



Development and quality evaluation of high-fibre bread bars from whole wheat and African breadfruit (*Treculia africana*) seed flour blends

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Abstract

African breadfruit, an indigenous edible seed and wheat were processed separately into whole flours, for development of bread bars. Whole wheat and African breadfruit flours were blended in the ratio of 100:0 = A, 95:5 = B, 90:10 = C, 85:15 = D, 80:20 = E, 75:25 = F and 0:100 = G respectively. Functional properties of the flour blends were evaluated. Proximate composition, physical properties, Anti-nutrient content and sensory qualities of the bread bars were also determined. Water absorption capacity, oil absorption capacity, swelling capacity, foam capacity, foam stability and bulk density decreased significantly ($p < 0.05$) from 6.80 – 4.00 g/cm³, 7.70 – 5.50 g/cm³, 30.00 – 20.00 %, 29.63 – 18.09 %, 83.33 – 50.00 % and 1.07 – 0.81 g/cm³ respectively, while gelatinization temperature (78.00 – 86.00 °C) and solubility (14.47 – 19.82 %) increased significantly ($p < 0.05$) with increase in African breadfruit seed flour inclusion. Loaf volume (54.23 – 21.78 g/cm³), specific volume (1.56 – 0.72 cm³/g), loaf height (3.61 – 1.80 mm) decreased, while loaf density (0.63 – 1.15 kg/m³) increased with increase supplementation of African breadfruit seed in the formulation. Bread colour varied from 35.30 – 52.58 in lightness (L*), 12.52 – 15.46 in redness (a*), 16.21 – 22.62 in yellow (b*), 20.75 – 27.12 in chrome (c*) and 51. – 78.71 in Hue angle (h°). Protein (11.60 – 15.15 %), fat (7.83 – 9.81 %), fibre (2.82 – 4.13 %), ash (3.37 – 4.93 %) increased, while carbohydrate (65.97 – 74.37 %) decreased with increasing supplementation of African breadfruit in the bread bars. Soluble dietary fibre decreased significantly ($p < 0.05$) from 4.05 to 7.56 %, while insoluble and total dietary fibre increased from 10.62 – 16.20 and 18.18 – 21.45 respectively, with African breadfruit increase. Anti-nutrient content evaluated had values within the acceptable limit for human consumption. Sensory analysis showed that, acceptable bread bars could be developed from 90% wheat and 10% African breadfruit seed flour. Processing of this nutritious seeds and use of its flour to develop bread bars could enhance utilization and give convenience to consumers and encourage extensive farming of the crop.

Keywords: African breadfruit seeds, bread bar, whole wheat, dietary fibre, indigenous crop

Introduction

In recent times, consumers are becoming interestingly aware and interested in healthy foods and lifestyles and there has been growing interest on the part of researchers and the food industry into foods that may help maintain or improve human health, or hinder and treat illnesses. As a result of increasing consumer demand for natural, wholesome, convenient and nutritive foods, efforts are being made to improve food products by modifying their compositions.

Bread is an important staple food in both developing and developed countries and constitutes one of the most important sources of nutrients such as carbohydrate, protein, fibre, vitamins and minerals in the diets of many people worldwide (Aider *et al.*, 2012) [3]. Bread is a simple food prepared by baking of dough of flour and water. The infinite combination of different preparations of ingredients has resulted in the wide varieties of types, shapes, sizes, texture and taste available around the world (Adake *et al.*, 2014). It may be leavened (aerated) by a number of different processes ranging from the use of naturally occurring microbes to high pressure artificial aeration during preparation and baking or may be left unleavened for religious ritual purposes. The simplest bread is made from grains such as wheat, oats, barley, millet, and corn which are milled into flour and mixed with milk or water. Wheat is highly nutritious and due to the numerous qualities and popularity of wheat the flour is used in bread making.

Fibre-rich foods are produced by adding functional fibre or using basic ingredients with high dietary fibre content. Interest in fibre enhanced foods, has resulted in the use of many local food components that are rich in fibre and readily available, which include African Breadfruit, Coconut grit (Edima-Nyah *et al.*, 2023) [10, 11, 12, 13, 14], Pineapple Pomace, wheat bran, refined cellulose, fruits and vegetable skins to enrich target foods like breakfast cereals, snacks bars, corn flakes etc.

African breadfruit is an evergreen tree with great potentials as a source of nutrients to man (Osabor *et al.*, 2009) [43]. *T. africana* seed is a rich source of fat (10%), protein (17%) and carbohydrates (40%), as well as several minerals such as magnesium, potassium, zinc, iron, calcium, sodium and copper, and vitamins (Osabor *et al.*, 2009) [43]. Despite its dense nutrient composition, African breadfruit is under-utilized, partly because of the current lifestyle and demand for convenience, and the cumbersome steps and time involved in its processing (Edima-Nyah *et al.*, 2023) [10, 11, 12, 13, 14]. Intensifying utilization of African breadfruit in production of foods would increase its usefulness and versatility. One such application is processing into high fibre snack bars (Edima-Nyah *et al.*, 2019a) [10, 11, 12, 13, 14], extruded snacks (Nwabueze *et al.*, 2008) [33], and malt for use in alcoholic beverage and ethanol production (Nwabueze and Uchendu, 2011) [33].

As a result of increasing consumer demand for natural, wholesome, convenient, nutritive and functional foods, the

objective of this study was to produce high-fibre bread bars from whole wheat and whole African breadfruit seeds composite flour blends and as well investigate on the functional properties, proximate composition, anti-nutrient content, physical properties, dietary fibre content and sensory attributes of bread bars produced from flours of whole wheat and whole African breadfruit seeds composite blends to deliver a nutritious healthy product. The outcome of this study would give alternative to people on weight control diet, diabetic patients, reduction in rapid rise in blood sugar and constipation, who are in search of fibre rich foods, would also help introduce fibre intake in our daily diets and serves as a protein supplement in diets of consumers and finally, would improve the nutritional quality of wheat flour and to diversify the use of African breadfruit seeds in formulated foods such as high fibre bread bars.

Materials and methods

1. Procurement of raw materials

Wheat grains and African breadfruit (*Treculia africana* Decne) seeds used for this study were purchased from Itam Market in Akwa Ibom State, Nigeria.

2. Processing of whole African breadfruit flour

The method of Edima-Nyah *et al.* (2023) [10, 11, 12, 13, 14] was adopted in this study. Whole African breadfruit seeds were cleaned, parboiled for 15 min at 100 °C, drained through

stainless-steel sieve and allowed to cool. Parboiled whole African breadfruit seeds were dried for 5h at 60°C and toasted for 20min at 150°C in an oven (Precision Compact, Model: PR305225M). Toasted seeds were milled using Colombian Grain Mill (Victoria, Model: 530025) to flour. The Whole African breadfruit flour was stored in a clean container with secured lid at room temperature (27±2°C).

3. Processing of whole wheat flour

The method of Peter *et al.* (2017) was adopted in the production of whole wheat flour. Whole wheat flour was obtained by cleaning to remove surface dirt, stones and other extraneous materials, washed with tap water, oven dried at 60°C for 24h. The dried grains were then milled using Colombian Grain Mill (Victoria, Model: 530025) to flour. The whole wheat flour was sieved through 75µm mesh sieve (British Standard) and packed in high density polyethylene bags and stored at ambient temperature (27±2°C) prior for use.

4. Flour blend and recipe for formulation of bread bars

Composite flour blends was prepared using the formulation of whole wheat flour and whole African breadfruit seeds flour as 100:0 = A, 95:5 = B, 90:10 = C, 85:15 =D, 80:20 =E, 75:25 = F and 0:100 = G in whole wheat: whole African breadfruit seed flour blends to obtain a 100%, and other ingredients for bread making were as presented in Table 1.

Table 1: Recipe for Bread Bars Formulations

Ingredients (100g of flour)	Formulations						
	A	B	C	D	E	F	G
WWF (g)	100	95	90	85	80	75	0
WAF (g)	0	5	10	15	20	25	100
Salt (g)	1	1	1	1	1	1	1
Yeast (g)	1	1	1	1	1	1	1
Sugar (g)	12	12	12	12	12	12	12
Margarine (g)	9	9	9	9	9	9	9
Water (ml)	60	60	60	60	60	60	50

All dry ingredients were measured using an S. Mettle Electronic Balance (Model, 2003) China. And water was measured with a measuring cylinder. WWF – whole wheat flour, WAF – whole African breadfruit seed flour.

5. Preparation of bread bars and baking

Dough preparation and baking of bread bars were carried out according to the method described by Lagnika *et al.* (2019) [27]. For one hundred grams (100g) flour, 9g of Margarine, 12g of sugar, 1g of yeast, 1g of salt and water, was used (Table 1). The dry ingredients were manually mixed together in a stainless bowl to obtain a uniform mixture. 60 ml of water was slowly added to the composite blends and 50 ml of water to the African bread fruits seed flour alone and kneaded into soft and smooth dough for 2-3 minutes. The dough was cut into five (5) smaller round pieces and the weight of each was 36g, rolled and placed in already greased aluminum baking pans, proofed at 35°C for 40 min and baked at 160°C for 15 min. Bread bars were cooled and packaged in air-tight polyethylene bags for sensory evaluation and other analyses.

Method of analysis

1. Determination of functional properties of flour blends.

Water absorption capacity, oil absorption capacity, foaming capacity, foaming stability and bulk density were determined by the method of Onwuka (2005) [42], swelling capacity and solubility by Robertson *et al.* (2000) [46] and gelatinization temperature by Shinde (2001) [48].

2. Proximate composition analyses of bread bars

Proximate composition of bread bars were determined using standard methods (AOAC, 2005) [6] for moisture content, crude fat, crude protein, total ash, crude fiber and carbohydrate and calorific (energy) value was calculated according to the method described by Osborne and Voogt, (1978) [44].

3. Physical properties determination of bread bars

Loaf volumes, specific volume, loaf density and loaf height of the bread bars samples were determined using the method described by AOAC (2005) [6], and Colour of the bread bars was measured using a colorimeter PCE-CSM2 (Deutschland GmbH) connected to a CQCS3 software.

4. Determination of Anti-Nutrient content of bread bars

Tannin, phytate and trypsin inhibitor activity contents of flour samples were determined by standard spectrophotometric methods of Pearson (1976) ^[45]. Oxalate and tannin determinations were by methods of Oberleas, (1973) ^[34] and Onwuka, (2005) ^[42] respectively.

5. Determination of soluble, insoluble and total dietary fibre

The soluble, insoluble and total dietary fibre in foods was determined using the Enzymatic – Gravimetric Method MES – TRIS Buffer (AOAC, 2005) ^[6].

6. Sensory evaluation of the bread bars.

A 30-member consumer acceptance panel (Semi-trained) was drawn from the student population of the Department of Food Science and Technology of the University of Uyo to evaluate the sensory characteristics of the based bread bars. This number was considered as rough product screening and for evaluating acceptance and or preference in a laboratory environment (Stone and Sidel, 1985; Nwabueze *et al.*, 2008) ^[33]. A 9-point hedonic scale questionnaire with 9=like extremely, 5 = neither like nor dislike and 1 = dislike extremely was adopted according to literature (Lawless and Heymann, 1998) ^[28]. Each based bread bars was assigned a 3 digit code and presented in a white ceramic plate in a white lighted and quiet laboratory environment. Samples were served in a randomized order with portable water and spit cup for rinsing of mouth in-between tasting of samples (Nwabueze *et al.*, 2008; Okafor and Ugwu, 2014) ^[33, 38]. Sensory attributes were evaluated by the panelists for product appearance, aroma, texture, taste, chewiness and overall acceptability.

7. Statistical analysis

Analysis was performed using IBM SPSS version 22 software. One-way Analysis of Variance (ANOVA) was used to determine significant differences between means which were separated using Duncan multiple range test (DMRT) was used to perform multiple comparison between means at $P < 0.05$ (Nwabueze, 2008) ^[33].

Results and discussion

1. Functional properties of composite flours of whole wheat and whole African breadfruit Seed blends

The functional properties of blends of whole wheat and whole African breadfruit seed flour are presented in Table 2. The functionality of food is the characteristics of food ingredient other than nutritional quality which has a great influence on its utilization (Mahajan and Dua, 2002) ^[30].

Water Absorption Capacity (WAC) is the ability of flour to absorb water and swell for improved consistency in food. Water absorption capacities of the flour blends varied from 4.00 to 6.80 g/cm³ with Sample A having the highest value, while Sample G had the least. The result in this study was higher than that (0.50 – 0.90g/g) as reported by Bello *et al.* (2020) for composite flours of wheat, unripe plantain and fluted pumpkin seed. According to Elmoniem *et al.* (2005) water absorption capacity gives an indication of the amount of water available for gelatinization. Oil Absorption

Capacity (OAC), the flavour retaining capacity, ranged from 5.50 – 7.70 g/cm³. Oil absorption capacity determines the suitability of flour in enhancement of flavour and mouthfeel when used in food formulation and preparation (Suresh and Samsheer, 2013) ^[49]. Water absorption and oil absorption capacity of the flour blends decreased significantly ($p < 0.05$) with increasing addition of whole African breadfruit seed flour in the composite flour blends.

Swelling capacity indicates the degree of exposure of the internal structure of the starch present in the flour to the action of water (Ruales *et al.*, 1993) ^[47]. Swelling capacity of flour blends (20.00 – 30.00 %), Foaming capacity (18.09 – 29.63 %) and Foaming stability (50.00 – 83.33 %) decreased significantly ($p < 0.05$) with increasing substitution of whole African breadfruit seed flour in the composite blends. Foam capacity is attributable to protein content and solubility since foamability is a function of solubilized proteins, and the higher the foaming capacity, the better the reconstitutive properties of the flour which has a marked effect on the kneading quality (Mbwana *et al.*, 2016). Results of foam stability obtained in this study were higher than the findings (29.0 – 50.0 %) of Akubor and Badifu (2004) ^[5] for wheat – African breadfruit kernel composite flour blends. Foam stability is important as the usefulness of whipping agents depends on their ability to maintain the whip as long as possible (Cherry and McWatters, 1981) ^[8]. Gelatinization temperature (GT) of the flour blends ranged from 78.00°C in sample A to 86.00°C in sample G. The trend in this study was in line with the values (75.00 – 84.00 °C) reported by Bello *et al.* (2020) for wheat, plantain and germinated fluted pumpkin seed composite flour used in the production of cookies. Variation in gelation characteristics of composite flours could be attributed to relative ratio of protein, carbohydrate and lipids that make up the flours and the interaction between such components (Iwe *et al.*, 2016) ^[25, 32].

Bulk density of the flour blends decreased with increasing level of whole African breadfruit seed flour substitution from 0.81 to 1.07g/cm³. Akubor and Badifu (2004) ^[5] also reported values within the same range (0.60 – 0.68 g/cm³) for wheat – African breadfruit Kernel composite flour blends. Bulk density is a reflection of the load the sample can carry if allowed to rest directly on one another. The lower the bulk density value, the higher the amount of flour that can stay together and thus increasing the energy content that could be derivable from such diets (Ikpeeme - Emmanuel *et al.*, 2009) ^[23]. The lower values of bulk density for composite flours make it suitable for high nutrient density formulations of food (Tumwine *et al.*, 2018) ^[50].

Solubility of flour blends increased from 14.23 to 19.82% with increase in the substitution of whole African breadfruit seed in the composite flour blend. Solubility is related to the presence of soluble molecules like amylase, albumins, sugars, oligosaccharides and other soluble components which differ significantly among different flours (Adebooye and Singh, 2008) ^[2]. Ajani *et al.* (2016) ^[4] reported lower values (4.0 – 7.0 %) for wheat-breadfruit composite flour blends which was contrary to result obtained in this study. According to Johnson *et al.*, (2001) ^[26] higher solubility would permit better digestibility. It is however observed that whole African breadfruit seed flour (Sample G) had a higher solubility value (19.82%).

Table 2: Functional Properties of Composite Flours of Whole Wheat and Whole African Breadfruit Seed Blends

Sample	WAC (g/cm ³)	OAC (g/cm ³)	SC (%)	FC (%)	FS (%)	GT (°C)	BD (g/cm ³)	Solubility (%)
A	6.80 ^a ±0.00	7.70 ^a ±0.00	30.00 ^a ±0.00	29.63 ^a ±0.02	83.33 ^a ±0.58	78.00 ^a ±0.00	1.07 ^a ±0.06	14.47 ^{de} ±0.06
B	6.63 ^b ±0.06	7.60 ^b ±0.00	28.53 ^b ±0.60	28.90 ^b ±0.07	76.66 ^b ±0.58	80.00 ^b ±0.00	0.92 ^b ±0.00	14.23 ^e ±0.15
C	6.60 ^b ±0.00	7.53 ^c ±0.00	28.06 ^c ±0.12	25.70 ^c ±0.06	68.00 ^c ±0.00	80.67 ^c ±0.58	0.89 ^c ±0.00	14.55 ^d ±0.13
D	6.50 ^c ±0.00	7.50 ^d ±0.00	27.53 ^d ±0.60	21.93 ^d ±0.03	68.00 ^c ±0.00	82.00 ^d ±0.00	0.87 ^d ±0.06	16.76 ^e ±0.05
E	6.20 ^d ±0.00	7.50 ^d ±0.00	24.50 ^e ±0.00	21.67 ^e ±0.06	62.00 ^d ±0.00	84.00 ^c ±0.00	0.85 ^e ±0.00	16.91 ^e ±0.03
F	6.13 ^e ±0.00	7.00 ^e ±0.00	24.20 ^f ±0.00	20.89 ^f ±0.01	56.00 ^e ±0.00	85.00 ^b ±0.00	0.83 ^f ±0.00	19.33 ^b ±0.32
G	4.00 ^f ±0.00	5.50 ^f ±0.00	20.00 ^g ±0.00	18.09 ^g ±0.10	50.00 ^f ±5.12	86.00 ^a ±0.00	0.81 ^g ±0.06	19.82 ^a ±0.07

Values are means ± standard deviation of triplicate samples. Means values bearing different superscript in the same column are significantly (P < 0.05) different.

Key: WAC – Water Absorption Capacity, OAC – Oil Absorption Capacity, SC – Swelling Capacity, FC – Foam Capacity, FS – Foam Stability, GT – Gelatinization Temperature, BD – Bulk Density. A= 100:0, B= 95:5, C= 90:10, D= 85:15, E= 80:20, F= 75:25, G= 0:100, for whole wheat: whole African breadfruit seed composite flour blend

2. Proximate composition of bred bars produced from composite flours of whole wheat and whole African breadfruit seeds

Results of proximate composition of bread bars produced from whole wheat and whole African breadfruit seed flour blends is shown in Table 3. Moisture contents ranged from 8.01 to 8.47% and were significantly (P < 0.05) different from each other. The moisture content values of bread bars obtained in this study were lower than the values (8.81-9.31%) reported by Okoye *et al.* (2019) [40] for breads produced from millet- African breadfruit composite flour blends. Moisture content of 11.64 – 16.34 % was reported by Ebahamiegbeho *et al.* (2020) [9] for breads from wheat and banana flours. The moisture content of a food affects its stability and overall quality (Ihekoronye and Ngoddy, 1985; Usman *et al.* 2015) [51]. Crude protein content ranged from 11.60 to 15.15%, and increased significantly (p<0.05) with increasing amount of whole African breadfruit seed flour in the composite bread bars. The observation was in line with that of Okoye *et al.* (2019) [40] with values (10.70 - 12.55 %) for bread produced from composite flour blends of millet-African breadfruit seeds. The observed increased in the protein content of bread bars is an indication that African breadfruit seed is a good source of protein (Osabor *et al.*, 2009) [43]. Proteins play a significant role in building and maintenance of body cells and tissues (Okaka *et al.*, 2006) [39].

Crude fat content of bread bars ranged from 7.33% in Sample G to 9.81% in sample F and were significantly (P< 0.05) different from each other. The values of crude fat (3.07 – 3.5 %) for breads produced from composite blends of millet - African breadfruit as reported by Okoye *et al.*

(2019) [40] was lower than the values obtained in this study. Fat is important in the diet of young children and adults as it provides essential fatty acids and facilitates the absorption of fat soluble vitamins (Michaelson *et al.*, 2000). This implies that foods prepared using composite flours could be energy dense foods suitable for people with high energy needs (Igbabul *et al.*, 2014) [21]. Crude fibre content of bread bars ranged from 2.82 to 4.13%, increasing with increased amount of whole African breadfruit seed flour in the composite blends. The increase might be due to the high fibre content present in the whole African breadfruit seed flour. The result of crude fibre in this study was higher than the values (3.05 - 3.78 %) reported by Okoye *et al.* (2019) for breads produced from millet- African breadfruit composite flour. Fibre helps in the promotion of excretion of bile acids, fats and sterols which have been implicated in the etiology of certain diseases in man (Lutter and Dewey, 2003) [29]. Ash contents of the formulated bread bars ranged from 3.37 to 5.05% and increased significantly (p<0.05) with increasing amount of whole African breadfruit seed flour in the composite flour blends. Similarly, Okoye *et al.* (2019) [40] reported values of (3.99 – 4.16) for bread from millet-African breadfruit which was lower than the values obtained in the present study. The ash content gives an overall estimate of the total mineral elements present in the food. Food with high ash content according to Elinge *et al.* (2012) [16] is expected to have high concentration of various mineral elements that may speed up and improves metabolic growth and development.

Carbohydrate contents of bread bars ranged from 65.97 to 74.37% and decreased with increasing addition of whole African breadfruit seed flour in the composite blends. Carbohydrate supplies quick source of metabolisable energy and assist in fat metabolism. Energy values of bread bars ranged from 395.25 to 414.33 kcal/100g, and increased with increasing amount of whole African breadfruit seed flour in the composite bread bars blend formulated. The energy values in this study were within the range reported (365.80 – 426.30 kcal/100g) for bread produced from wheat and banana flour blends as reported by Ebahamiegbeho *et al.* (2020) [9]. Energy value of a food is much more related to the fat content (Ihekoronye and Ngoddy, 1985).

Table 3: Proximate Composition of Bread Bars Produced from Whole Wheat and Whole African Breadfruit Seed flour blends

Sample	Moisture Content (%)	Crude Protein Content (%)	Crude Fat Content (%)	Crude Fibre Content (%)	Ash Content (%)	Carbohydrate Content (%)	Energy Value (kcal/100g)
A	8.45 ^b ±0.00	11.60 ^g ±0.01	7.82 ^f ±0.01	2.82 ^g ±0.03	3.37 ^f ±0.02	74.37 ^a ±0.03	414.33 ^a ±0.09
B	8.47 ^a ±0.01	11.93 ^f ±0.02	7.90 ^e ±0.00	3.22 ^f ±0.00	4.50 ^e ±0.01	72.44 ^b ±0.02	408.60 ^f ±0.02
C	8.33 ^c ±0.00	12.50 ^e ±0.01	8.45 ^d ±0.00	3.52 ^e ±0.02	4.55 ^d ±0.01	70.97 ^d ±0.02	409.92 ^e ±0.11
D	8.30 ^d ±0.00	13.04 ^d ±0.01	8.95 ^c ±0.01	3.80 ^d ±0.01	4.65 ^d ±0.00	69.54 ^c ±0.01	410.95 ^d ±0.05
E	8.21 ^e ±0.01	13.88 ^b ±0.01	9.33 ^b ±0.02	3.90 ^c ±0.01	4.71 ^c ±0.00	68.16 ^c ±0.01	412.20 ^c ±0.11
F	8.16 ^f ±0.00	15.15 ^a ±0.01	9.81 ^a ±0.00	4.13 ^a ±0.02	4.93 ^b ±0.01	65.97 ^e ±0.02	412.79 ^b ±0.05
G	8.01 ^g ±0.01	13.31 ^c ±0.02	7.33 ^g ±0.02	4.04 ^b ±0.02	5.05 ^a ±0.01	71.25 ^c ±0.02	395.25 ^g ±0.19

Values are means ± standard deviation of triplicate samples. Mean values bearing different superscript in the same column are significantly (P < 0.05) different A= 100:0, B= 95:5, C= 90:10, D= 85:15, E= 80:20, F= 75:25, G= 0:100, for whole wheat: whole African breadfruit seed composite flour blend

3. Physical properties of bread bars produced from whole wheat and whole African breadfruit seed flour blends

Table 4 shows the physical properties of bread bars developed from composite blends of whole wheat and whole African breadfruit seed flours.

The results showed that loaf volume (LV) decreased

significantly (p<0.05) from 54.23 to 21.78 g/cm³ with increasing addition of whole African breadfruit seed flour in composite blends. Specific volume (SV) decreased from 1.56 to 0.65 g/cm³ while loaf density (LD) increased from 0.632 to 1.52 kg/m³ with increase addition of whole African breadfruit seed flour from 0 to 25 % in the blends. There was no significant difference (P>0.05) among samples B, C and D in specific volume while in loaf density, sample B and C, F and G were statistically the same. Loaf height (LH) decreased significantly (P<0.05) from 3.61 to 1.80 cm with increase in whole African breadfruit seed flour substitution. Loaf colour varied from 35.30 to 52.58 for (L*) Lightness, 12.52 to 15.46 for redness (a*), 16.21 to 22.62 for yellowness (b*) and 20.75 to 27.12 for chrome (c*), and while the hue angle ranged from 51.30° to 58.71°.

Table 4: Physical Properties of Bread Bars produced from Whole Wheat and Whole African Breadfruit Seed Flour Blends.

Parameters	A (100:0)	B (95:5)	C (90:10)	D (85:15)	E (80:20)	F (75:25)	G (0:100)
LV (g/cm ³)	54.23 ^a ±0.00	43.55 ^b ±0.02	38.65 ^c ±0.01	37.64 ^d ±0.01	30.24 ^e ±0.00	25.07 ^f ±0.01	21.78 ^g ±0.00
SV (cm ³ /g)	1.56 ^a ±0.00	1.14 ^b ±0.17	1.13 ^b ±0.00	1.07 ^b ±0.00	0.89 ^c ±0.02	0.65 ^d ±0.00	0.72 ^d ±0.12
LD (kg/m ³)	0.63 ^a ±0.00	0.86 ^d ±0.02	0.87 ^d ±0.00	0.93 ^c ±0.01	1.11 ^b ±0.01	1.52 ^a ±0.00	1.51 ^a ±0.00
LH (mm)	3.61 ^a ±0.00	3.30 ^b ±0.00	3.00 ^c ±0.00	2.80 ^d ±0.00	2.40 ^e ±0.01	2.20 ^f ±0.01	1.80 ^g ±0.00
L*	52.58 ^a ±3.25	47.99 ^a ±7.26	46.53 ^a ±1.93	47.29 ^a ±4.68	49.58 ^a ±0.96	52.14 ^a ±4.04	35.30 ^b ±1.59
a*	14.32 ^{ab} ±0.62	13.78 ^{ab} ±2.03	15.46 ^a ±1.10	14.05 ^{ab} ±0.36	12.52 ^b ±0.76	12.83 ^b ±1.61	12.94 ^b ±0.88
b*	22.14 ^a ±0.53	22.62 ^a ±2.53	22.27 ^a ±0.64	20.62 ^{ab} ±1.36	19.25 ^b ±0.25	19.76 ^{ab} ±2.27	16.21 ^c ±1.35
c*	26.37 ^{abc} ±0.40	26.49 ^{ab} ±3.21	27.12 ^a ±1.14	24.96 ^{abc} ±0.93	22.97 ^{cd} ±0.54	23.56 ^{bcd} ±2.79	20.75 ^b ±1.59
h°	57.10 ^{ab} ±1.54	58.71 ^a ±1.10	55.27 ^b ±1.21	55.72 ^b ±2.49	56.99 ^{ab} ±1.47	57.03 ^{ab} ±0.31	51.38 ^c ±0.67

Values are means ± standard deviation of triplicate samples. Means values bearing different superscript in the same column are significantly (P < 0.05) different

Key: LV – Loaf Volume, SV – Specific Volume, LD – Loaf Density, LH – Loaf Height

L* - Lightness, a*- Redness, b*- Yellowness, c*- Chroma, h°-Hue angle.

4. Anti-nutrients contents of bread bars produced from whole wheat and whole African breadfruit seed composite flour blends

Anti-nutrients contents of bread bars are shown in Table 5. Anti-nutrients are substances that impact negatively on bioavailability, digestibility and utilization of nutrients in food. Oxalate content ranged from 0.98 to 9.19 mg/100g, and increased significantly as the percentage substitution of whole African breadfruit seed flour increased in the composite flour blends. Edima-Nyah *et al.* (2019) [10, 11, 12, 13, 14] reported

lower values (0.06 – 0.29 mg/100g) for snack bars using Whole African breadfruit seed, maize and coconut grits.

Oxalates occur naturally in plants, and high levels in diet may lead to irritation of the tissues, the digestive system particularly the stomach and kidney (Ogbuagu, 2008). Toxic level of 2.5g was reported by Onimaowo and Akubor (2012) [5], with reduction in the bioavailability of essential nutrients in plant foods.

Tannin content of bread bars increased significantly from 0.20 to 4.94 mg/100g with increasing level of whole African breadfruit seed flour substitution in the composite blends. Oguntause *et al.* (2019) reported values (1.39 – 3.24 mg/g) for bread from Bambara groundnut-orange peel and wheat composite flour blends. The presences of tannin in foods sometimes give it a dark colour due to its reaction with iron, and can provoke astringent reaction in the mouth making the food unpalatable (Ogunwolu *et al.*, 2015) [37]. All the bread

bars could be considered safe for consumption since tannin contents were within the reported safe limit (below 90mg/100g) for humans (Ifie and Emeruwa, 2011; Maseta *et al.*, 2016) [20, 31].

Saponin content of bread bars increased significantly (p<0.05) with increase in African breadfruit level, from 2.46 to 8.53mg/100g with Sample G (100% whole African breadfruit seed bread) having the highest value, while Sample A, control (100% whole wheat bread) had the least value. The result obtained in this study is comparable to the values (5.02- 10.14 mg/100g) reported by Bello *et al.* (2020) for cookies produced from wheat, unripe plantain and germinated fluted pumpkin seed composite flours. The trend of results in this study was in line with the values (0.64 – 7.13%) reported by Edima-Nyah *et al.* (2019a) for snack bars produced from African breadfruit seed, maize and coconut flour blends.

Trypsin inhibitor activity (TIA) of the bread bars increased significantly (p<0.05) with increasing level of African breadfruit supplementation from 11.15 to 34.80 TIU/100g. Lethal dose of TIA in man is 200mg/100g (Inuwa *et al.*, 2011) [24]. Therefore all the bread bars formulated could be considered safe for consumption.

Phytate content of bread bars ranged from 0.66 to 37.80mg/100g, and increased significantly (p<0.05) with increasing addition of whole African breadfruit seed flour in the composite flour blends. Akubor and James (2014) [5] reported lower values (0.80 – 1.20 mg/100g) for bread prepared from wheat and African breadfruit kernel flour blends. Phytate result in this study was higher than the values (2.10 – 3.61mg/100g) reported by Edima-Nyah *et al.* (2019a) [10, 11, 12, 13, 14] for snack bars produced from whole, dehulled, malted and defatted African breadfruit seed flour blends. Ingestion of 2.5g (lethal dose) or more of phytic acid per day has been reported to cause reduction on the bioavailability of calcium, iron, magnesium and zinc (Onimaowo and Akubor, 2012) [5].

Table 5: Anti-nutrients Contents of Bread Bars Produced from Whole Wheat and Whole African Breadfruit Seed Composite Flour Blends

Parameters	Oxalate (mg/100g)	Tannin (mg/100g)	Saponin (mg/100g)	Trypsin inhibitor (TIU/100g)	Phytate (mg/100g)
A (100:0)	0.98 ^g ±0.00	0.20 ^g ±0.01	2.46 ^g ±0.01	11.15 ^f ±0.02	0.66 ^g ±0.02
B (95:5)	2.65 ^f ±0.02	0.40 ^f ±0.00	2.62 ^f ±0.05	11.21 ^f ±0.02	4.72 ^f ±0.02
C (90:10)	2.81 ^e ±0.02	0.61 ^e ±0.01	3.26 ^e ±0.01	15.81 ^e ±0.01	6.81 ^e ±0.01
D (85:15)	3.31 ^d ±0.02	1.71 ^d ±0.01	3.48 ^d ±0.01	18.30 ^d ±0.01	9.08 ^d ±0.02
E (80:20)	3.53 ^c ±0.02	1.92 ^c ±0.03	4.16 ^c ±0.03	20.52 ^c ±0.12	15.54 ^c ±0.02
F (75:25)	3.92 ^b ±0.0	2.26 ^b ±0.01	4.60 ^b ±0.01	20.81 ^b ±0.01	32.27 ^b ±0.01
G (0:100)	9.19 ^a ±0.03	4.94 ^a ±0.03	8.53 ^a ±0.04	34.80 ^a ±0.01	37.80 ^a ±0.01

Values are means ± standard deviation of triplicate samples. Mean values bearing different superscript in the same column are significantly ($P < 0.05$) different.

5. Soluble, insoluble and total dietary fibre contents of bread bars produced from whole wheat and whole African breadfruit seed flour blends

Dietary fibre is a group of non-starch polysaccharides and lignin, which are resistant to digestion and absorption in the small intestine. Within the body, they promote beneficial physiological effects such as reduction in blood cholesterol and modulation of blood glucose (Brennan, 2005) [7]. Soluble dietary fibre (SDF), Insoluble dietary fibre (IDF) and Total dietary fibre (TDF) contents of bread bars produced with different proportions of whole wheat and whole African breadfruit seed composite flours are shown in Table 6. Soluble dietary fibre (SDF) content of bread bars decreased significantly from 4.05 to 7.56 %, with increase substitution of African breadfruit flour in the blend. Afolabi *et al.* (2020) reported lower values (1.25 - 1.82 %) for bread from wheat, malted millet and Okara flour blends. Also, the result of soluble dietary fibre in this study was higher than those reported (2.87 – 5.18%) by Edima-Nyah *et al.* (2019a)

[10, 11, 12, 13, 14] for snack bars produced from blends of whole African breadfruit seed, maize and coconut flours.

Insoluble dietary fibre (IDF) and Total dietary fibre (TDF) increased significantly ($p < 0.05$) from 10.62 to 16.20 % and 18.18 to 21.45 % respectively, with increasing percentage of whole African breadfruit seed flour in the composite blends. Insoluble dietary fibre (IDF) content of 7.25 – 14.76% was reported by Edima-Nyah *et al.* (2019a) [10, 11, 12, 13, 14] for snack bars from blends of whole African breadfruit seed, maize and coconut flour. Afolabi *et al.* (2020) reported lower values (7.98 - 9.43 %) for bread developed from wheat, malted millet and Okara flour blends. Raikos *et al.* (2020) reported lower total dietary fibre (TDF) values (8.53 – 19.19 g/100g) for high fibre bread from wheat and broad bean hull composite blends, and Afolabi *et al.* (2020) also reported lower TDF (9.23 – 11.25 %) for bread developed from wheat, malted millet and Okara flour blends.

Food can be referred to as high in fibre provided that it contains at least 6g/100g or 3g/100kcal of dietary fibre. Since all the bread bars produced in this study contain a value within the range of 18.18 – 21.45 g/100g of dietary fibre, they could therefore be rated as high fibre bread bars. Fibre is important for the removal of waste from the body thereby preventing constipation and many health disorders.

Table 6: Dietary Fibre Content of Bread Bars Produced from Whole Wheat and Whole African Breadfruit Seeds Flour Blends

Parameters	Oxalate (mg/100g)	Tannin (mg/100g)	Saponin (mg/100g)	Trypsin inhibitor (TIU/100g)	Phytate (mg/100g)
A (100:0)	0.98 ^g ±0.00	0.20 ^g ±0.01	2.46 ^g ±0.01	11.15 ^f ±0.02	0.66 ^g ±0.02
B (95:5)	2.65 ^f ±0.02	0.40 ^f ±0.00	2.62 ^f ±0.05	11.21 ^f ±0.02	4.72 ^f ±0.02
C (90:10)	2.81 ^e ±0.02	0.61 ^e ±0.01	3.26 ^e ±0.01	15.81 ^e ±0.01	6.81 ^e ±0.01
D (85:15)	3.31 ^d ±0.02	1.71 ^d ±0.01	3.48 ^d ±0.01	18.30 ^d ±0.01	9.08 ^d ±0.02
E (80:20)	3.53 ^c ±0.02	1.92 ^c ±0.03	4.16 ^c ±0.03	20.52 ^c ±0.12	15.54 ^c ±0.02
F (75:25)	3.92 ^b ±0.0	2.26 ^b ±0.01	4.60 ^b ±0.01	20.81 ^b ±0.01	32.27 ^b ±0.01
G (0:100)	9.19 ^a ±0.03	4.94 ^a ±0.03	8.53 ^a ±0.04	34.80 ^a ±0.01	37.80 ^a ±0.01

Values are means and standard deviation of triplicate determinations

Key: SDF – Soluble Dietary Fibre, IDF – Insoluble Dietary Fibre, TDF – Total Dietary Fibre

6. Sensory properties of bread bars produced from whole wheat and whole African breadfruit seed flour blends

Sensory attribute is considered a key factor in food acceptance because consumers look out for food with specific sensory characteristics. The acceptance of a food will depend on whether it responds to consumer's needs and on the degree of satisfaction that it is able to provide (Heldman, 2004) [19]. Table 7 shows the mean sensory scores of the panelist for product appearance, aroma, texture, taste, gumminess or chewiness and overall acceptability of bread bars produced with whole wheat and whole African breadfruit seed composite flour blends. Mean sensory score for appearance ranged from 4.46 to 8.00.

There was no significant difference ($p < 0.05$) between samples D, E and F. Appearance is one of the important factors in sensory evaluation (Edima-Nyah *et al.*, 2022) [10, 11, 12, 13, 14]. Akhtar *et al.* (2016) reported higher mean sensory scores (6.80 – 8.60) on

appearance of breads produced from wheat and sesame meal composite blends. Panelists mean score for aroma, determined by the sense of smell, was between 4.23 and 7.20. Texture of food products is an indicator of food safety and food quality to consumers, and so, important characteristics affecting consumer acceptance (Edima-Nyah *et al.*, 2022) [10, 11, 12, 13, 14], and sometimes embraces appearance (Eduardo *et al.*, 2013) [15]. Mean hedonic scores for texture of bread bars ranged from 4.17 to 7.43, with the control sample (A- 100% whole wheat) having the highest, and G (100% whole African breadfruit) having the lowest score. Taste showed the mean sensory score ranging from 4.03 to 7.70. There was no significant difference ($p < 0.05$)

between A (100:0, Control) and C (90:10). Average sensory score for gumminess/chewiness ranged from 4.26 to 7.83. Mean sensory score on overall acceptability ranged from 4.23 in Sample G (100% African breadfruit flour) to 8.20 in Sample A (100% wheat). Sample C (90% wheat and 10%

African breadfruit) had the highest score (7.46) among the bread bars from the composite flour blends, and was not significantly different ($p < 0.05$) from Sample A (Control, whole wheat bread bar). And so, was most preferred and acceptable by the consumers.

Table 7: Sensory Attributes of Bread Bars Produced from Whole Wheat and Whole African Breadfruit Seed Composite Flour Blends

Sensory Attributes	A (100:0) (Control)	B (95:5)	C (90:10)	D (85:15)	E (80:20)	F (75:25)	G (0:100)
Appearance	8.00 ^a ±1.01	7.20 ^b ±0.89	7.60 ^{ab} ±0.72	6.33 ^c ±1.35	6.56 ^c ±1.14	6.16 ^c ±1.12	4.46 ^d ±1.98
Aroma	7.20 ^a ±1.37	7.36 ^a ±0.93	7.26 ^a ±1.20	5.93 ^b ±1.48	6.06 ^b ±1.20	6.00 ^b ±1.14	4.23 ^c ±1.74
Texture	7.43 ^a ±1.17	6.83 ^a ±1.02	6.90 ^a ±1.35	6.03 ^b ±1.25	5.90 ^b ±1.58	5.83 ^b ±1.46	4.17 ^c ±1.82
Taste	7.70 ^a ±1.51	6.76 ^b ±1.10	7.03 ^{ab} ±1.29	5.76 ^c ±1.61	5.73 ^c ±1.79	5.23 ^c ±1.91	4.03 ^d ±2.01
Gumminess/Chewiness	7.83 ^a ±1.05	6.76 ^b ±1.30	7.03 ^{ab} ±1.33	6.33 ^{bc} ±1.69	5.96 ^c ±1.67	5.86 ^c ±1.66	4.26 ^d ±2.27
Overall Acceptability	8.20 ^a ±0.81	7.33 ^b ±1.09	7.46 ^{ab} ±0.86	6.46 ^c ±1.59	6.06 ^{cd} ±1.57	5.43 ^d ±1.89	4.23 ^e ±2.27

Values are means ± standard deviation of triplicate samples. Mean values bearing different superscript in the same column are significantly ($P < 0.05$) different.

Conclusion

Acceptable bread bars, with high fibre, could be produced from wheat-African breadfruit composite flour blends. The substitution of African breadfruit at different levels significantly increased protein, fat, fibre, ash content and loaf density, but reduced the loaf height, loaf volume and carbohydrate content of the bread bars. Ten percent (10%) African breadfruit supplementation in bread bars compared favourably with whole wheat (100%) bread bars and was most accepted by consumers. The inclusion of whole African breadfruit seed (*Treculia africana*) flour into the conventional wheat flour in the production of high fibre bread bars would greatly benefit consumers seeking high fibre foods and enhance the utilization of this crop in developing countries like Nigeria and West African, since the crop has not been optimally utilized. Using African breadfruit seed (*Treculia africana*) flour as substitute with wheat flour could help reduce the cost of the conventional wheat flour and would expand its usage and thereby encourage commercial farming of this indigenous crop.

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