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Dietary Fibre, *In-Vitro* Starch and Protein Digestibility, Glycemic Index, and Acceptability of Whole Wheat-African Breadfruit Seed Based Fibre-Rich Bread Bars

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ABSTRACT: The study was carried out to elucidate the suitability and utilization of African breadfruit (*Treculia africana*) seed flour in the development of bread bars. Whole wheat and whole African breadfruit seeds were processed to flours and bread bars were developed from the flour blends in the ratio of 100:0, 95:5, 90:10, 85:15, 80:20, 75:25 and 0:100% respectively. The bread bars were evaluated of their proximate composition, *in-vitro* starch and protein digestibility, glycemic index, total dietary fibre and organoleptic properties. African breadfruit flours inclusion in the development of the bread bar showed that protein (11.60-15.15 %) and crude fibre (2.82 – 4.04 %) increased with increase breadfruit flour inclusion, but there was a noticeable decrease (74.37-65.97 %) in the carbohydrate content. Soluble dietary fibre (SDF = 7.56 – 4.05 %) decreased while insoluble (IDF = 10.62 – 16.20 %) and total dietary fibre (TDF = 18.18 – 21.45 %) increased significantly ($p<0.05$) with increasing African breadfruit flour inclusion. *In vitro* glycemic index (IVGI) and starch digestibility (IVSD) decreased significantly ($p<0.05$) from 94.52 – 80.46 % and 70.62 – 49.14 % respectively, with increasing substitution of African breadfruit seed flour. *In vitro* protein digestibility ranged from 75.85 to 86.92 %. With reference to standard classifications, the formulated African breadfruit seed-based bread bars could be referred to as 'high fibre' and 'low glycemic' foods, and may have positive health benefit to the consumers, especially the diabetics and those interested in weight management.

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KEYWORDS: African breadfruit seeds, bread bars, Total dietary fibre, Starch digestibility, Glycemic index, protein digestibility.

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INTRODUCTION

The awareness of innovative food products, with health promoting benefits, is increasing every day, with corresponding demand. In food industry, functional foods have become an interesting research area. Functional food is a food which is given an additional function, by adding a new ingredient or more of the existing ingredients, that provide physiological benefit to health (Feili *et al*., 2013).

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). It is a simple food prepared by baking of dough of flour and water. Traditionally, wheat is the major ingredient for bread production in Nigeria and other parts of the world. High-fibre bread is one of the popular products classified as functional foods, which is loaded with health benefits. White bread is popular because of its organoleptic qualities. However, there is an increasing demand for the consumption of high-fibre bread due to their health promoting properties.

Searching for protein and fibre sources that will Supplement wheat flour with high biological-valued protein has been a subject for many researchers (Wabali *et al*., 2020). Protein requirements are defined in terms of intakes required to meet metabolic needs for body maintenance, in terms of age group and those associated with normal growth for infants and children, pregnancy and lactation mothers (FAO, 2013). Recent studies indicated that high dietary fibre intake is beneficial to human health in preventing cardiovascular diseases, diabetes mellitus colon cancer and reducing cholesterol (Ajila and PrasadaRao, 2013). Angioloni and Collar (2011) showed that bread production calls for a careful selection of dietary fibre (DF); choosing fibre with the most appropriate physicochemical properties to prevent permanent protein matrix disruption for purposes of avoiding excessive weakening, particularly in highly substituted flour systems. The interest in enhancing the nutritional qualities of many well-known food products arose as a result of changing eating habits and increased consumer demand for healthy food with functional ingredients (Ibidapo *et al*., 2020). Therefore, the production of bread bar with African breadfruit seed flour with higher nutritive value especially protein and dietary fibre is very crucial.

African breadfruit is one of the under-utilized and under-exploited forest tree crops in Nigeria, known botanically as *Treculia africana.* African breadfruits have been reported to be cheap source of protein, carbohydrate, fat, vitamins and minerals. (Wabali *et al*., 2020). African Breadfruit protein has an impartially balanced composition of amino-acid, with a lysine content higher than what is in wheat (Nwabueze *et al.*, 2008). African breadfruit has drawn attention because of its abundance throughout the tropical regions, low cost and great versatility as a food source. As snacks, toasted African breadfruit could be eaten with fresh maize or mature coconut (Edima-Nyah *et al*., 2023). Several efforts have been made in the utilization of African breadfruit in production of foods which would increase its usefulness and versatility. One such application is processing into high fibre snack bars (Edima-Nyah *et al*., 2019), extruded snacks, and malt for use in alcoholic beverage and ethanol production (Nwabueze and Uchendu, 2011). The use of composite flour from locally grown crops in bread production will be beneficial, both nutritionally and economically, as this will improve the nutrient composition of the food and reduce the cost on wheat importation while increasing the utilization of local crops. And, since bread is accepted and consumed widely by people of all ages, it would as such serve as a valuable vehicle for supplementation for nutritional improvement (Inyang *et al*., 2018).

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 the proximate composition, *in-vitro* starch and protein digestibility, glycemic index, total dietary fibre and organoleptic properties of the bread bars. These could serve as healthy alternatives to people searching for weight control diets, diabetic patients, who are in need of reduction in rapid rise of blood sugar and others who desire high fibre foods. They could also help in the introduction of fibre intake in the daily diets and serves as a protein supplement in diets of consumers and may contribute to the global solution of alleviating hunger and protein energy malnutrition.

MATERIALS AND METHODS

Procurement of Raw Materials

Whole African breadfruit (*Treculia africana*) seeds and whole wheat grains used for this study were purchased from Itam Market in Itu Local Government Area, Akwa Ibom State, Nigeria. The grains were processed into flour.

Processing of Whole African breadfruit flour

The method of Edima-Nyah *et al*. (2023) was adopted in this study. Whole African breadfruit seeds were cleaned, parboiled for 15 min at 100 ºC, drained through stainless-steel sieve and allowed to cool. Parboiled whole African breadfruit seeds were dried for 5h at 60 ºC and toasted for 20min at 150 ºC 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 sieved through 75µm mesh sieve (British Standard) and packed in high density polyethylene bags and stored at ambient temperature (27±2ºC) prior for use.

Processing of whole wheat flour

The method of Peter and James (2014) 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^{0}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±2ºC) prior for use.

Flour Blend Formulation for Bread bars

Composite flour blending 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%, as presented in Table 1.

Table 1: Percentage of Composite Flour Blends Formation

Sample code	Whole Wheat Flour (%)	Whole African Breadfruit Seeds Flour (%)	Total
WWA	100	0	100
WWB	95	5	100
WWC	90	10	100
WWD	85	15	100

WWE	80	20	100
WWF	75	25	100
WWG	0	100	100

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). Samples were made from wheat flour, substituted with 5, 10, 15, 20, 25 and 100% of African breadfruits seed flour. For one hundred grams (100g) flour the following ingredients were used; 9g of Margarine, 12g of sugar, 1g of yeast, 1g of salt and water (Table 2). 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 a 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 for the cut dough.

The dough was rolled and 5cm diameter bar shape cuts were made. The dough cuts were filled in already greased aluminum baking pans and were compressed using a spatula to give a uniform mass and were left to proofed at 35^0C for 40 minutes. The dough was baked at 160^0C for 15 minutes. The bread bars were cooled and packaged in air-tight polyethylene bags for sensory evaluation.

Table 2: Bread Bars Formulations

Ingredient (100g of flour)	Formulations WWA	WWB	WWC	WWD	WWE	WWF	WWG
WWF (g)	100	95	90	85	80	75	0
WABSF (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 the liquid, being water, was measured with a measuring cylinder.

METHOD OF ANALYSIS

Proximate analyses of the bread bars

Proximate composition of raw materials and snack bars were determined using standard methods (AOAC, 2005) 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).

Determination of *in-vitro* protein digestibility

An enzymatic method described by Kanu *et al*. (2009) as adopted for the determination of *in-vitro* protein digestibility of snack bars produced.

Determination of *in-vitro* starch digestibility

The method of analysis, with enzymes, described by Singh *et al.* (2012) was used for determination of *in-vitro* starch digestibility of snack bars.

***In vitro* glycemic index analysis by starch hydrolysis**

The in-vitro glycemic index (GI) of the bread bars were determined according to the method described by Leoro *et al.* (2010).

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).

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 (Nwabueze *et al.*, 2008).

STATISTICAL ANALYSIS

Analysis was performed using IBM SPSS version 22 software. One-way Analysis of Variance (ANOVA) was used to determine mean and standard deviation of triplicate determinations, and significant differences between means which were separated using New Duncan multiple range test (NDMRT) was used to perform multiple comparism between means at $p< 0.05$.

RESULT AND DISCUSSION

Proximate Composition of Bred bars Produced from Composite Flours of Whole Wheat and Whole African Breadfruit Seeds

Results of the proximate composition of high fibre bread bars produced from whole wheat and whole African breadfruit seed flour blends is shown in Fig. 1. Moisture content varied significantly ($p<0.05$) from 8.01 to 8.47%. Moisture content of a food affects its stability and overall quality. Crude protein content of bread bars increased significantly ($p<0.05$) with increasing level of African breadfruit flour from 11.60 to 15.15%, and the highest value was recorded in sample WWF (75:25). Okoye *et al.* (2019) reported close values (10.70 - 12.55 %) for bread produced from composite flour blends of millet-African breadfruit seeds, and Akoja and Coker (2019) reported higher range of (13.71 – 19.11 %) for breads produced from wheat/seapurse (*Dioclea reflexa*). The observed increased in the protein content of the bread bars samples is an indication that African breadfruit seed is a good source of protein. Protein plays a significant role in building and maintenance of body cells and tissues.

Crude fat content of bread bars ranged from 7.33 to 9.81 %. Akoja and Coker (2019), reported lower values (2.31 – 2.92 %) for composite breads produced from wheat – seapurse (*Dioclea reflexia*), while higher values (10.97 - 20.23 %) were reported for bread from wheat and banana flours (Ebabhamiegbebho *et al.*, 2020). 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) 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. Crude fibre content of bread bars ranged from 2.82 to 4.13 %, and increased with increasing amount of whole African breadfruit seed flour in the composite blends. The bread bars had higher fibre content when compared to the values reported (1.2-1.8%) for bread produced from African breadfruit kernel flour by Akubor and James (2014). 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). Crude fibre is reported to be important in glycemic control and helps improves the morbidity of diabetic patients. The fibre content of the bread bars (2.84- 4.13%) was within the recommended FAO/ WHO (1994) level of not more than 5% for both children and adults.

Ash contents of bread bars increased significantly ($p<0.05$) from 3.37 to 5.05 % with increase in African breadfruit seed substitution. Values of ash in this study were higher than that (2.8-3.5%) reported by Akubor and James (2014) for breads containing fermented and toasted African breadfruits kernel flour. Okoye *et al.* (2019) reported close values (3.99 – 4.16 %) for bread from millet–African breadfruit. Ash content gives an overall estimate of the total mineral elements present in the food. Food with high ash content is expected to have high concentration of various mineral elements that may speed up and improves metabolic growth and development (Elinge *et al.*, 2012). Carbohydrate contents of bread bars ranged from 65.97 to 74.37% and decreased significantly ($p<0.05$) with increasing addition of whole African breadfruit seed flour in the composite blends. Carbohydrate supplies quick source of metabolizable energy and assist in fat metabolism.

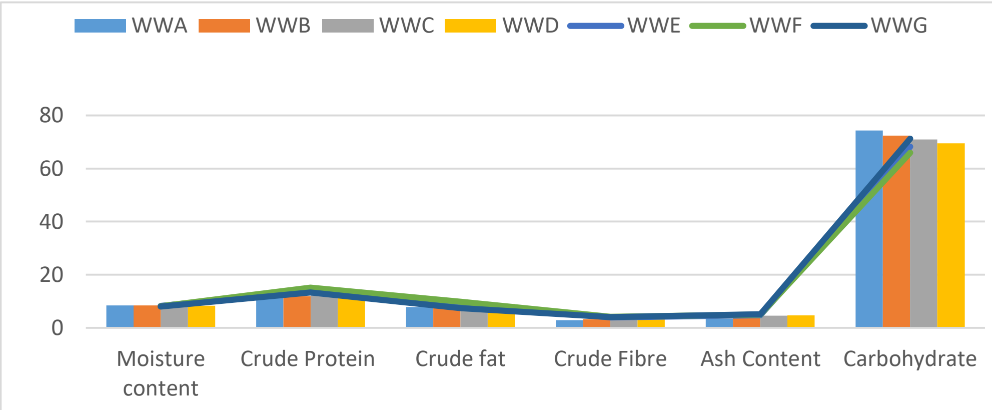

Fig 1: Proximate composition of Bread Bars produced from whole wheat and whole African breadfruits seeds

Key: WWA (100:0), WWB (95:5), WWC (90:10), WWD (85:15), WWE (80:20), WWF (75:25), WWG (0:100) of Whole wheat and African breadfruit seed flours.

Soluble, Insoluble and Total Dietary Fibre Contents of Bread Bars Produced from Whole Wheat and Whole African Breadfruit Seed Composite Flours

Soluble dietary fibre (SDF), Insoluble (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 3. Soluble dietary fibre (SDF) content increased significantly (p<0.05) from 4.05 to 7.56% with increasing level of African breadfruit seed 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 that (2.87 – 5.18%) reported by Edima-Nyah *et al.* (2019) 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) with increased level of whole African breadfruit seed flour, from 10.62 – 16.20 % and 18.18 – 21.45 % respectively, in the bread bars. TDF values (8.53 – 19.19 g/100g) reported by Raikos *et al.* (2020) for high fibre breads from wheat-broad bean hull composite blends were lower than the values obtained in this study. The increase in fibre content of bread bars could be as a result of the presence of wheat bran and African breadfruit seeds coats in the flour samples. According to European Food Safety Authority (EFSA) (2011), a food can be referred to as high in fibre provided that the food contains at least 6g/100g or 3g/100kcal of dietary fibre. All bread samples produced 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 3: Fibre Composition of Bread Bars Produced from Whole Wheat and Whole African Breadfruit Seeds Flour Blends

SAMPLE (W:A)	SDF (%)	IDF (%)	TDF (%)
WWA (100:0)	$7.56^{a}\pm0.01$	$10.62^{g}\pm0.01$	$18.18^{g}\pm0.02$
WWB (95:5)	$6.85^{b}\pm0.00$	$11.96^{f}\pm0.01$	$18.81^{f}\pm0.02$
WWC (90:10)	$6.15^{c}\pm0.01$	$12.95^{e}\pm0.01$	$19.10^{e}\pm0.02$
WWD (85:15)	$5.80^{d}\pm0.01$	$14.10^{d}\pm0.00$	$19.90^{d}\pm0.01$
WWE (80:20)	$5.21^{e}\pm0.01$	$14.75^{c}\pm0.00$	$19.96^{c}\pm0.01$
WWF (75:25)	$4.99^{f}\pm0.01$	$15.02^{b}\pm0.01$	$20.01^{b}\pm0.00$
WWG (0:100)	$4.05^{g}\pm0.00$	$16.20^{a}\pm0.00$	$21.45^{a}\pm0.00$

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

Key: W:A – wheat:African breadfruit**,** SDF – Soluble Dietary Fibre**,** IDF – Insoluble Dietary Fibre**,** TDF – Total Dietary Fibre

***In Vitro* Protein Digestibility, Starch Digestibility and Glycemic Index of Bread Bars Produced from Whole Wheat and Whole African Breadfruit Seed Composite Flours**

In vitro protein digestibility (IVPD), *In vitro* starch digestibility (IVSD) and *in vitro* glycemic index (IVGI) contents of bread bars produced from whole wheat and whole African breadfruit seed composite flour blends are presented in Table 4.

In vitro protein digestibility (IVPD) of high fibre bread bars increased significantly (p<0.05) from 75.85 to 86.92% with increased levels of African breadfruit flour. The result of *in vitro* protein digestibility in this study was slightly higher than the values (70.86 – 78.24 %) reported by Akhtar *et al.* (2016) for bread supplemented with defatted sesame meal. Wabali *et al.* (2020) also recorded lower values (25.73 – 47.33%) for biscuits produced from wheat flour, African breadfruit seed flour and Moringa seed flour.

In vitro starch digestibility (IVSD) ranged from 80.46 to 94.52% and all the values were significantly (P<0.05) different from one other. IVSD decreased with increasing substitution level of whole African breadfruit seed flour in the composite flour blends for bread bar formulation. Akhtar *et al.* (2016) reported similar decrease of IVSD with increasing substitution of defatted sesame meal, and a range of 34.28 to 36.63 % in wheat defatted sesame meal bread. Ogoda *et al.* (2018) reported values ranging from 42.48 - 50.36% for bread from Bambara groundnut flour and Lab-consortium from maize and sorghum fermented samples. The decrease in *in vitro* starch digestibility with increase in whole African breadfruit seed flour in the composite blends could be due to corresponding increase in fat (lipid) and protein content, which consequently limited starch transformation. Starch digestibility has been observed to be influenced by the presence of even small amount of protein in cereals and other food production (Singh *et al.,* 2010).

Glycemic index (GI) is a property of starchy food, which describes the rate of blood glucose absorption after consumption (Odenigbo *et al.,* 2013). *In vitro* glycemic index (IVGI) of the bread bars ranged from 49.14 to 70.62 %, and decreased with increasing level of substitution of whole African breadfruit seed flour in the composite blends. High fibre bread bars produced with 100% whole African breadfruit seed flour had the lowest IVGI value 49.14%. According to the Classification by Englyst and Hudson (1996), glycemic index (GI) of foods can be classified into three general categories; low GI foods (≤ 55) – cause a short rise in blood sugar, intermediate GI foods (56 – 69) cause a medium rise in blood-glucose and high GI foods (70 or higher) cause a rapid rise in blood glucose level. Therefore, Sample WWA could be regarded as a high glycemic bread bars; while Samples WWB, WWC, WWD, WWE could be referred to as medium glycemic bread bars, and Samples WWF and WWG as low glycemic bread bars. The consumption of low glycemic foods has been shown to have positive health benefits in a variety of chronic diseases including insulin resistance, diabetes, cardiovascular disease, obesity and cancers (Miao *et al.,* 2015).

Table 4: Protein and Starch Digestibility and Glycemic Index of Bread Bars produced from Whole Wheat and Whole African Breadfruit Seed Composite Flour Blends

SAMPLE (W:A)	IVPD (%)	IVSD (%)	IVGI (%)
WWA (100:0)	$75.85^{g}\pm0.01$	$94.52^{a}\pm0.01$	$70.62^{a}\pm0.02$
WWB (95:5)	$78.12^{f}\pm0.01$	$92.77^{b}\pm0.01$	$63.54^{b}\pm0.01$
WWC (90:10)	$80.56^{e}\pm0.01$	$90.17^{e}\pm0.01$	$59.13^{bc}\pm0.01$
WWD (85:15)	$82.11^{d}\pm0.01$	$88.15^{d}\pm0.00$	$57.06^{bc}\pm0.02$
WWE (80:20)	$83.25^{c}\pm0.02$	$86.32^{e}\pm0.01$	$55.90^{c}\pm0.01$
WWF (75:25)	$84.87^{b}\pm0.01$	$85.93^{f}\pm0.0$	$53.93^{cd}\pm0.00$
WWG (0:100)	$86.92^{a}\pm0.01$	$80.46^{g}\pm0.01$	$49.14^{d}\pm0.01$

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

Key: IVPD – *In vitro* Protein Digestibility, IVSD – *In vitro* Starch Digestibility, IVGI – *In vitro* Glycemic Index, W:A – Wheat:African breadfruit

Organoleptic properties of Bread Bars Produced from Whole Wheat and Whole African Breadfruit Seed Composite Flours

Organoleptic properties are considered key factors in acceptability of food because consumers look out for food with specific sensory characteristics. Fig. 2 shows the mean sensory scores of the panelist for appearance, aroma, texture, taste, gumminess or chewiness and overall acceptability of bread bars produced. Panelist mean score ranged from 4.46 to 8.00 for appearance, 4.23 to 7.36 for aroma, 4.17 to 7.43 for texture, 4.03 to 7.70 for taste, 4.26 to 7.83 for chewiness/gumminess, and 4.23 to 8.20 for overall acceptability. Sample WWG (100% whole African breadfruit seed bread bars) had the least score in all organoleptic properties assessed. This could be due to the relatively darker product appearance and lack of gluten to give the bread its characteristic quality. WWG looked and tasted more like a chocolate cake than bread. Eddy *et al.* (2007) reported a high mean score a (7.80 – 8.10) for bread from wheat – cassava composite which is comparable to the trend in this study. The bread bars developed with 10% whole African breadfruit seed flour, Sample WWC (90:10) compared favourably with Sample WWA (Control – 100% wheat flour), and were most preferred in the overall acceptability, among the wheat - African breadfruit seed bread bars.

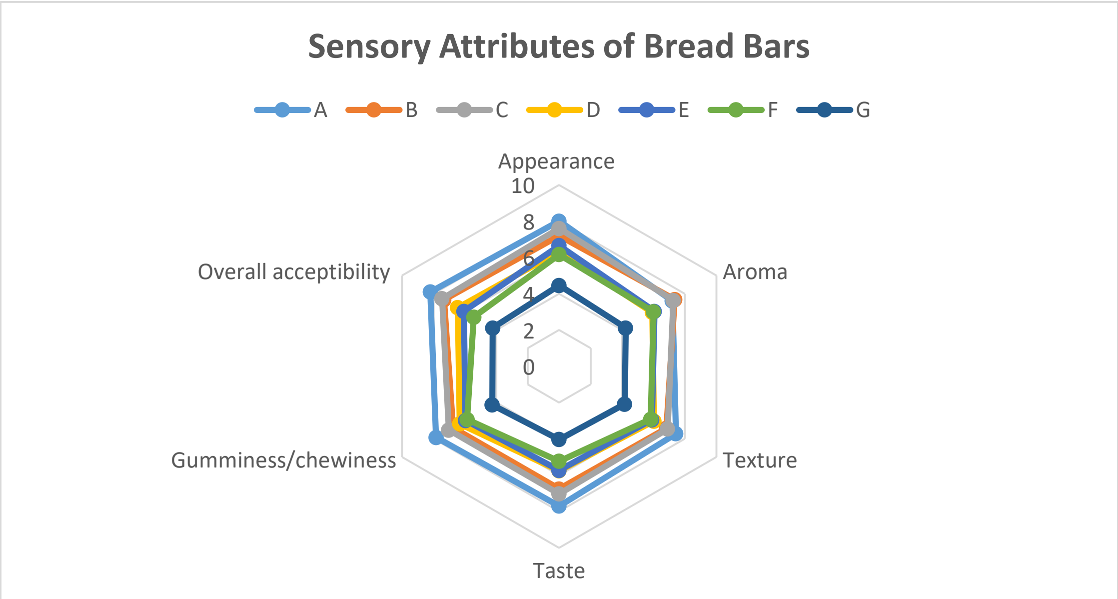

Fig. 2: Sensory Attributes of Bread Bars Produced from Whole Wheat and Whole African Breadfruit Seed Composite Flour Blend

Key: A=(WWA–100:0), B=(WWB-95:5), C=(WWC-90:10), D=(WWD-85:15), E=(WWE-80:20), F=(WWF-75:25), G=(WWG-0:100) of Wheat: African breadfruit respectively.

CONCLUSION

The overall purposes of this investigation were to develop high-fibre bread bars from whole wheat and locally available whole African breadfruit seeds composite flour blends and as well investigate on the proximate composition, dietary fibre content, in-*vitro* starch and protein digestibility, glycemic index and organoleptic properties in order to deliver a nutritious health product. The study indicated that the bread bars showed good nutritional quality, with high fibre content, which was as a result of the inclusion of African breadfruit flour. The sensory acceptability revealed that the developed bread bars from this study, especially those with 10% African breadfruit, could compete favourably with the already existing bread products in the target market. Based on these findings, one can infer that nutritious, digestible and high fibre bread bars made from whole wheat and whole African breadfruit seed flour blends may be a possible solution to helping alleviate hunger and protein energy malnutrition in our country Nigeria and other under-developed areas where the crop is indigenous. The knowledge of this study would help food scientists and technologists as well as nutritionists in further research, and application of African breadfruit seed flour, in composite blends, for industrial scale production.

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