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ANTIOXIDANT PROPERTIES, ANTIOXIDANT MINERALS AND VITAMINS COMPOSITION OF SORGHUM-CARROT AGIDI ENRICHED WITH *TERMINALIA CATAPPIA* L SEED FLOUR

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ABSTRACT

Agidi is a thick gel-like fermented food made from cereal pastes; it serves as a major complementary food for infants in many parts of West Africa. The aim of this work was to investigate the nutritional and antioxidant properties of sorghum-carrot agidi enriched with Terminalia catappia seed flours. The composition of minerals (Cu, Zn, Fe, Mn) and Vitamins (A, B_1, B_2, B_{12}, D and E) in the sorghum based agidi samples were analyzed using standard protocol. The antioxidant properties of the agidi samples were determined by Ferric Reducing Properties (FRAP), Free Radical Scavenging Ability (DPPH), Hydroxyl Radical Scavenging Ability (OH) and Fe^{2+} chelating (Fe^{2+}). The results showed that iron content of the agidi samples ranged from 0.754±0.066 to 1.363±0.069ppm while the Zinc content of the samples were between 0.756±0.030 to 1.96±0.015 ppm. The Vitamin A content of the Agidi samples was between 21.77 – 41.78 mcg RAE while that of Vitamins $B_1$and B_2 were 0.0773 – 1.39µg/g. The enriched Agidi sample J_5 had the highest values of Vitamins D and E, 1.20 and 1.35µg/g respectively. The antioxidant properties determined showed FRAP values ranged from 3.265±0.026 µg/g to 26.460±0.026 µg/g, DPPH values were between 78.976±0.168 to 87.976±0.168% and sample J_4 had the highest Fe^{2+} chelation values 29.545±0.267%. The vitamins and minerals composition of the sorghum agidi samples were enhanced significantly ($P<0.05$) by enrichment with carrot and tropical almond seed flours and this was reciprocated in their antioxidant potencies.

Keywords: Antioxidant, minerals, vitamins, agidi, almond

INTRODUCTION

Antioxidant is a molecule that inhibits the oxidation of other molecules (Alenisan *et al*., 2017). Oxidation is any chemical reaction that transfers electron or hydrogen from substances to an oxidizing agent (Vishnoi, *et al.,* 2018). Oxidation reactions can produce free radicals and these radicals can initiate chain reactions. When the chain reactions occur in a cell, it can cause alteration of gene (Mutation and cancer) or death to the cell (Ng *et al*., 2022). Antioxidants terminate these chain reactions by removing free radical intermediates and inhibit other oxidative reactions. They do so by being oxidized themselves (Vishnoi, Badla and Kant 2018). Antioxidants are classified based on their origin into Primary or Natural antioxidants and Secondary or synthetic antioxidants. Primary antioxidants are chain breaking antioxidants that convert lipid radicals into stable molecules, examples are antioxidants minerals, vitamins and phytochemicals. While secondary antioxidants are phenolic compounds that capture free radicals and stop chain reactions, they are often used as preservatives to extend food shelf life in the food industry; examples of secondary antioxidants are Butylated Hydroxyanisole (BHA) and Butylated hydroxytoluene (BHT) (Vishnoi, Badla and Kant 2018). The presence of antioxidants in food can significantly decrease or prevent the adverse effects of reactive oxygen and nitrogen species that can affect the normal physiological functions in humans (Kebede and Admassu 2019). Antioxidants play major roles in the defense mechanisms of organisms against the pathologies associated with free radicals in the body. Thus, the intake of natural antioxidants is involved in the prevention and management of degenerative diseases caused by oxidative stress such as atherosclerosis, cancer and Parkinson's diseases (Bernatoniene and Kopustinskiene 2018). Cancer is one of the major causes of death globally and is of great concern to stakeholders in the health sector because of the difficulties associated with its treatment and management (Cortes *et al.*, 2020). Nigeria has its fair share in cancer cases as the number of diagnosed new cases keep on increasing on a daily basis (Olabumuyi *et al.*, 2020). Humans are exposed to carcinogenic substances daily from the environment, foods, creams, soaps and drugs (Okoro *et al.*, 2017). The best approach to diseases like cancer is prevention. It is therefore necessary to reduce these risk factors and expel or destroy carcinogenic free radicals through the consumption of foods with high antioxidant potentials.

Agidi is a thick gel-like local fermented food made from cereal pastes such as maize, sorghum and millet. In many parts of West Africa, it serves as a major complementary food for infants (Adegbehingbe, *et al.,* 2019). *Agidi a*nd *ogi* are consumed with other Nigerian meals like *akara, moi-moi,* and pepper soups which are commonly consumed as breakfast and dinner in Nigeria (Kolawole *et al.,* 2020)

Considering the importance of *agidi* in Nigerian traditional consumed diets, it is therefore necessary to produce *agidi* that contain minerals, vitamins and other antioxidants as part of the preventive measures for degenerative diseases like cancer and atherosclerosis among *agidi* consuming population of Nigeria. This research, therefore aimed to produce sorghum-carrot *agidi* enriched with defatted and non-defatted tropical almond seed flours and to determine the antioxidant properties, antioxidant minerals and vitamins composition of the *agidi* samples.

MATERIALS AND METHODS

Sample Collection and preparation

Sorghum (*Sorghum bicolor*) and carrot (*Daucus carota*) used for this research were bought from Wadata Market, and the fruits of tropical almond (*Terminalia catappa* L) used were sourced from Law Park, Benue State University, Makurdi, Nigeria. Food grade reagents and other facilities were obtained from the Department of Chemistry, Benue State University Makurdi.

The plant materials were authenticated by specialists in the Department of Botany, University of Agriculture Makurdi. Sorghum flour and Fermented sorghum flour were prepared using the method described by Akinola, Olarewaju and Enujuigha (2015) with slight modification little modification as shown in Figure 1 and 2

The flow chart for carrot (*Daucus carota* (L.)) flour production is provided in Figure 3. The carrot flour was prepared as described by Humaira *et al*. (2013) with little modifications.

The flow chart for the production of tropical almond seed flour is shown in Figure 4 the fruits were sun dried and manually cracked to get the nuts in their whole form. Debris and

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other foreign matters were sorted out of the nuts. The kernels were then oven dried at 60°C for 6hr after which the dried kernels were milled using an electric blender. The milled almond seed kernels were divided into two portions. One of the portions was further dried in the oven at 60°C for 4hr, milled again and sieved using kitchen metal mesh sieve to obtain the non-defatted almond seed flour.

The second portion of the milled almond seed kernel was defatted using n-hexane in a Soxhlet apparatus. The n-hexane was recovered from the extracted oil using a Rotary evaporator. The defatted almond seed kernel was then oven dried at 60°C for 4hr after which it was milled using an electric blender and sieved.

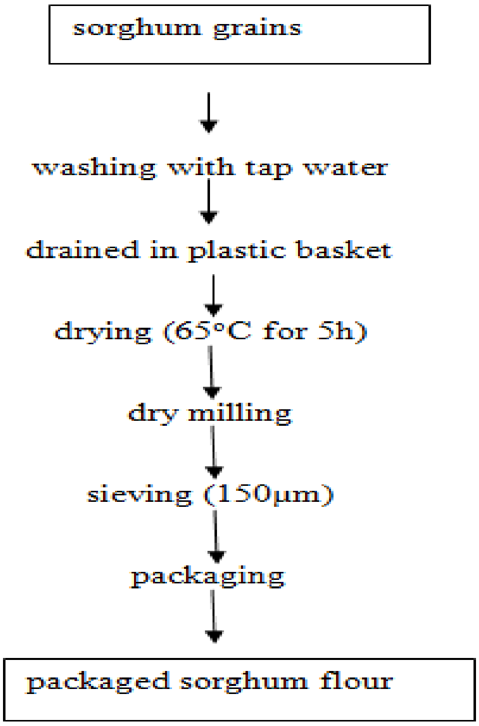

Figure 1: Flow chart for the production of non-fermented sorghum flour

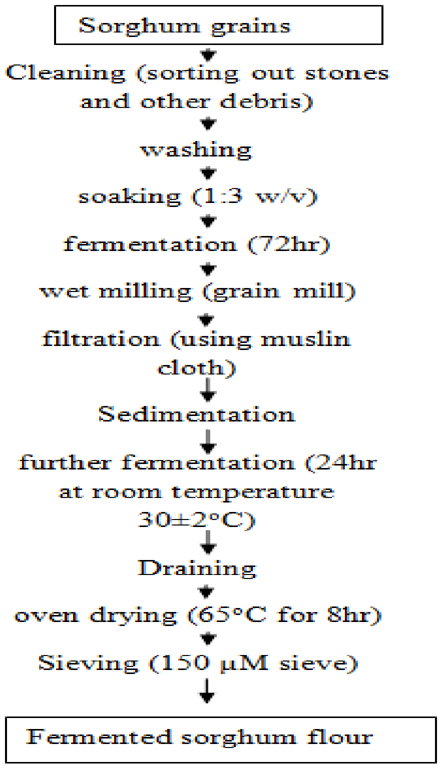

Figure 2: Flow chart for the production of fermented sorghum flour

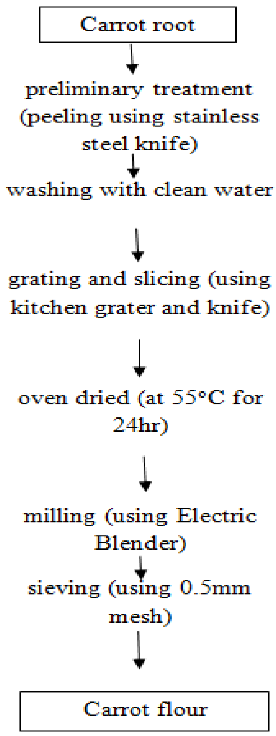

Figure 3: Flow chart for the production of carrot flour

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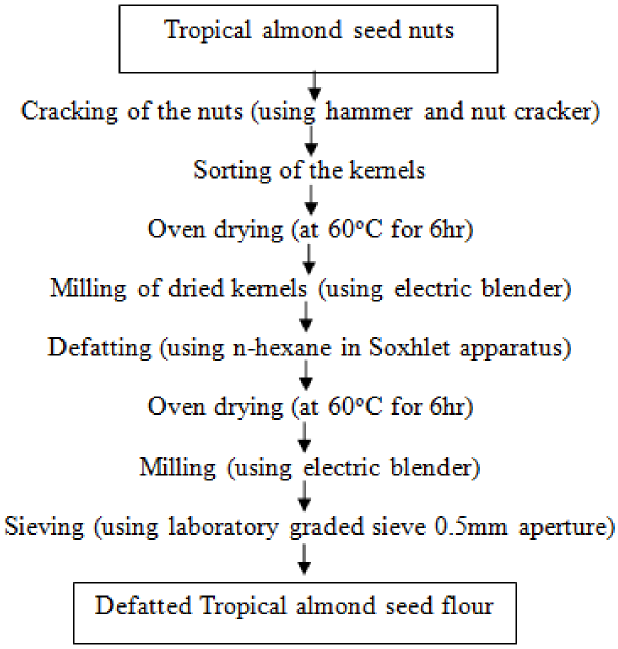

Figure 4: Flow chart for tropical almond seed flour production

Product formulation

Five products were formulated as shown in Table 1 the products comprised J_3: 95% Sorghum flour + 5% Carrot flour; J_4: fermented sorghum flour + Carrot flour + non-defatted almond seed flour; J_5: Sorghum flour + Carrot flour + Defatted almond seed flour. J_4 and J_5 were formulated to give 16g protein/100g as recommended by the Protein Advisory Group (PAG, 1971). The amounts of the materials required to meet the protein target were achieved through material balancing from their respective protein contents, using the method described by Chiba (2009).

Table 1: Formulation of *agidi* samples from sorghum, carrot and tropical almond seed flours

	Ingredients mix (g/100g)				
Sample	Non fermented sorghum flour (g)	Fermented sorghum flour (g)	Fermented sorghum-carrot flour (95:5) (g)	Non-defatted tropical almond seed flour (g)	Defatted tropical almond seed flour (g)
J_1	100	-	-	-	-
J_2	-	100	-	-	-
J_3	-	-	100	-	-
J_4	-	-	80	20	-
J_5	-	-	89	-	11

J_1 = Sorghum flour, J_2 = Sorghum flour, J_3 = Sorghum flour + carrot flours J_4= Sorghum flour + carrot + defatted almond seed flours, J_5= Sorghum flour + carrot + non-defatted almond flour

Preparation of *Agidi*

Agidi was produced from fermented sorghum flour J_2 (control), and each of the three blends, J_3 (95:5 fermented sorghum and carrot) J_4 (J_3 + defatted Tropical almond seed flour) and J_5 (J_3 + non-defatted Tropical almond seed flour) using the method of Akpapunam *et al*. (1997). The *agidi* samples were coded with letters A, B, C and D respectively.

Mineral analysis

Mineral determination was carried out by acid digestion according to AOAC (2005). Ash obtained after incineration at 500°C was dissolved in aqua regia (10mL nitric acid + 30mL HCL) solution and boiled for 30min. The mixture was filtered into 100mL volumetric flask and made up to the mark with distilled water. The mineral concentrations of Iron (Fe), Zinc (Zn), Cupper (Cu) and Manganese (Mn) were determined using the Atomic Absorption Spectrophotometer (AAS Buck Scientific 210 VGP, FP 902).

Determination of Vitamin composition of the *agidi*

The vitamins A, B_1, B_2, B_{12}, D and E contents of the Agidi samples were determined using standard methods as described by AOAC (2006).

Determination of antioxidant properties of the *agidi* samples

The Ferric reducing property (FRAP) of the *agidi* samples was determined following the method described by Pulido *et al*. (2000). The free radical scavenging ability of the *agidi* samples against DPPH (1,1-diphenyl-2-picrylhydrazyl) was determined using the method described by Gyamfi *et al*. (1999). The ability of the *agidi* to chelate Fe^{2+} was determined using a modified method of Minotti & Aust (1987) by Puntel *et al* (2005). The OH Radical Scavenging Ability of the *agidi samples* to prevent Fe^{2+}/H_2O_2 induced decomposition of deoxyribose was carried out using the method of Halliwell and Gutteridge (1981).

Statistical Analysis

Data were statistically analyzed with one way Analysis of Variance (ANOVA) to determine significant difference at 5% level of acceptance using SPSS version 20. All data were expressed as mean ± Standard deviation.

RESULTS AND DISCUSSIONS

Results

The results of antioxidant minerals composition of sorghum-carrot based *agidi* enriched with defatted and non-defatted tropical almond seed flour are shown in Table 2. The Iron (Fe) content of the *agidi* samples ranged from 0.754±0.066 to 1.363±0.069ppm and Zinc (Zn) content of the *agidi* samples ranged from 0.756±0.030 to 1.196±0.015 ppm. There was significant difference ($p<0.05$) in iron and zinc content between sorghum-carrot based *agidi* enriched with tropical almond seed flour (J_4 and J_5) and the non-enriched samples (J_1, J_2, and J_3). The copper (Cu) content of the *agidi* samples ranged from 0.499±0.012 to 0.712±0.024 ppm and The Manganese (Mn) content of the agidi samples ranged from 0.137±0.006 to 0.476±0.006 ppm. There was significant difference ($p<0.05$) in the copper and manganese content of sorghum-carrot based *agidi* enriched with defatted tropical almond seed flour (J_4) and the none-enriched ones (J_1, J_2, and J_3). *Agidi* sample J_4 had the highest amount of Copper (0.712±0.024 ppm) and manganese (0.476±0.006 ppm).

The Vitamin contents of the *agidi* samples are shown in figure 1a-d. The Vitamin A contents ranged from 435.300 – 835.95 I.U., Vitamin B_1 (thiamine) content of the *agidi* samples

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ranged from 0.729 – 1.39µg/g. The agidi sample enriched with defatted almond seed flour (J_5) had the highest value while J_3 had the lowest value. Vitamin B_2 (Riboflavin) contents of the *agidi* samples ranged from 0.0773 – 0.676 µg/g. Vitamin B_{12} (Cobalamins) contents of the *agidi* samples ranged from 387.400 – 988.907µg/g. Vitamin D content of the samples ranged from 0.013 – 1.200µg/g. The vitamin E content of the samples ranged from 0.101 – 1.353µg/g. *Agidi* sample enriched with defatted almond seed flour (J_5) had the highest value of Vitamin E while J_3 had the lowest value.

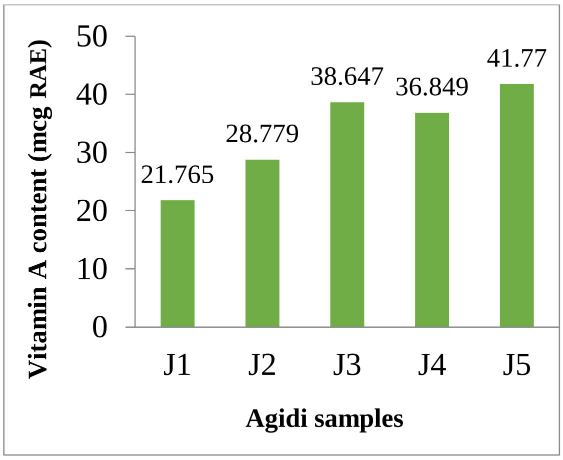
The result of antioxidant properties of the *agidi* samples are shown in Table 3. The FRAP values ranged from 3.265±0.026 µg/g to 26.460±0.026 µg/g). There was a significant difference ($P<0.05$) between the enriched and the non-enriched *agidies.* The DPPH values of the sorghum samples ranged from 78.976±0.168 to 87.976±0.168%, sample J_5 had the highest value. The OH^- radical scavenging properties of the *agidi* samples ranged from 23.981±0.319 to 65.158±0.319% and sample J_2 had the highest value. Ferric chelating ability of the samples ranged from 0.757±0.267 to 29.545±0.267%, sample J_4 had the highest value of Fe^{2+} chelating ability

Table 2: Effects of fermentation and addition of tropical almond seed flour on the mineral composition of Sorghum carrot based *agidi*

Minerals	Agidi samples				
	J_1	J_2	J_3	J_4	J_5
Fe (ppm)	$0.845±0.012^{cd}$	$0.975±0.051^{c}$	$0.754±0.066^{d}$	$1.363±0.069^{a}$	$1.139±0.006^{b}$
Zn (ppm)	$0.756±0.030^{c}$	$0.972±0.055^{b}$	$0.941±0.005^{b}$	$1.196±0.015^{a}$	$1.006±0.006^{b}$
Cu (ppm)	$0.515±0.007^{c,d}$	$0.548±0.002^{b,c}$	$0.499±0.012^{d}$	$0.712±0.024^{a}$	$0.572±0.004^{b}$
Mn (ppm)	$0.137±0.006^{d}$	$0.279±0.006^{c}$	$0.362±0.014^{b}$	$0.476±0.006^{a}$	$0.382±0.026^{b}$

Values are Means ± Standard deviation of two replications. Means within a row with the same superscript across columns were not significantly different ($p>0.05$) J_1 = Sorghum flour, J_2 = Sorghum *agidi*, J_3 = Sorghum *agidi* + carrot flours J_4= Sorghum *agidi* + carrot + defatted almond seed flours, J_5= Sorghum *agidi* + carrot + non-defatted almond flour

a



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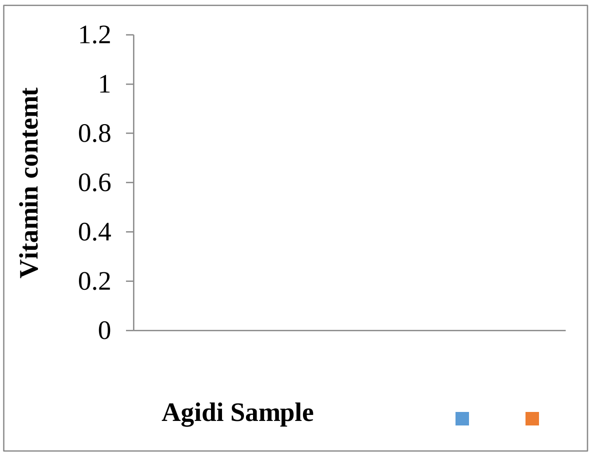

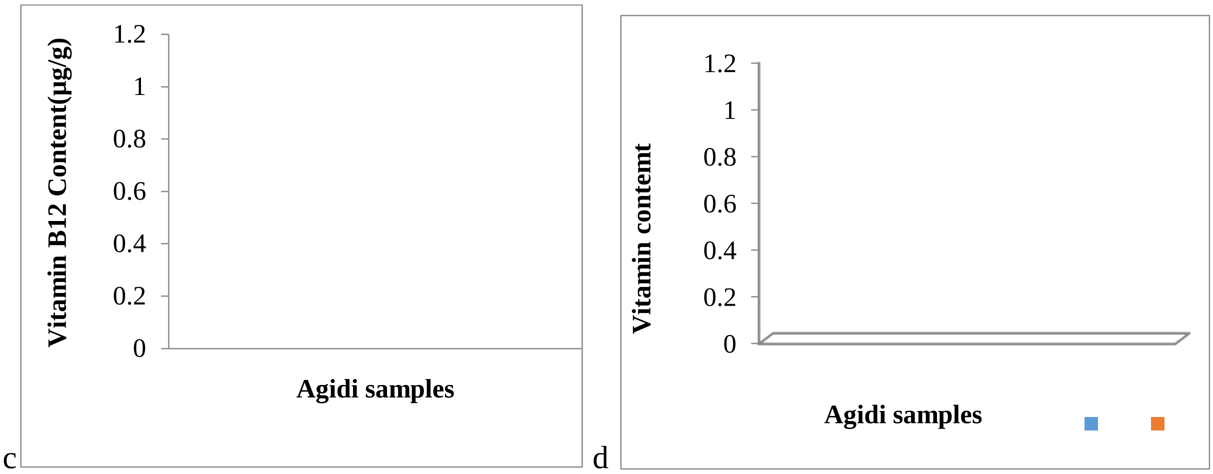

Figure 1: Antioxidant Vitamins composition of Sorghum carrot based *agidi* enriched with tropical almond seed flours (a) Vitamin A **(b)** Vitamins B_1 and B_2 **(c)** Vitamin B_{12} **(d)** Vitamins D and E

Key J_1 = Sorghum flour, J_2 = Sorghum *agidi*, J_3 = Sorghum *agidi* + carrot flours J_4= Sorghum *agidi* + carrot + defatted almond seed flours, J_5= Sorghum *agidi* + carrot + non-defatted almond flour

Table 3: The antioxidant properties of the instant sorghum-carrot based *agidi* enriched with tropical almond seed flour

	FRAP (µg/g)	DPPH (%)	OH^- radical (%)	Fe^{2+} chelation (%)
J_1	28.460 ± 0.026^e	80.238 ± 0.168^b	23.981 ± 0.319^a	7.954 ± 0.267^b
J_2	3.265 ± 0.026^a	82.381 ± 0.168^d	65.158 ± 0.319^d	1.136 ± 0.267^a
J_3	22.213 ± 0.026^d	78.928 ± 0.168^a	60.859 ± 0.319^d	0.757 ± 0.267^a
J_4	22.119 ± 0.026^c	81.071 ± 0.168^c	46.153 ± 0.319^c	29.545 ± 0.267^c
J_5	20.590 ± 0.026^b	87.976 ± 0.168^e	30.543 ± 0.319^b	29.356 ± 0.267^c

Values are Means ± Standard deviation of two replications. Means within a column with the same superscript across columns were not significantly different ($p>0.05$)

J_1 = Sorghum flour, J_2 = Sorghum *agidi*, J_3 = Sorghum *agidi* + carrot flours J_4= Sorghum *agidi* + carrot + defatted almond seed flours, J_5= Sorghum *agidi* + carrot + non-defatted almond flour

DISCUSSION

The iron content of the enriched *agidi* samples ranged from 0.754-1.363 ppm. It was observed that the enrichment of sorghum *agidi* with carrot and tropical almond (*Terminalia catappa*) seed flours significantly increased ($p<0.05$) the concentration of iron in the *agidi*. This finding agreed with the report of Kolawole *et al*. (2020). They reported significant increased in iron concentration of *agidi* enriched with orange-fleshed sweet potato and soybean. The sorghum carrot based *agidi* enriched with the defatted *Terminalia catappa* seed flour (J_5) had the highest iron content of 1.363ppm. This increment in iron concentration of the sorghum *agidi* enriched with tropical almond flour could be traced to the inherent iron concentration of *Terminalia*

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catappa. Iron is needed for proper growth of infants and formation of healthy blood cells as well as prevention of iron anemia (Burke *et al*., 2014; Oroniran *et al.,* 2016). It is a vital component of hemoglobin, the part of red blood cells that carries oxygen through the body (Burke *et al*., 2014). Iron intake is inadequate during 6 months to two years of age because of low iron content of breast milk and rapid growth rate in infants and children. Children need iron to meet the requirement for red blood cells synthesis and growth (Oroniran *et al.,* 2016). It was observed that enrichment of sorghum-carrot agidi with tropical almond seed flour significantly (p<0.05) increased the zinc and manganese contents of the *agidi* sample. This finding is in accordance with the findings of Kolawole *et al*. (2020). They reported similar increment in mineral composition of enriched Agidi. These increments of some minerals could be from the cellular metabolism of the microorganisms responsible for fermentation and from the enrichment with tropical almond seed flour. This agreed with the findings of previous studies on food supplementation and fortification (Oyarekhua 2013; Kolawole *et al*., 2020) Zinc is needed for the body's defensive (immune) system to properly work. It plays a role in cell division, cell growth, wound healing and breakdown of carbohydrates. Zinc is also needed for the sense of smell and taste. During pregnancy, infancy and childhood the body needs zinc to grow and develop properly. Zinc is necessary for protein and blood formation to maintain Vitamin A concentration in plasma (Oyarekhua 2013). Zinc is a limiting factor in the growth of severely malnourished infants in developing countries due to diets low in phytates. Deficiency of zinc may negatively affect the behavioral development and growth of infants (Oyarekhua 2013). Zinc also acts as cofactor and coenzymes that play key roles in reproduction and digestion as well as absorption of nutrients in the digestive tracts (Oyarekhua 2013).

However, it was observed that the addition of carrot flour significantly decreased (p<0.05) the concentration of copper in the *agidi* samples from 0.548ppm to 0.499pmm similar findings were also reported in previous studies (Sule *et al*., 2019). They reported that the addition of carrot significantly reduced the concentration of copper in wheat pasta. Copper is needed in a very small amount in the body but it is an essential cofactor for several enzymes involved in energy production, iron metabolism, and neurotransmitter synthesis. Copper deficiency is uncommon in humans based on samples in animals and humans; the effects of copper deficiency include anemia, hypopigmentation, hypercholesterolemia, connective tissue disorders, osteoporosis and other bone defects (Prohaska, 2014).

The Vitamin content of the *agidi* samples as shown in Figure 1a, The Vitamin A contents ranged from 435.300 – 835.95 I.U., it was observed that enrichment of sorghum Agidi with carrot and tropical almond seed flours significantly increased (p<0.05) the concentration of vitamin A. this findings agreed with work of previous studies (Oyarekhua 2013; Kolawole *et al*., 2020). The sorghum carrot based *agid*i fortified with defatted almond seed flour (J5) had the highest value and it was not unexpected as carrot and almond are known for their high β-carotene content, the precursor of Vitamin A (Humaira *et al*., 2013; Sule *et al.,* 2019). It was based on this fact that carrot flour was used to fortify the sorghum agidi. Vitamin A is one of the antioxidant vitamins that preserve the integrity of epithelial cells; formation of rhodopsin for vision in dim light; necessary for wound healing, growth, and normal immune function (Oroniran *et al*., 2016). Vitamin A also supports cell growth and differentiation, playing a critical role in the normal formation and maintenance of the hearts, lungs, kidneys and other delicate organs in the body. This fat soluble vitamin is also important in the regulation of nervous and endocrine systems. Vitamin A is often considered a singular nutrient; it's really the name for a group of fat-soluble compounds, including retinol, retinol and retinyl esters. There are two forms of vitamin A found in food, preformed vitamin A which comprises Retinol and Retinyl esters, they occur exclusively in animal products such as dairy, liver and fish. Provitamin A, also known as carotenoids are abundant in plant food like fruits, vegetables and oils. To use them the body must convert both forms of Vitamin A to retinal and retinoic acid, the active forms of the vitamin, because vitamin A is fat soluble, its stored in the body tissue for later use most of the vitamin A in the body are kept in the liver in the form of retinyl esters. All *the agidi* samples contained sufficient amounts of this vitamin to meet the minimum daily requirements as recommended by FOA (2001). It was observed that fermentation increased the amount of vitamin A in sorghum based *agidi* from 435.300unit/g to772.930 unit/g this increment could be as a result of microbial activities during fermentation and from *Terminalia catappa* seed flours. This result agreed with the findings of Kolawole *et al*. (2020) that reported similar increment in vitamin A content of maize agidi enriched with orange-potato and soya flours.

Vitamin B1 (thiamine) content of the agidi samples ranged from 0.729 – 1.39µg/g with *agidi* fortified with defatted almond seed flour (J5) having the highest value while J3 had the lowest value. It was observed that fermentation and fortification with almond seed flours significantly ($p<0.05$) increased the concentration of vitamin B1 in the *agidi* samples. Vitamin B1 is found in many foods including yeast, cereal grains, beans, nuts and meat (Hrubša *et al*., 2022). Vitamin B1 is one of the vitamin B complex vitamins that are useful in transketolation, essential in neutral transmission and in the maintenance of normal appetite and healthy mental attitude.

Vitamin B2 (Riboflavin) content of the *agidi* samples ranged from 0.0773 – 0.676 µg/g Similar trends as seen in Vitamin B1 content was observed with *agidi* fortified with defatted almond seed flour (J5) having the highest value. However it was observed that the Vitamin B2 content of fermented sorghum flour (J2) 0.585±0.002µg/g was significantly ($p<0.05$) higher than that of the non-fermented sorghum flour (J1) 0.0730±0.002µg/g. This may be due to the fact that these Vitamins are usually synthesized by bacteria during natural fermentation of cereals such as rice, millet and sorghum (Oroniran *et al*., 2016). Vitamin B2 helps with energy production in the body, nervous system function, and protein metabolism. Riboflavin (Vitamin B2) is always in connection with flavoproteins and essential in metabolism regulation.

Vitamin B12 (Cobalamins) content of the *agidi* samples ranged from 387.400 – 988.907µg/g with the *agidi* produced from non-fermented sorghum (J1) having the highest value while sorghum carrot based agidi fortified with defatted almond seed flour (J5) had the lowest value. It was observed that defatting of almond seed and fermentation of sorghum significantly ($p<0.05$) reduced vitamin B12 concentration of the instant *agidi* samples. This reduction of vitamin B12 in the fermented and almond fortified *agidi* could be as a result of leaching of nutrients during the processes of defatting and fermentation.

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Vitamin B12 (Cobalamins) exists in several forms and contains the mineral cobalt; methylcobalamin and 5-deoxyadenosylcobalamin are the forms of vitamin B12 that are active in human metabolism (Arslan *et al*., 2013). Vitamin B12 is required for proper Red blood cell formation, neurological function, and DNA synthesis. Vitamin B12 functions as a cofactor for methionine synthase and L-methylmalonyl-Co-A mutase. Methionine synthase catalyzes the conversion of homocysteine to methionine. Methionine is required for the formation of S-adenosylmethionine,a universal methyl donor for almost 100 different substrates, including DNA, RNA, hormones, proteins, and Lipids.

The Vitamin D content of the samples ranged from 0.013 – 1.200µg/g. It was observed that fermentation and enrichment with tropical almond seed flour significantly increased the vitamin D composition of sorghum-carrot *agidi*, this increment from 0.013µg to 0.928µg is as a result of microbial metabolism during fermentation and the inherent vitamin content of *Terminalia catappa* Vitamin D is necessary for bone formation and strengthening of weak bones.

The Vitamin E content of the samples ranged from 0.101 – 1.353µg/g with *agidi* fortified with defatted almond seed flour (J5) having the highest value while J3 had the lowest value. It was observed that fermentation and enrichment with *Terminalia catappa* seed flours significantly ($p<0.05$) increased the concentration of vitamin E in the *agidi* samples. This increment might be from microbial metabolites. Vitamin E (Tocopherol) is another antioxidant vitamin known for fertility and reproductive health.

It was observed that fermentation of sorghum for *agidi* production increased the contents of all the minerals and vitamins tested significantly ($P<0.05$) except for vitamin B_{12}. This is because most microorganisms responsible for fermentation cannot synthesize Vitamin B_{12}(Yun *et al*., 2020), so they absorbed it from the substrates. It was also observed that defatting of tropical almond seed flours significantly ($P<0.05$) reduced the amount of all the minerals and vitamins tested for in the almond enriched *agidies* except for Vitamin B_{12}. This is because most of the antioxidant minerals and vitamins are fat soluble; hence they leached away during the processes of defatting.

This study showed that enrichment of sorghum *agidi* with tropical almond seed flour significantly increased ($P<0.05$) the antioxidant potency of the sorghum *agidi*. This study showed that fermentation significantly ($P<0.05$) increased the Hydroxyl radical (OH^-) scavenging properties; however, enrichment with tropical almond seed flours significantly ($P<0.05$) reduced the hydroxyl radical scavenging ability of the *agidi* samples. The study also showed that fermentation significantly ($P<0.05$) reduced the ferric (Fe^{2+}) chelating activity of the *agidi* samples, however, enrichment with tropical almond seed flour significantly ($P<0.05$) increased the Fe^{2+} chelation of the *agidies.*

The enrichment of sorghum *agidi* with tropical almond seed flours significantly increased FRAP values as compared to the control J_2 (3.265±0.026 µg/g) to 22.119±0.026 µg/g. Sorghum, inherently has high DPPH potency as seen in this study and agreed with the work reported by Mawouma *et al*. (2022), they reported similar DPPH (%) results for sorghum varieties which ranged from 64.09±3.29 to 93.14±4.46%. However, it was observed that fermentation of sorghum to produce *agidi* (J_2) lowered the DPPH properties of sample J_2 (82.381±0.168%). This reduction in DPPH values was complemented in the enriched sorghum *agidi* with tropical almond seed flour. The findings of this research agreed with the report of Odunlade *et al*. (2016) they reported that the inclusion of cocoa powder to sorghum *ogi* significantly enhanced the functional and antioxidants properties of sorghum *ogi*

CONCLUSION

The data obtained from the minerals, vitamins and antioxidant properties of sorghum-carrot *agidi* enriched with tropical almond seed flour show that *Terminalia catappa* seed flour contains considerable amount of minerals and vitamins that increased the antioxidant potency of sorghum *agidi* for the wellbeing of *agidi* consumers against degenerative diseases such cancer and atherosclerosis. We therefore recommended the use of *Terminalia catappa* seed flour for the enrichment of sorghum based diets as source of minerals, vitamins and antioxidants.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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