenging ability (>70%), with the 5g baobab (BLFB) sample and 20g baobab (BLFB) showing the highest DPPH activities. Baobab leaf flour bread control sample A has low DPPH antioxidant property (70-80%) compared to sample B (80-85%), sample C (80-85%), sample D (82-85%) and sample E 84-86%) respectively.

Thus, in the composite bread sample, the DPPH is increasingly higher with the proportion of BLF in them. Similar pattern of DPPH values were observed for the bread made from baobab pulp $31-66.72 \pm 0.07\%$ [13], however this report by Dossa S, et al.,¹³ is lower than the bread made from this study. Similar observations were made by Dossa S, et al.,¹⁹ they opined that anti-oxidant properties increased when higher baobab proportion were incorporation into bakery products, it can be in sighted that the substitution of BLF by WF significantly increased anti-oxidant properties of composites bread. Baobab leaf flour (BLF) is therefore an alternative ingredient for the formulation of bread products with high antioxidant activity without the use of chemical additives. The ability of 5g, BLFB sample to scavenging similar with 20g BLFB sample may be due to synergistic protein interaction with possible hydrophobic amino acids dominance in the composite bread samples.³⁵ Baobab leaf flour is therefore an alternative for the formulation of bread products with high antioxidant activity and without the use of premix with vitamin A or additives (Figure 3).

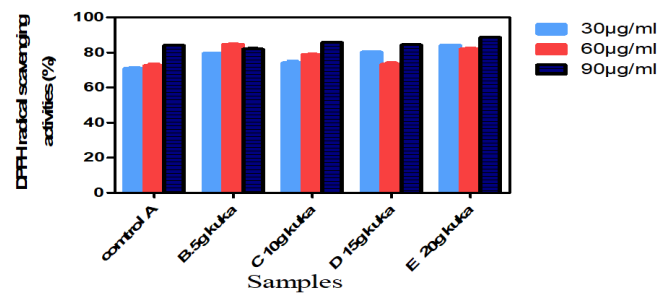


Figure 3 DPPH graph of bread with composite baobab leaf flour (*Andosonia digitata*) and wheat flour.

Sensory characteristics of bread with composite baobab (*Andosonia digitata*) leaf flour

The sensory evaluation was conducted with a panelist of 20 panelist using a nine-point hedonic scale. The mean scores for the sensory attributes (appearance, aroma, taste, crust texture and general acceptability) of the baobab leave flour bread studied (sample A control composite bread 500% wheat flour: sample B 5% BLF and 495g WF, sample C 10% BLF and 490g wheat flour; Sample D BWB2: 15% BLF and 485G wheat flour; and sample E 20% BLFr and 480g wheat flour are presented in the Table 5 below. The analysis of this figure shows that the control sample (A) obtained the best scores independently of the sensory criteria (appearance, aroma, taste, crust texture and general acceptability.²³ Among the bread samples with different proportions of baobab leaf flour (B, C) were the most appreciated by the panelist for appearance, taste and general acceptability significantly, followed by sample D, respectively. Not only was sample B taste crust texture and general acceptability the most accepted characteristics amongST the baobab composite flour samples, but it also obtained values close to those of the control sample (A). However sample B and C were very acceptable with scores between 6.45 and 5.10) for its taste, (6.25 and 5.85) for crust texture and general acceptability (6.66,5.75), which indicates that the bread product is acceptable in relation to the criteria studied.

Table 5 Sensory characteristics of bread with Composite baobab (*Andosonia digitata*) leaf flour

Characteristics/ samples	Control A	sample B 5g BLFB	Sample C 10g BLFB	Sample D 15 g BLFB	Sample E 20g kuka BLFB
Appearance	7.25 ^a ±0.12	6.20 ^b ±0.20	6.40 ^b ±2.01	5.35 ^c ±0.45	4.85 ^d ±0.01
Aroma	6.50 ^a ±2.20	5.30 ^c ±0.30	5.05 ^d ±1.03	5.95 ^b ±0.34	5.35 ^c ±0.10
Taste	6.65 ^a ±0.01	6.45 ^a ±0.43	5.10 ^c ±0.20	5.05 ^d ±0.61	5.40 ^b ±0.02
Crust texture	5.95 ^a ±2.10	6.25 ^a ±1.03	5.85 ^a ±0.50	5.70 ^b ±0.34	5.25 ^c ±0.04
General acceptability	7.45 ^a ±0.01	6.60 ^b ±2.20	5.75 ^b ±0.45	5.35 ^c ±0.90	5.25 ^d ±0.54

Values are Means ± standard deviation of triplicate determinations. Means values along row followed with the same superscripts are not significantly ($p < 0.05$) different.

Keys:

A. 500% Wheat, 0% baobab leaf flour BLF

B. 495% Wheat, 5% baobab leaf flour BLF

C. 490% Wheat, 10% baobab leaf flour BLF

D. 485% Wheat, 15% baobab leaf flour BLF

E. 480% Wheat, 20% baobab leaf flour BLF

BLFB= baobab leaf flour bread

Conclusion

This study highlighted the nutritional, phytochemical, physicochemical, rheological, and organoleptic properties of baobab leave flour in bread making. It revealed that baobab leaf flour can be a source of fortification especially of vitamin A and E for bakery products, especially bread. The partial substitution of wheat flour for baobab leaf flour has resulted in functional bread with better physical attributes, nutritional anti-oxidant and sensory properties, especially in vitamins, minerals and anti-oxidant capacity than standard bread made from 100% wheat flour. It is also observed to be an alternative to increase gluten stretching in dough, as baobab leaf flour do contain mucilaginous substance. This study also reveals an improvement in physical parameters due to the substitution of wheat flour with baobab leaf flour. Hence, with a high substitution rate above 15%, the nutritional, vitamin and anti-oxidant values increased. Therefore, with a substitution rate exceeding 10%, the bread obtained is not only rich in nutrients and bio actives properties, also presentable and well appreciated by the consumers with no negative effects on the rheological and technological characteristics.

Recommendation

From the results of this work, it is therefore recommended that baobab leaf flour can be used to improve and enrich bread with vitamin A from baobab leaf flour and it is recommended that home and commercial bread producer should harness the potential of baobab leaf flour inclusion for bread production up to 15 %. Government legislation should also encourage use of local resource ingredient compactable to improve our food products. The use baobab flour could have a huge potent in alleviating vitamin A deficiencies in our growing children.

Author contributions

Conceptualization, original draft preparation: Ogori A F

Methodology: Ogori A.F, Jackson

Formal analysis: Jackson V and Fadipe E.O

Review and editing, validation: Ogori A.F

Supervising: Ogori .A.F Fadipe E.O and Jackson V

Funding

This research work is supported by the project; IBR of the Federal University Gashua with code IBR-FUGA 043 sponsored by TETFund.

Conflicts of interest

The authors declare no conflict of interest.

References

1. Chauhan GS, Zillman RR, Eskin NAM. Dough mixing and bread making properties of quinoa-wheat flour blends. *Int J Food Sci Technol*. 1992;27(6):701–705.
2. Dhingra S, Jood S. Organoleptic and nutritional evaluation of wheat breads supplemented with soybean and barley flour. *Food Chem*. 2001;77(4):479–488.
3. Dooshima IB, Amove J, Okoh A. Quality evaluation of composite bread produced from wheat, defatted soy and banana flours. *Int J Nutr Food Sci*. 2014;3(5):471–476.
4. Fendri L, Chaari F, Maaloul M, et al. Wheat bread enrichment by pea and broad bean pods fibers: effect on dough rheology and bread quality. *LWT Food Sci Technol*. 2016;73:584–591.
5. Hernandez-Aguilar C, Dominguez-Pacheco A, Valderrama-Bravo C, et al. Photoacoustic characterization of wheat bread mixed with *Moringa oleifera*. *Curr Res Food Sci*. 2021;4:521–531.
6. Badejo AA, Nwachukwu U, Ayo-Omogie H, et al. 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. *J Food Meas Charact*. 2020;14(1):438–445.
7. Ihekoronye AI, Ngoddy PO. *Integrated Food Science and Technology*. Macmillan Publishers; 1985:296–301.
8. Saleh ASM, Zhang Q, Chen J, et al. Millet grains: nutritional quality, processing, and potential health benefits. *Compr Rev Food Sci Food Saf*. 2013;12(3):281–295.
9. Mikušová GL, Petra KM, Ernest Š, et al. Nutritional, antioxidant, and glycaemic characteristics of new functional bread. *Chem Pap*. 2013;67(3):284–291.
10. Ibidapo O, Henshaw F, Shittu T, et al. Bioactive components of malted millet (*Pennisetum glaucum*), soy residue “okara” and wheat flour and their antioxidant properties. *Int J Food Prop*. 2019;22(1):1886–1898.
11. Eke-Ejiofor J, Deedam JN, Beleya EA. Effect of addition of three leaf yam flour on dough properties and sensory qualities of bread. *J Food Res*. 2015;4(6):133.
12. American Association of Cereal Chemists. *Approved Methods of the American Association of Cereal Chemists*. 10th ed. American Association of Cereal Chemists; 2000.
13. Dossa S, Negrea M, Cocan I, et al. Nutritional, physico-chemical, phytochemical, and rheological characteristics of composite flour substituted by baobab pulp flour (*Adansonia digitata* L.) for bread making. *Foods*. 2023;12(4):2697.
14. Plustea L, Negrea M, Cocan I, et al. Lupin (*Lupinus* spp)–fortified bread: a sustainable, nutritionally, functionally, and technologically valuable solution for bakery. *Foods*. 2022;11(14):2067.
15. Association of Official Analytical Chemists. *Official Methods of Analysis*. 19th ed. Association of Official Analytical Chemists; 2012.
16. Abraham ISI, Abu JO, Dick IG. Effect of *Moringa oleifera* leaf powder supplementation on some quality characteristics of wheat bread. *Food Nutr Sci*. 2013;4(3):270–275.
17. Dziki D, Różyło R, Gawlik-Dziki U, et al. Current trends in the enhancement of antioxidant activity of wheat bread by the addition of plant materials rich in phenolic compounds. *Trends Food Sci Technol*. 2014;40(1):48–61.
18. Oyesola O, Oshodi T, Ogundele O, et al. Toxicity screening and in vitro antioxidant activities of aqueous extracts of *Morinda lucida* and *Saccharum officinarum* leaves. *Biochem*. 2013;25(2):72–78.
19. Barakat H. Nutritional and rheological characteristics of composite flour substituted with baobab (*Adansonia digitata* L.) pulp flour for cake manufacturing and organoleptic properties of their prepared cakes. *Foods*. 2021;10(4):716.
20. PhytoTrade. *Nutritional Evaluation of Baobab Dried Fruit Pulp and Its Potential Health Benefits: Leatherhead Food Research for Africa Summary Report*. 2009. Accessed May 10, 2023. [URL as provided]
21. Stadlmayr B, Wanangwe J, Waruhiu CG, et al. Nutritional composition of baobab (*Adansonia digitata* L.) fruit pulp sampled at different geographical locations in Kenya. *J Food Compos Anal*. 2020;94:103617.
22. Osman M. Chemical and nutrient analysis of baobab (*Adansonia digitata*) fruit and seed protein solubility. *Plant Foods Hum Nutr*. 2004;59:29–33.
23. Mounjouenpou P, Ngono Eyenga SNN, Kamsu EJ, et al. Effect of fortification with baobab (*Adansonia digitata* L.) pulp flour on sensorial acceptability and nutrient composition of rice cookies. *Sci Afr*. 2018;1:e00002.

24. Vidal. Food supplement: potassium. 2014. Accessed April 18, 2023.
25. World Health Organization. *Guidelines: Potassium Intake in Adults and Children: Summary of Guidance*. WHO/NMH/NHD/13.1. World Health Organization; 2013. Accessed May 2, 2023.
26. EFSA Panel on Dietetic Products, Nutrition and Allergies. Scientific opinion on the tolerable upper intake level of calcium. *EFSA J*. 2012;10(7):2814.
27. PassportSant . Magnesium. 2014. Accessed April 18, 2023.
28. EFSA Panel on Dietetic Products, Nutrition and Allergies. Scientific opinion on dietary reference values for magnesium. *EFSA J*. 2015;13(7):4186.
29. Frances SS, Ellis W. *Nutrition: Concepts and Controversies*. 10th ed. Thomas Higher Education; 2016.
30. World Health Organization, Food and Agriculture Organization. *Directives sur l'enrichissement des aliments en micronutriments*. World Health Organization/Food and Agriculture Organization; 2011. Accessed May 2, 2023.
31. ANSES. *Le Sel ou Chlorure de Sodium*. ANSES; 2022.
32. Lockett C, Calvert C, Grivetti L. Energy and micronutrient composition of dietary and medicinal wild plants consumed during drought: study of rural Fulani, northeastern Nigeria. *Int J Food Sci Nutr*. 2000;51(3):195–208.
33. Frances SS, Ellis W. *Nutrition: Concepts and Controversies*. 10th ed. Thomas Higher Education; 2016.
34. National Study Commission on Dietary Reference Intakes. *Food and Nutrition: Dietary Reference Intakes for Macronutrients*. National Academy Press; 2002.
35. Pownall TL, Udenigwe CC, Aluko RE. Amino acid composition and antioxidant properties of pea seed (*Pisum sativum* L.) enzymatic protein hydrolysate fractions. *J Agric Food Chem*. 2010;58(8):4712–4718.