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In Vitro Nutrient Analysis of High Fibre Snack Bars Produced From Blends of African Breadfruit, Maize and Coconut

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Abstract: *The objective of this study was to develop high fibre snack bars by utilizing whole African breadfruit seed flour (AF) with maize flour (MF) and coconut grits (CG), and to characterize the products. Proximate composition revealed 3.49 to 3.78% moisture, 2.12 to 3.25% ash, 5.09 to 8.43% fat, 10.18 to 20.34% crude fibre, 13.81 to 26.10% protein, 38.25 to 65.65% carbohydrate and 333.27 to 386.33Kcal/100g energy. Carbohydrate and energy value decreased, while protein, fibre, fat and ash content increased, with increasing addition of African breadfruit seed flour in the blend. Soluble dietary fibre decreased (5.18 to 2.87%) while insoluble (7.25 to 14.76%) and total dietary fibre (12.43 to 17.63%) increased with increasing addition of African breadfruit seed flour in the snack bars. In vitro protein and starch digestibility decreased, 88.19 to 63.93% and 57.48 to 29.59% respectively, with increase in African breadfruit seed flour. In vitro glycemic index of snack bars decreased significantly (P<0.05) with increase in African breadfruit seed flour in the formulation from 57.34 in the control to 44.37. All snack bars formulated with whole African breadfruit seed flour met the high fibre and low glycemic index classification, therefore could have positive health benefit to the consumers.*

Keywords*: dietary fibre, glycemic index, protein digestibility, snack bars, starch digestibility.*

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I. Introduction

Snack foods have now become an important part of human diets and nutrition due to their availability, affordability and convenience. There are increasingly attracting the attention of consumers. Mostly available in the Nigerian markets are snacks made with refined flours from cereals, which are mostly reach in fats, salts and digestible carbohydrates [1]. In developed countries, snacks are eaten in between meals to check hunger, provide energy and tasty appeal, but in the developing countries, they are eaten as main meal because of their readily availability and affordability [2]. With the recent increase reported about the consumption of snack foods, there has also been a corresponding increase in obesity and thus an unhealthy population [1]. Consequently, growing interests has been observed in the recent time by the researchers on health-promoting snack foods.

Snack bars (otherwise known as cereal bars) are standard, well-accepted and convenient foods, ideal to deliver fruit-derived phenolic antioxidants and fibre [3]. They are often made of a base of processed cereal grains (such as oats, wheat, soy, rice, maize, etc.) and may contain different ingredients such as nuts, seeds, fruits, raisins, and chocolate [4]. Among snack foods, snack bars are known for their convenience and balanced nutrient composition [5] and are usually considered a good choice for a quick meal because of their high nutritional value. Acceptable snack bars can also be made from indigenous food crops such as African breadfruit seeds [6].

African breadfruit (Treculia africana) is produced in the Eastern and Southern parts of Nigeria between March and July, when cultivated plant food sources are limited, that is, yet to be harvested. It is also available in Ghana, Gambia, Republic of Congo, and other tropical countries like East Indices, Angola, Cameroon, Tanzania, Sierra Leone, Malawi, Benin, Togo, Senegal and many others [7]. The seed of African breadfruit is obtained after macerating the fruit in water. The seeds are traditionally cooked in water with or without other ingredients (Jellof breadfruit), roasted or fried. The seeds are also dried and milled into flour known as breadfruit flour, which can be used to produce variety of baked foods. African breadfruit seeds are used to supplement the bulk of diets in the rural communities in south-eastern Nigeria, whose diets comprises essentially of cereal grains, starchy root and tuber crops [8]. The crop constitutes a strategic reserve of essential food nutrients that are available at certain critical period of the year when common sources of other food nutrients are short in supply or out of season. T. africana seed is a rich source of vegetable oil (10%), protein

(17%) and carbohydrates (40%), as well as several minerals and vitamins [9]. Expanding the food applications for African breadfruit seeds would increase its versatility and utility.

Maize (Zea mays L.) is the most important cereal in the world after wheat and rice with regard to cultivation [10]. In sub-Saharan Africa maize is a staple food for an estimated 50% population. It is an important source of carbohydrate, protein, iron, vitamin B, and minerals. Maize is a cereal crop that is grown widely throughout the world in a range of agroecological environments. More maize is produced annually than any other grain and is globally. It is known as queen of cereals because of its highest genetic yield potential. About 50 species exist and consist of different colors, textures and grain shapes and sizes. White, yellow and red are the most common types. The white and yellow varieties are preferred by most people depending on the region. Maize is the only food cereal crop that can be grown in diverse seasons, ecologies and for diverse uses [11]. It is cultivated globally on more than 160-million-hectare area across 166 countries. In Nigeria, maize is a very important, as it provides an inexpensive nutritious food that helps to sustain the rapidly increasing population. It is also an important crop in industrial and livestock production in the country. The level of maize production in Nigeria is estimated at almost 5.5 million tons per year [11].

Coconut (Coco nucifera) flour is naturally low in digestible carbohydrate, contains no gluten, is cheaper than most other nut flours, is loaded with health promoting fiber and important nutrients, and tastes terrific. It is a soft, flour like product made from the pulp of a coconut. It's actually a by-product made during the coconut milk making process. Coconut flour is extremely high in fiber with almost double the amount found in wheat bran and can be used much like wheat flour to make different forms of delicious breads, pies, cookies, cakes, snacks and desserts. It contains more calorie free fiber than other wheat alternatives. This flour also provides a good source of protein. It can improve digestion, help regulate blood sugar, protect against diabetes, help prevent heart disease and cancer, and aid in weight loss [12].

The objective of this study is to develop high fibre snack bars from African breadfruit seed, maize and coconut flour blends and assess the nutrient composition, the degree of starch and protein digestibility and the glycemic index of the products. It is hoped that the results of this findings will cause a distinct shift towards non wheat-based snacks for obvious advantages of higher nutritional and fibre content, better digestibility and low glycemic index, and thereby enhances its utilization.

II. Materials And Methods

2.1 Procurement of Materials

African breadfruit seeds were purchased from Ndoro market, Abia State. Maize, coconut and ingredients used for snack bar production (salt, margarine, milk powder, sodium bicarbonate, and nutmeg) were purchased from Umuahia main market in Umuahia, Abia State, Nigeria.

2.2 Preparation of Materials

2.2.1 Production of African breadfruit flour

Clean African breadfruit seeds were parboiled at 100^{o}C for 15min, drained through stainless steel sieve and allowed to cool. The parboiled seeds were dried at 60^{o}C for about 5h and further toasted at 150^{o}C in a Precision Compact Oven (Model: PR305225M). The toasted seeds were milled with Victoria Grain Mill (Model Ref: 530025, Colombia) to flour. The whole African breadfruit flour was packaged in airtight plastic container, labeled and stored at ambient temperature (27±2°C) for subsequent use.

2.2.2 Production of Maize flour

Maize grains were sorted to remove extraneous materials and cleaned by winnowing. The cleaned maize were toasted at 150^{o}C in an oven, then milled using Victoria Grain Mill (Model Ref: 530025, Colombia) to flour. Maize flour was packaged in a clean dry plastic container, securely covered, labeled and stored at ambient temperature (27±2°C) for subsequent use.

2.2.3 Production of coconut grits

Coconuts were cracked to expel the liquid content. The coconut flesh (meat) were manually removed from the shell with the aid of a sharp pointed stainless steel knife. The flesh were grated manually (using a plastic grater) to shreds, to facilitate drying and subsequent toasting. The coconut shreds were dried at 60^{o}C and toasted at 150^{o}C in a Precision Compact Oven (Model: PR305225M). The toasted shreds were milled manually (using Victoria Grain Mill, Model Ref: 530025, Colombia) to full fat coconut grits. The grits produced was stored in airtight plastic container at ambient temperature (27±2°C) for subsequent use.

2.3 Formulation of Composite blends

Composite flours blends were formulated into six groups with different proportions of African breadfruit and maize, with coconut grits and designated as A, B, C, D, E and F. The blending ratios are presented in Table 1.

Table 1. Formulation of composite flour (%)

Samples	A	B	C	D	E	F
African breadfruit seed flour	0	20	25	30	35	95
Maize flour	95	75	70	65	60	0
Coconut grit	5	5	5	5	5	5

2.4 Snack Bar Ingredients Composition

Ingredients composition for snack bar formulations (Table 2) consisted of dry ingredients (solid phase) and the liquid ingredients (binder phase). The dry ingredients included the African Breadfruit Seed flour, Maize Flour, Coconut Grit, salt, sodium bicarbonate, milk powder, margarine, and nutmeg flour. The liquid ingredients were caramel, coconut oil and water.

Table 2: Ingredients composition for Snack Bar formulations

	Formulations					
Ingredients	**A**	**B**	**C**	**D**	**E**	**F**
Dry ingredients (g/100g of flour)						
African breadfruit seed flour	0	20	25	30	35	95
Maize flour	95	75	70	65	60	0
Coconut grits	5	5	5	5	5	5
Salt	0.2	0.2	0.2	0.2	0.2	0.2
Baking powder	2	2	2	2	2	2
Milk powder	5	5	5	5	5	5
Margarine	15	15	15	15	15	15
Nutmeg flour	2	2	2	2	2	2
Liquid ingredients (g/100g of flour)						
Caramel	25	25	25	25	25	25
Coconut oil	10	10	10	10	10	10
Water	40	40	40	40	40	40

2.5 Production of snack bars

The snack bars were produced according to the method described by Edima-Nyah et al. [6]. Dry ingredients were manually mixed together in a stainless steel bowl for about 3min to obtain a uniform mixture. Caramel and coconut oil were added and mixed for 3min, water was incorporated slowly and the entire dough was mixed thoroughly for about 5min to obtain a uniform dough. The dough was transferred into greased aluminum pans and compressed in the pans using a spatula to give a uniform mass. The pan covers were placed over them to smoothen the top and give the bars the desired shape. The dough were baked in an oven at 150^{o}C for 25min. They were cooled to about 60^{o}C, de-panned and cut into bars seizes: 5cm x 3cm x 2cm. The bars were further dried in an air-circulation oven at 60^{o}C for 6h to reduce the moisture content, cooled at ambient temperature (27±2^{o}C), packaged in high density polyethylene, labeled (Fig.1) and stored for sensory evaluation and other determinations.

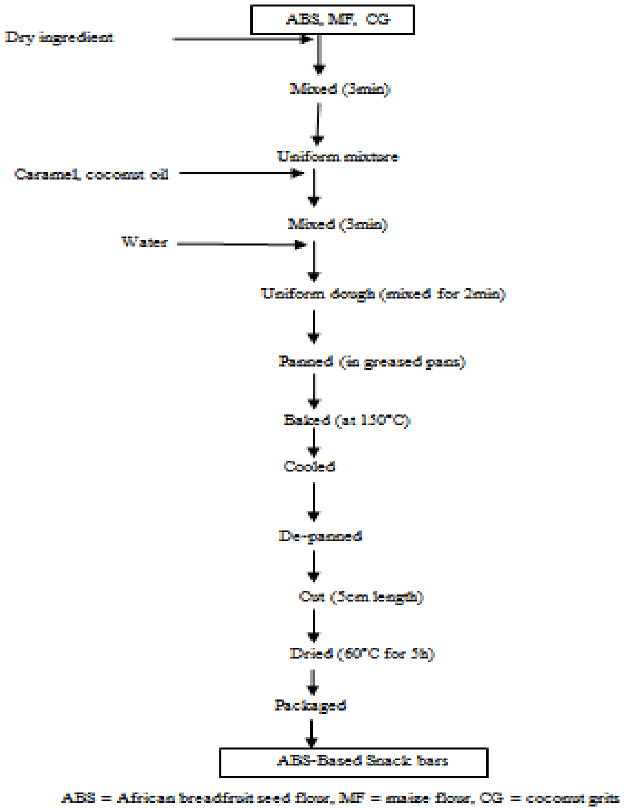

Fig. 1: **Flow diagram for the production of Snack bars from African breadfruit seed flour, maize flour and coconut grit blends.**

2.6 Methods of Analysis

2.6.1 Determination of Proximate Composition of Snack Bars

Moisture, ash, crude fat, crude fibre and crude protein were determined using the standard methods [13]. Carbohydrate content was calculated by difference [14], while Energy value was calculated using Atwater factor formula [15].

2.6.2 Determination of soluble, insoluble and total dietary fibre of snack bars

The soluble, insoluble and total dietary fibre in foods was determined using the Enzymatic-Gravimetric method MES-TRIS Buffer [13]. Samples were extracted with 85% ethanol to remove most of the sugars. Residues were suspended in MES-TRIS buffer and digested sequentially with heat-stable α-amylase at 95–100^{o}C, protease at 60^{o}C, and amyloglucosidase at 60^{o}C. Enzyme digestates were filtered through trittled crucibles with celite. Crucibles containing the digestates residues (insoluble fibre) were rinsed with dilute alcohol followed by acetone, and dried overnight in hot air oven at 105^{o}C. Filtrates plus rinses (Soluble fibre) were mixed with 4-volume of 95% ethanol to precipitate materials that were soluble in the digest. After 1 h, precipitates were filtered through trittled crucibles with celite. The digestates residue (insoluble fibre residue) and the filtrate precipitates (soluble fibre residue) were made in duplicates. One of each set of duplicate insoluble fiber residues and soluble fiber residues were ashed in a muffle furnace at 550^{o}C for 3 h. Another set of residues were used to determine protein as Kjeldahl nitrogen multiplied by 6.25. Insoluble or soluble dietary fibre residues (% original sample weight) minus % ash and % crude protein found in the residues were taken to be the values for insoluble (IDF) and soluble (SDF) dietary fibre fractions respectively. Total dietary fibre, TDF**,** was calculated as the sum of insoluble and soluble dietary fibre.

2.6.3 Determination of In Vitro Protein Digestibility

In vitro protein digestibility of each sample was determined using the enzymatic method described by Kanu et al. [16]. Five grams of each of the formulated samples were weighed into 5 ml centrifuge tubes and 15 ml of 0.1 M HCl containing 1.5 mg pepsin-pancreatin added. The tubes were incubated at 37^{o}C for 3 h. The suspension was then neutralized with a phosphate buffer (pH 8.0) containing 0.005 M sodium azide. Exactly 1 ml of toluene was added to prevent microbial growth, and the mixture was repeatedly shaken gently and incubated for 24 h at 37^{o}C. After incubation, samples were treated with 10ml of 10% trichloroacetic acid (TCA) and centrifuged at 5000rpm for 20minutes at room temperature. The TCA soluble fraction in the supernatant liquid was assayed for nitrogen using the micro-Kjedahl method. The percentage of protein digestibility was calculated using the formula;

$$\text{Protein digestibility (\%)} = \frac{\text{N in the supernatant} - \text{N in the blank} \times 100}{\text{N in the sample}}$$

2.6.4 Determination of In Vitro Starch Digestibility

In vitro starch digestibility was determined using the Method of Singh et al. [17]. Exactly 50 mg each of the snack bars were weighed into test tubes and mixed with 1 ml of 0.2 M phosphate buffer (pH 6.9). Pancreatic α-amylase (0.5 ml; 20 mg enzyme dissolved in 50 ml of the same buffer) was added to the sample mixtures and incubated at 37^{o}C for 2 h. After incubation, 2 ml of 3,5-DNS reagent (prepared by dissolving 200 mg crystalline phenol, 1 g of 3,5-dinitrosalycyclic acid and 50 mg sodium sulphite in 1% NaOH solution) was added immediately. The mixture was heated for 5-15 min in a boiling water bath. Exactly 1 ml of K-Na Tartarate solution was added to the mixture test tubes and allowed to cool at 25^{o}C. The solution was therefore made up to 25 ml with distilled water and filtered prior to reading of the absorbance at 550 nm. A blank was run simultaneously. A standard curve was prepared using maltose and values obtained were expressed as mg maltose equivalent per 100 mg of sample.

2.6.5 In Vitro Glycemic Index Analysis

The in vitro glycemic index (GI) of the snack bars was determined according to the method described by Goñi et al. [18] as modified by Leoro et al. [19]. Exactly 50 mg of samples were mixed with 10 ml HCl-KCl buffer (pH 1.50). The mixtures were homogenized for 2 min using a vortex (Buck Scientific Limited, LV, USA). Exactly 0.20 ml of pepsin solution containing 1 mg pepsin in 10 ml of HCl–KCl buffer (pH 1.50), was added to each mixture. Mixtures were incubated at 40°C in a water bath for 60 min with constant shaking. The digests were diluted to 25 ml by adding 15 ml Tris-maleate buffer (pH 6.9). Starch hydrolysis was initiated by adding 5 ml tris-maleate buffer containing 2.60 IU porcine pancreatic α-amylase. The mixtures were incubated at 37°C in a water bath maintain at moderate agitation. Exactly 1ml sample were taken from each flask every 30 min from 0 to 3 h. The α-amylase was inactivated immediately by holding the flask in a boiling water bath for 5 min. Then, 3 ml of 0.40 M sodium acetate buffer (pH 4.75) followed by 60 µl amyloglucosidase from Aspergillus niger was added and the mixture was incubated at 60°C for 45 min.

The glucose concentration was determined using a glucose oxidase-peroxidase kit (Baloworld scientific G3254 – Acap 01). The rate of starch digestion was expressed as a percentage of the total starch hydrolyzed at different times (30, 60, 90, and 120 min). A non-linear model was applied to describe the kinetics of the starch hydrolysis [18]. The first order equation had the form

$$C = C \infty (1 - e -kt) \quad (1)$$

And the areas under the Hydrolysis Curve (AUC) were calculated using the following equation:

$$AUC = C\infty (t_f - t_0) - (C\infty/k) [1 - \exp (t_f - t_o)] \quad (2)$$

C = Percentage of starch hydrolyzed at time t, C∞= Equilibrium percentage of starch hydrolyzed after 120 min, k = Kinetic constant, t = Time, t_f= Final time (120 min) and t_o = Initial time (0 min)

The Hydrolysis Index (HI) was obtained by dividing the area under the hydrolysis curve of each sample by the corresponding area of a reference sample (glucose).

$$HI = \frac{\text{AUC of sample}}{\text{AUC of glucose}} \quad (3)$$

The Glycemic Index (GI) was calculated using this equation:

$$GI = 39.71 + (0.549 \times HI) \quad (4)$$

2.7 Statistical Analysis

Data obtained were subjected to a one-way Analysis of Variance (ANOVA) to determine significant differences at P<0.05 using IBM SPSS version 20 software. Means were separated using New Duncan Multiple Range Test (NDMRT).

III. Result And Discussion

3.1 Proximate composition

Table 3 shows the results of the proximate composition of various blends of whole African breadfruit seed flour, maize flour and coconut grits. Moisture content was low, within the range of 3.49 to 3.78%. Significant difference (P<0.05) existed among the blends. Higher moisture content (9.60 – 12.87%) were reported by Ajani et al. [20] for wheat-breadfruit flour blends and 21.00% by [2] for African breadfruit-soybean-corn flour blend. Ash content ranged from 2.12 to 3.25%, fat content was between 5.09 to 8.43%, fibre content ranged from 10.18 to 20.34%, while protein content was between 13.81 to 26.10%. Ash, Crude fat, crude fibre and crude protein content of the blends increased with increasing amount of African breadfruit seed flour. Significant differences (P<0.05) existed in fat, fibre and protein contents of all the blend compositions. The protein contents of these flour blends were higher than 1.08 – 1.42 % reported by [20] for wheat-breadfruit (Artocapus artilis) flour blends and lower than 30.80% in African breadfruit-soybean-corn flour blend reported by [2]. The carbohydrate and energy values ranged from 38.25 – 65.15% and 333.27 – 386.33 Kcal/100g respectively, and significantly (P<0.05) decreased with increasing amount of African breadfruit seed flour in the blends. James and Nwabueze [2] reported 48 00% carbohydrate in African breadfruit-soybean-corn flour blend while Ajani et al. [20] reported a higher range (96.91 to 97.64%) for wheat-breadfruit (Artocapus artilis) flour blends. The energy content of African breadfruit-soybean-corn flour blend (389.00 Kcal/100g) reported by [2] was higher than those recorded in this research.

Table 3: Proximate composition and Energy Values of Whole African breadfruit seed, Maize and Coconut blends.

Sample	Moisture content (%)	Ash (%)	Crude Fat (%)	Crude Fibre (%)	Crude Protein (%)	Carbohydrate (%)	Energy (Kcal/100g)
A	$3.65{\pm}0.01^{b}$	$2.12{\pm}0.12^{d}$	$5.09{\pm}0.01^{f}$	$10.18{\pm}0.00^{f}$	$13.81{\pm}0.01^{f}$	$65.65{\pm}0.03^{a}$	$386.33{\pm}0.01^{a}$
B	$3.52{\pm}0.01^{e}$	$2.19{\pm}0.01^{c}$	$7.32{\pm}0.02^{e}$	$16.81{\pm}0.01^{e}$	$20.28{\pm}0.01^{e}$	$49.88{\pm}0.01^{b}$	$346.52{\pm}0.12^{b}$
C	$3.78{\pm}0.10^{a}$	$2.20{\pm}0.00^{c}$	$7.45{\pm}0.01^{d}$	$17.82{\pm}0.04^{d}$	$20.84{\pm}0.12^{d}$	$47.91{\pm}0.01^{c}$	$342.05{\pm}0.01^{c}$
D	$3.59{\pm}0.02^{d}$	$2.67{\pm}0.02^{b}$	$7.82{\pm}0.00^{c}$	$18.58{\pm}0.01^{c}$	$23.16{\pm}0.01^{c}$	$44.18{\pm}0.12^{d}$	$339.74{\pm}0.02^{d}$
E	$3.49{\pm}0.01^{f}$	$3.22{\pm}0.01^{a}$	$8.36{\pm}0.01^{b}$	$19.61{\pm}0.03^{b}$	$25.33{\pm}0.01^{b}$	$39.99{\pm}0.01^{e}$	$336.52{\pm}0.01^{e}$
F	$3.63{\pm}0.01^{c}$	$3.25{\pm}0.02^{a}$	$8.43{\pm}0.01^{a}$	$20.34{\pm}0.10^{a}$	$26.10{\pm}0.01^{a}$	$38.25{\pm}0.01^{f}$	$333.27{\pm}0.10^{f}$

A =0:95:5, B = 20:75:5, C = 25:70:5, D = 30:65:5, E = 35:60:5, F = 95:0:5 of Whole African breadfruit seed: Maize: Coconut blends. Values are Means ± standard deviation of triplicate determination, and means along the same column with different superscript are significantly different at P<0.05.

3.2 Soluble (SDF), Insoluble (IDF) and Total (TDF) Dietary Fibre Content of Snack Bars produced with different Levels of Whole African Breadfruit Seed Flour.

Soluble (SDF), insoluble (IDF) and total dietary fibre (TDF) contents of snack bars produced with different levels of whole African breadfruit seed flour, maize flour and coconut grit blends are shown in Table 4. SDF content ranged from 2.87 to 5.18%. IDF content was between 7.25 and 14.76%, while TDF ranged from 12.43 to 17.63%. SDF significantly (P<0.05) decreased, while IDF and TDF increased significantly with increasing addition of whole African breadfruit seed flour in the snack bars. This could imply that whole African breadfruit seed flour contributed significantly to the fibre content of the snack bars.

Obasi and Nwabueze [21] reported lower results; TDF range of 10.23 to 10. 86%, 9.09 - 9.57 for IDF and a range of 1.14 to 1.29% for SDF in African breadfruit seed based high fibre snacks. The differences observed here could be due to the method of processing used. Also, TDF range of 4.7 to 12.8g/100g, SDF of 1.8 to 4.9g/100g, IDF of 2.9 to 7.9g/100g was reported for cereal bars enriched with dietary fibre and omega 3 [22]. This report is slightly lower than the results obtained in this research. Paiva et al. [23] in their research of food bars manufactured with agro industrial by-products and waste, reported higher TDF (11.61-21.19%), higher IDF (10.21-19.34%), but a lower SDF (1.40-1.85%).

According to EFSA [24], a food can be referred to as high in fibre provided that the food contains at least 6 g/100g or 3 g/100Kcal of dietary fibre. All the snack bars in this research (with whole African breadfruit seed flour, including the control) contained as high as 12.43 to 17.63 g/100g dietary fibre, and therefore qualifies to be named “high fibre snack bars”. Fibre is important for the removal of waste from the body thereby preventing constipation and many health disorders. Consumption of vegetable fibre has been shown to reduce the cholesterol level, risk of coronary heart diseases, colon and breast cancers and hypertension. It also enhances glucose tolerance and increases insulin sensitivity [25].

Table 4: Soluble, Insoluble and Total Dietary Fibre Content of Snack Bars Produced with Different Levels of Whole African Breadfruit Seed Flour.

Snack bar ABS:MF:CG	SDF %	IDF %	TDF %
A (00:95:5) (Control)	5.18 ± 0.00^a	7.25 ± 0.01^f	12.43 ± 0.02^f
B (20:75:5)	3.65 ± 0.00^b	10.26 ± 0.00^e	13.91 ± 0.00^d
C (25:70:5)	3.41 ± 0.00^c	10.46 ± 0.01^d	13.87 ± 0.02^e
D (30:65:5)	3.37 ± 0.02^d	10.66 ± 0.01^c	14.03 ± 0.03^c
E (35:60:5)	3.13 ± 0.02^e	11.90 ± 0.01^b	15.03 ± 0.03^b
F (95:00:5)	2.87 ± 0.01^f	14.76 ± 0.02^a	17.63 ± 0.03^a

Values are Mean ± standard deviation of triplicate determinations. Values with different superscript along the same column are significantly different at P<0.05.
ABS: MF: CG = African breadfruit: Maize: Coconut blends.
SDF = soluble dietary fibre, IDF = Insoluble dietary fibre, TDF = Total dietary fibre.

3.3 In Vitro Protein Digestibility of Snack Bars produced with different Levels of Whole African Breadfruit Seed Flour.

Table 5 shows the in vitro protein digestibility of snack bars. In vitro protein digestibility (IVPD) of snack bars ranged from 63.93 to 88.19%. Significant differences (P<0.05) existed in IVPD value at all levels of African breadfruit seed flour substitution in snack bars. Except for control snack bars, IVPD decreased significantly (P<0.05) with increasing level of African breadfruit seed flour. This reduction could be attributed to the corresponding increase in the dietary fibre content (Table 4) of the snack bars. Alonso et al. [26] reported similar reduction in protein digestibility with increase in dietary fibre in Faba and Kidney bean flour-based foods. The presence of high levels of insoluble fibre and high concentrations of anti-nutritional factors in foods (which are based on less refined cereals and grain legumes as major sources of protein) are responsible for poor digestibility of protein [27].

Yadav and Bhatnagar [28] reported 12.50 – 25.60 g IVPD for cereal bars formulated from defatted soy flour. Other researcher reported 25.43 – 71.57% in vitro protein digestibility of tigernut-pigeon pea biscuits [29], 70.43 – 72.86% protein digestibility in extruded African breadfruit-soy based snacks [30] and 76 – 92% IVPD in extruded insect-riched snacks [31]. The IVPD value of the snack bars in this research are also close to those mentioned in literature [32] on commonly consumed Mexican snack foods: Bologna (75.4%), corn tortillas (77.9%), fried steak (80.7%), white bread (83.8%), hamburger (84.4%), breakfast roll (85.1%).

Table 5: In Vitro Protein and Starch Digestibility of Snack Bars Produced with Different Levels of Whole African Breadfruit Seed Flour.

Snack bar (ABS:MF:CG)	**Protein digestibility (%)**	**Starch digestibility (%)**
A (0:95:5)	88.19 ± 0.01^a	57.48 ± 0.00^a
B (20:75:5)	84.40 ± 0.01^b	48.81 ± 0.02^b
C (25:70:5)	72.15 ± 0.02^c	43.71 ± 0.02^c
D (30:65:5)	68.39 ± 0.01^d	36.05 ± 0.07^d
E (35:60:5)	65.82 ± 0.02^e	32.48 ± 0.01^e
F (95:0:5)	63.93 ± 0.01^f	29.59 ± 0.02^f

ABS: MF: CG=African breadfruit flour: Maize flour: Coconut grit blend.

3.4 In Vitro Starch Digestibility of Snack Bars produced with different Levels of Whole African Breadfruit Seed Flour.

Results of the substituted levels of African breadfruit seed flour on in vitro starch digestibility (IVSD) of snack bars is shown in Table 5. In vitro starch digestibility of snack bars ranged from 29.59 to 57.48%. Azzollini et al. [31] reported a range of 34 to 57% for IVSD of extruded insect-rich snacks. Lower values (11.6 – 13.4%) were reported [33] for snacks from unripe plantain, chickpea and maize flour blends, and 4.65 mg/g starch digestibility for multi-millet extruded snacks [34]. James and Nwabueze [30] also reported lower values of in vitro starch digestibility (27.45 – 28.23%) in extruded African breadfruit-soy based snacks.

IVSD decreased with increasing addition (substitution) of African breadfruit seed flour (ABS) in the snack bars. The degree of starch digestibility is mainly linked to its gelatinization [35]. The reduction in in vitro starch digestibility due to increase in African breadfruit flour is probably due to corresponding increase in fat (lipid) content (as shown in Table 3 of proximate compositions) and consequent limited starch transformation. It is reported that the presence of 5% fat reduces the mechanical energy and the melt temperature, causing a decrease in starch gelatinization and thus starch digestibility [36]. Fat is said to prevent absorption of moisture and gelatinization by forming a hydrosphobic layer outside starch granules.

It was also observed that the higher the proportion of African breadfruit seed flour in the formulation, the higher the crude protein content (Table 3), and consequently, the lower the In Vitro Starch Digestibility. This finding is in line with the report that the presence of protein in the food matrix may influence the rate of starch digestion [37]. The digestibility of starches and proteins in various cereal products is significantly affected by their interaction with each other. Starch digestibility have been observed to be influenced by the presence of even small amount of protein in cereals and other food products [37].

3.5 In Vitro Glycemic Index of Snack Bars produced with different Levels of Whole African Breadfruit Seed Flour.

Results of in vitro glycemic index (IVGI) of snack bars produced with African breadfruit seed flour, maize and coconut blends are shown in Table 6. In vitro glycemic index of snack bars ranged from 44.37 to 57.34, with the control having the highest value. IVGI of snack bars decreased significantly ($P<0.05$) with increasing level of African breadfruit seed flour in the formulation. This could probably be as a result of the increase in dietary fibre content of the snack bars. A negative correlation was observed (Fig. 2) between the in vitro glycemic index and the total dietary fibre of the whole African breadfruit seed-based snacks, with an equation 5:

$$y = -0.2963x + 28.832 \quad (5)$$

Table 6: In Vitro Glycemic index of Snack Bars produced with different Levels of Whole African Breadfruit Seed Flour.

Snack bars	(%) In Vitro Glycemic index
A (0:95:5)-Control	57.34 ± 0.00^{a}
B (20:75:5)	48.35 ± 0.01^{b}
C (25:70:5)	47.43 ± 0.00^{c}
D (30:65:5)	46.82 ± 0.01^{d}
E (35:60:5)	46.26 ± 0.01^{e}
F (95:0:5)	44.37 ± 0.01^{f}

Means in the same column with different superscript are significantly different at $P<0.05$.
A =0:95:5, B = 20:75:5, C = 25:70:5, D = 30:65:5, E = 35:60:5, F = 95:0:5 of African breadfruit: Maize: Coconut blends

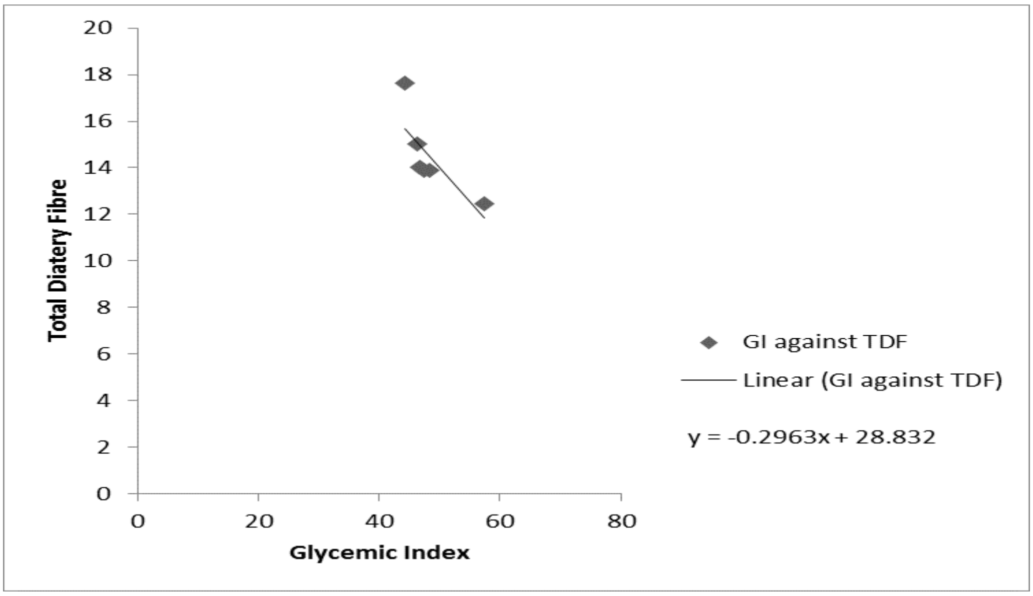

Fig. 2: A graphical plot showing the correlation between the in vitro Glycemic index and Total Dietary Fibre content of Snack bars produced from whole African breadfruit seed, maize and coconut blends.

There are no references in literature about the GI of snack bars or cereal bars. However, these values are much lower than those mentioned in literature [18] for boiled potatoe (101), white bread (100), rice (81), biscuit (79), spaghetti (78), peas (74), potatoe chips (74) and beans (60), higher than those mentioned for lentils (42), but the same with chickpeas (47). GI of snack bars were also in the same range with those reported (47.93-49.74%) in fiber-rich extruded breakfast cereals [19]. Higher values were reported [38] in sweet corn (60), croissant (67) and corn flakes (92), while 57.57 – 67.78 was reported [39] as predicted GI for non-parboiled and parboiled rice.

Glycemic index (GI) is a property of starchy food, which describes the rate of blood glucose absorption after consumption [39]. Control snack bars (GI=57.34) could be referred to as 'medium GI food' based on standard classification [40]. Snack bars produced with whole African breadfruit seed flour had IVGI ranging from 44.37 to 48.35, and can be classified as 'low GI foods'. The consumption of these snack bars could be beneficial, since the consumption of a low GI foods (GI ≤ 55) has been shown to have positive health benefits in a variety of chronic diseases including insulin resistance, diabetes, cardiovascular disease, obesity and cancers [40, 41]. A reduction in the GI of starch-based foods can be obtained with the use of fibres which could be beneficial to diabetic patients by adding in the control of postprandial insulin release [19]. This confirm the fact that the fibres from African breadfruit and coconut are beneficial [12], thus making the snack bars of health importance to the consumers.

IV. Conclusions

The results obtained from this study have demonstrated that possible nutritious snack bars with high fibre and low glycemic index can be developed from composite blends of African breadfruit seed and maize flour with coconut grits. In vitro protein and starch digestibility of the snack bars were recommendable. These snack bars may be considered as possible "health food" alternatives for people on weight control diets, diabetics, or those seeking for healthier eating habits.

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