

Influence of Dehulled African Breadfruit Substitution on Starch Digestibility, Dietary Fibre and Glycemic Index of High-Fibre Snack Bars from Maize and Coconut Flour Blends

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Abstract

In this article, African breadfruit seeds were dehulled and made into flour alongside with maize and coconut, and the flours analyzed of their particle sizes and nutritive value. Snack bars were prepared by substituting different levels of dehulled African breadfruit (*Treculia africana*) seed flour with maize flour at a constant level of coconut grits viz., 0:95:5=T₀, 20:75:5=T₁, 25:70:5=T₂, 30:65:5=T₃, 35:60:5=T₄, 95:0:5=T₅. The snack bars were analyzed of its starch fractions, in vitro starch digestibility, glycemic index and dietary fibre fractions. Rapidly digestible starches (RDS) ranged from 26.32 – 34.62 %, slowly digestible starches (SDS) ranged from 34.46 – 38.71 %, and resistant starch (RS) content was from 3.15 to 9.24 %, while total starch content (TS) was 62.44 – 72.42 %. In vitro starch digestibility (IVSD) and glycemic index (IVGI) ranged from 34.29 – 57.48 % and 47.32 – 57.34 % respectively. Dietary fibre content showed 3.46 – 5.18%, 6.66 – 13.72% and 10.72 – 17.18 % for soluble dietary fibre (SDF), insoluble dietary fibre (IDF) and total dietary fibre (TDF) respectively. SDS and SDF increased, while IVSD and IVGI decreased significantly ($p < 0.05$) with increase in dehulled African breadfruit flour substitution. The higher the TDF, the lower the glycemic index (GI) of the snack bars. All snack bars prepared showed high fibre content and low – medium GI, indicating that they could be useful for consumers interested in weight management or battling diabetes.

Keywords: Snack Bars, Dehulled African Breadfruit Seed, Slowly Digestible Starch, Dietary Fibre, Starch Digestibility, Glycemic Index.

Introduction

Recently, the consumption of snacks has significantly increased due to changes in lifestyle of the populace and the availability of different forms of snack foods in the market. There is also a growing demand by consumers for foods that are natural, healthy and convenient. Therefore, food processors are attempting to produce convenient foods by modifying food compositions, utilizing nutritionally rich local materials, to improve the values of snack foods.

Snack bars, sometime called cereal bars, are made from cereals such as wheat, rye, rice, oat and maize. Nuts, fruits, chocolates and candies are other ingredients that enhance the nutrient content, taste and flavor of snack bars, usually with syrups as a glue to bind the

ingredients together for proper shape formation. Nowadays, nutritious but under-utilized food crops are being engaged in food production. African breadfruit (*Treculia africana*), an under-utilized edible woody plant, is grown in outlying fields and around homesteads, in Nigeria especially in the rainforest regions, and other African countries. There is an increased interest in African breadfruit seed, because of it constitutes a cheap source of vitamins, minerals, proteins, carbohydrate, fats and dietary fibre (Edima-Nyah *et al.*, 2023). Traditionally, the seeds are eaten boiled, baked, roasted, dehulled and toasted with fresh maize or coconut. There is therefore need to utilize these seeds in convenience food formulations that will be attractive and acceptable to consumers, and thereby increase its utilization. Maize (*Zea mays*), also known as corn, is a multipurpose crop, providing fuel and food for human being and feed for animals (such as poultry and other livestock). Its grain has great nutritional value and can be used as raw material for manufacturing many industrial products. (Afzal *et al.*, 2009).

Maize has become a staple food in many parts of the world, with total production of maize surpassing that of wheat and rice. However, little of this maize is consumed directly by humans; most is used for corn ethanol, animal feed, and other maize products, such as corn starch and corn syrup (Edima-Nyah *et al.*, 2020a). Maize is also used in making ethanol and biofuels. Genetically Modified maize made up 85% of the maize planted in the United States in 2009. In Nigeria, fresh boiled maize is a delicacy with dehulled and toasted African breadfruit seed as snacks. Coconut, (*Cocos nucifera*), is one of the palm species with significant economic importance and cultivated mainly for the endosperm. The coconut provides a nutritious source of meat, juice, milk, and oil that has fed and nourished populations around the world for generations. Nearly one third of the world's population depends on coconut to some degree for their food and their economy. Coconut is highly nutritious and rich in fiber, vitamins, and minerals. It is classified as a "functional food" because it provides many health benefits beyond its nutritional content. Several food uses or products exist for coconut. Coconut meat is dried to 2.5% moisture content, shredded, and used in cakes, candies, and other confections. The uses of local food materials for innovative food products for promoting health benefits are increasingly necessary in functional food production.

Statement of Research Problem

The desire for convenience to compliment the busy lifestyle of many Nigerians has caused them to depend on convenient foods such as snacks and ready-to-eat foods which can be eaten directly or reconstituted with cold or warm water/milk. Available in the market are high calorie and fat, low protein, fibre and micronutrient, snacks such as biscuits, chin-chin, cookies, and the likes. The increasing awareness of the importance of dietary fibre has led to increased demand for fibre-rich ingredients and products. Snack bars are known for their convenience and balanced nutrient composition (Silva *et al.*, 2013). The raw materials (African breadfruit seed, maize and coconut) chosen for this research could be possible sources of these nutrients which most of the snacks currently available in the markets lack,

but are desired by consumers who are seeking healthy, convenience snack foods, with high slowly digestible starch, fibre and low glycemic index. African breadfruit is readily available in Nigeria and there are no known snack bars with this nutritional balance anticipated from this source.

Objectives of the Study

The aim of this research is therefore to:

- Substitute different levels of dehulled African breadfruit seed flour in maize - coconut blends to formulate high fibre snack bars, and
- Determine the influence of the dehulled African breadfruit seed flour substitution on the starch composition, dietary fibre content, starch digestibility and the glycemic index of the snack bars.

Materials and Methods

Source of Materials

African breadfruit seeds were purchased from Ndoro market, Abia State. White dent maize was obtained from Etaha Itam main market, Uyo. Coconuts were obtained from a local farmer in Uyo, Akwa Ibom State.

Processing of Materials

Production of dehulled African breadfruit seed flour

African breadfruit seeds, previously washed and drained, were parboiled at 100°C for 15 min (to facilitate the separation of the seed coats from the endosperm). The parboiled seeds were drained through stainless steel sieve and allowed to stand for 20 min to further soften the seed coat and effect cooling. Dehulling was by cracking the grains using Victoria Grain Mill (Model Ref: 530025, Colombia), and winnowed to obtain clean dehulled seeds. The dehulled seeds were dried for 5 h at 60°C in a hot air oven (Precision Compact Oven, Model: PR305225M) and the temperature increased to 150°C for toasting of the seeds for 20 min. Toasted seeds were milled to flour using a manual mill (Victoria Grain Mill, Model Ref: 530025), packaged and stored at ambient temperature (27±2°C) in a clean plastic container with a secured cover.

Production of maize flour

Maize grains were processed into flour according to the procedures outlined by Edima-Nyah *et al.* (2022). The grains were sorted to remove extraneous materials and cleaned by winnowing. The cleaned maize was toasted at 150 °C for 20 min in a hot air 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, labelled and stored at room temperature.

Production of full fat coconut grits

Coconut was processed to grits following the steps described by Edima-Nyah *et al.* (2022). Mature coconuts were harvested, dehusked, cracked, and the coconut flesh was manually removed from the hard endocarp with the aid of a sharp pointed stainless-steel knife. The flesh was grated manually (with a plastic grater) to shreds. The grated flesh was dried at 60°C and toasted at 150°C in a Precision Compact Oven (Model: PR305225M). The toasted shreds were then milled with a hand operated colloid mill (Victoria Grain Mill, Model Ref: 530025, Colombia) to yield coconut grits. The grits were stored in a plastic container at room temperature until used.

Characterization of Flours

The particle sizes of the raw materials were determined according to the AOAC method (2005) using a shaker sieve mesh with a series of sieves which varied from 20 to 100 mesh. The sieves were vibrated at the speed of 5000 rpm and the quantity of flour retained in each sieve was reported as percentage flour retained.

Product Development

Table 1 shows the formulation of flour blends and the recipe for the development of snack bars. Flours of dehulled African breadfruit seeds, maize and coconut were blended at the ratio of 0:95:5 (T₀), 20:75:5 (T₁), 25:70:5 (T₂), 30:65:5 (T₃), 35:60:5 (T₄) and 95:0:5 (T₅) respectively. Ingredients for baking consisted of dry ingredients (solid phase) and the liquid ingredients (binder phase). The dry ingredients included salt, baking powder (sodium bicarbonate), milk powder, margarine, nutmeg flour, in addition to the dehulled African Breadfruit Seed flour, Maize Flour, Coconut Grits. The liquid ingredients were caramel, coconut oil and water.

Table 1: Flour Blend Formulation and Recipe for Snack bar Development

	Formulations					
Ingredients	T ₀	T ₁	T ₂	T ₃	T ₄	T ₅
Flour Formulations (%)						
A	0	20	25	30	35	95
M	95	75	70	65	60	0
C	5	5	5	5	5	5
Dry ingredients (g/100g of flour)						
Salt	0.2	0.2	0.2	0.2	0.2	0.2
Margarine	15	15	15	15	15	15
Baking powder	2	2	2	2	2	2
Milk powder	5	5	5	5	5	5
Nutmeg powder	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

A = Dehulled African breadfruit seed flour, M = Maize flour, C = Coconut grits.

Production of Snack Bars

The snack bars were produced, according to the method described by Edima-Nyah *et al.* (2019). The dry ingredients were manually mixed together in a stainless-steel bowl for about 3min to obtain a uniform mixture. The liquid ingredients (caramel and coconut oil) were added and mixed for 3min, water was incorporated slowly and the entire dough was mixed thoroughly for about 2min to obtain 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 tops and give the bars the desired shape. The dough was baked in an oven at 150°C for 25min. They were cooled to about 60°C, de-panned and cut into bars sizes: 5cm x 3cm x 2cm. The bars were further dried in an air-circulation oven at 60°C for 6h to reduce the moisture content, cooled at ambient temperature (27±2°C) and packaged in a high-density polyethylene. The packaged snack bars were labeled, sealed using an electronic sealing machine, Double Leopard (Model: SP 200H, Taiwan) and stored at ambient temperature in the laboratory for various determinations.

Analytical Procedures

Determination of Proximate Composition

Proximate analyses of the materials were carried out using standard methods of AOAC (2005) for moisture content, crude fat, crude protein, total ash, crude fiber and carbohydrate.

Determination of Energy Value

The total energy was determined by the method described by Osborne and Voogt (1978). The total energy or the caloric values was estimated by calculation using the water quantification factors of 4, 9 and 4 kcal/100g respectively for protein, fat and carbohydrate as expressed below. Calorific value (Kcal/100g) = $P \times 4 + F \times 9 + C \times 4$. Where: P = Protein content (%), F = Fat content (%), C = Carbohydrate content (%)

Determination of Anti-Nutrient Factors

Tannin, phytate, and trypsin inhibitor activity content were determined using the standard method (Onwuka, 2005). Oxalate and saponin contents were determined using the solvent extraction gravimetric method described by AOAC (2005).

Total Starch (TS), Resistant Starch (RS) and Digestible Starch

i. Total Starch and Resistant Starch

Resistant starch was determined by Megazyme Resistant Starch Assay procedure (AOAC, 2005). Boiled and homogenized samples were incubated with 10 ml of HCl-KCl buffer (pH

1.5) and 20 mg pepsin for 1h at 37°C. Then, samples were incubated with pancreatic α -amylase (10 mg/ml) solution containing amyloglucosidase (AMG) for 16 h at 37°C with constant shaking for starch hydrolysis. After hydrolysis, sample mixtures were washed thrice with ethanol (99% v/v and 50% ethanol). The separated pellet from supernatant was further digested with 2 M KOH. Digested pellet and supernatant were separately incubated with AMG. Megazyme glucose oxidase–peroxidase kit was used to determine the amount of glucose released. The absorbance was read in a spectrophotometer (Jenway 6405, UK) at 510 nm wavelength against the reagent blank. The glucose content of the supernatant and digested pellet was used in calculation of digestible starch (DS) and resistant starch (RS) respectively, by applying the factor of 0.9. Total starch (TS) was then derived as the sum of DS and RS.

ii. Rapidly digestible starch (RDS) and slowly digestible starch (SDS)

A modified *in vitro* method of Goñi *et al.* (1997) was adopted. The boiled food sample was homogenized and incubated with 10 ml HCl–KCl buffer (pH 1.5) and 20 mg pepsin at 37°C for 1 h with constant shaking. The pH was raised with the addition of 200 μ L pancreatic α -amylase solution (1.5 mg/10ml phosphate buffer) and incubated at 40°C for 45 min. The enzyme activity was stopped by adding 70 μ L Na₂CO₃ solution and samples diluted to 25 ml with tris-maleate buffer (pH 6.9). Exactly 5ml of pancreatic α -amylase solution was then added to the mixture and incubated at 37°C with constant shaking. Aliquots (1 ml) of the mixtures were taken in duplicates at 30- and 120-min intervals from the mixtures and transferred into boiling water with vigorous shaking for 5 min to inactivate the enzyme activity. Aliquots (2 ml) were treated with 3 ml of 0.4 M sodium acetate buffer (pH 4.75) and 60 μ L of AMG (3300 U/ml) then incubated at 60°C for 45 min with constant shaking. The glucose content released was quantified using a glucose oxidase-peroxidase (GOPOD) kit. Glucose was converted into starch by applying the factor of 0.9. The 30- and 120-min hydrolysis represented the rapidly digestible starch (RDS) and slowly digestible starch (SDS) respectively.

Determination of *In Vitro* Starch Digestibility

In vitro starch digestibility was determined using the Method of Singh *et al.* (2012). 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 °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-dinitrosalicylic 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 °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.

***In Vitro* Glycemic Index Analysis**

In vitro glycemic index (GI) of the snack bars was determined according to the method described by Goñi *et al.* (1997) as modified by Leoro *et al.* (2010). 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 1 ml 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 μ l 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 (Goñi *et al.*, 1997). 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:

$$AUC = C_{\infty} (t_f - t_0) - (C_{\infty}/k) [1 - \exp (t_f - t_0)] \quad (2)$$

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_0 = 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).

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

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

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

Determination of Soluble, Insoluble and Total Dietary Fibre

Soluble, insoluble and total dietary fibre in foods was determined using the Enzymatic-Gravimetric method MES-TRIS Buffer (AOAC, 2005). 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 °C, protease at 60 °C, and amylo-glucosidase at 60 °C. Enzyme digestates were filtered through tritlled 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 °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 tritlled 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 °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.

Statistical Analysis

Data obtained from the analyses conducted were subjected to a one-way analysis of variance (ANOVA) using IBM SPSS version 20 software. Significant differences at $p < 0.05$ were determined. Mean separation was carried out using the New Duncan Multiple Range Test (NDMRT).

Results and Discussion

Particle size distribution of dehulled African breadfruit seed, maize and coconut flours for snack bars development

Results of particle size analysis of the flours for use in snack bars production is presented in Table 2. Significant ($P < 0.05$) differences existed between all the particle sizes the flour samples retained at 2.36 mm, 2.00 mm, 1.18 mm, 425 μ m, and 75 μ m sieve opening. Dehulled African breadfruit seed flour had the finest particles, with about 10%, 71% and 17% flour particles measuring 1.18 mm, 425 μ m and 75 μ m respectively; followed by maize flour, with 36%, 56% and 5% at the same openings. Coconut showed a different particle size distribution (a reverse) from the other flour samples. About 70%, 22%, 4% and 2% coconut particles were obtained at 2.36mm, 2.00mm, 1.18mm and 425 μ m respectively. The particles of coconut were larger and gritty in nature. This is probably the reason it is referred to as grits. All raw materials showed heterogeneous particle size distribution. These particle size distributions could have been the reason for the unique chewiness characteristic of the snack bars.

Edima-Nyah *et al.* (2022) reported heterogeneous particle size distribution with 7%, 67% and 24% retention at sieve no 0.16 (1.18 mm), 0.40 (425 μ m) and 0.200 (75 μ m) respectively in malted African breadfruit seed flour. Leoro *et al.* (2010) also reported heterogeneous

particle size distribution in passion fruit fibre with 29 %, 32 % and 22.5 % retention between 20-32 mesh, 32-60 mesh and <100 mesh, respectively.

Table 2: Particle size distribution of Dehulled African breadfruit seed flour, Maize flour and Coconut grits.

Samples	Sieve No. (openings)/Weight Retained (g/100g)				
	0.8 (2.36mm)	0.10 (2.00mm)	0.16 (1.18mm)	0.40 (425µm)	0.200 (75µm)
A	0.01±0.16 ^c	0.01±0.05 ^c	10.52±0.06 ^b	71.63±0.11 ^a	17.75±0.13 ^a
M	0.33±0.32 ^b	0.30±0.12 ^b	36.74±0.04 ^a	56.80±0.06 ^b	5.26±0.02 ^b
C	70.12±0.22 ^a	22.95±0.11 ^a	4.14±0.11 ^c	2.60±0.10 ^c	0.06±0.04 ^c

Means in the same column with different superscript are significantly different at $p < 0.05$.

A = Dehulled African breadfruit seed flour, M = Maize flour, C = Coconut grits.

Proximate composition and energy values of dehulled African breadfruit seed, maize and coconut flours for snack bars development

Results of the proximate composition and energy value of materials for development of snack bars is as presented in Table 3. Moisture content of materials ranged from 3.48 – 4.86 %. Moisture content below 10% is of advantage since it reduces the chances of spoilage by bacteria and increases the shelf life (Feili *et al.*, 2013). Coconut had the highest ash (6.28%) fat (42.12%), fibre (10.67%) and protein (27.11%) content followed by dehulled African breadfruit seed flour, which had 3.39%, 11.09%, 7.77% and 22.56% respectively. Edima-Nyah *et al.* (2022) reported higher contents of fibre (20.18%) and protein (23.32%) in malted African breadfruit seed flour, which could probably be due to degradation of reserved materials that brings about increase in the protein and fibre content. Gwirtz and Garcia-Casal (2014) reported lower protein (6.9%) and higher carbohydrate (73.58%) content compared with the result of this research. This could be due to varietal differences.

Coconut grits showed the highest energy value (531.41kcal/100g), followed by dehulled African breadfruit flour (397.29kcal/100g), while the maize flour showed the least value (370.43kcal/100g). The result of ash, fat, fibre, protein and carbohydrate content suggest that African breadfruit seed is a valuable source of nutrients and may be important for Nigeria as a developing country (James and Nwabueze, 2013).

Fibre content of coconut was significantly higher (10.67%) than those of dehulled African breadfruit (7.77) and maize (7.73%) flour. Coconut fiber stands out in importance from other fibre sources because; it slows down the rate of emptying food from the stomach, thus allowing food more time in the stomach to release minerals, leading to higher levels of minerals available for the body to absorb (Edima-Nyah *et al.*, 2022). Also, coconut fibre does not remove minerals from the body, unlike other fibre sources, but rather prevents mineral removals and consequently increases mineral absorption (Wasser, 2016). Risk of heart attack and stroke through blocked arteries is lower with coconut fibre (Schill and

Munz, 2013). It is also useful in appetite and obesity reduction, and prevention of colon diseases such as pile, appendicitis and hemorrhoids (Segura-Campos *et al.*, 2014).

Table 3: Proximate composition and Energy values of Dehulled African breadfruit seed flours, Maize flour and Coconut grits

Sample	Moisture content %	Ash content %	Crude Fat %	Crude Fibre %	Crude Protein %	CHO %	Energy value Kcal/100g
A	3.48±0.00 ^b	3.29±0.04 ^b	11.09±0.01 ^b	7.77±0.12 ^b	22.56±0.01 ^b	52.14±0.01 ^b	397.29±0.03 ^b
M	3.82±0.01 ^b	1.83±0.12 ^c	4.79±0.03 ^c	7.73±0.14 ^b	9.65±0.04 ^c	72.18±0.01 ^a	370.43±0.02 ^c
C	4.86±0.04 ^a	6.28±0.01 ^a	42.12±0.01 ^a	10.67±0.03 ^a	27.11±0.01 ^a	10.95±0.02 ^c	531.41±0.04 ^a

Means along the same column with different letters are significantly different at $p < 0.05$

A = Dehulled African breadfruit seed flour, M = Maize flour, C = Coconut grits, CHO = Carbohydrate.

Anti-nutrient Content of Dehulled African Breadfruit Seed, Maize and Coconut Grits for the Development of Snack Bars

Results of tannin, oxalate, phytate, saponin and trypsin inhibitor content of flours from dehulled African breadfruit seed, maize and coconut for the development of snack bars are presented in Table 3. Tannin content of dehulled African breadfruit seed flour (0.28%) was not significantly different from the maize flour (0.27%). The concentrations of tannin in the flours posed no health risk, since the reported lethal dose is 90 mg/100g (Ifie and Emeruwa, 2011; Maseta *et al.* 2016). Tannins are the oligomeric higher molecular of polyphenols compound occurring naturally in plants (Adeoti *et al.*, 2017). Due to their binding ability with protein and carbohydrate, tannin can inhibit digestive enzymes and reduces the bioavailability of proteins (Ayodele and Kigbu, 2003). The amount of oxalate in the processed flour (0.11 – 0.31 mg/100g), equally, could not be toxic under meal portion since they were lower than the safe level (15-30 g/100g food consumed) reported in literature for man (Coe *et al.*, 2005). Concentrations of phytate in the flours was 2.09 – 7.42 mg/100g, and were lower than 250 mg/100g, the amount considered lethal to health (Nagel, 2010; Maseta *et al.*, 2016). This indicated that the concentration of phytate in the flour samples were of acceptable safe levels. According to Kumar *et al.* (2010), high levels of phytates in human foods limit the bioavailability, consequently, utilization of minerals, especially calcium, magnesium, iron, manganese, by forming insoluble compounds that are indigestible. Adeoti *et al.* (2017) reported saponin content of 9.54 – 18.50 mg/100g for akee apple seed and ariel flour, which was higher than the content in snack bars (2.23 – 19.21 %). Saponin has both beneficial and adverse effects on human health. Apart from their hypocholesterolemic properties (Oakfenfall and Sidu, 1990), and also shows hemolytic activity by reacting with the sterols of erythrocyte membrane (Bauman *et al.*, 2000). Trypsin inhibitor activity in the flours ranged from 0.95 to 7.82 TIU/mg. Trypsin inhibitor activity has a lethal dose of 200mg/100g in human (Thapliyal *et al.*, 2014), therefore, the flours were considered safe for use for development of snack bars.

Table 4: Anti-nutrient Content of dehulled African Breadfruit Seed flour, Maize flour and Coconut grits for Snack Bars Development

Sample	Tannin (%)	Oxalate (mg/100g)	Phytate (mg/100g)	Saponin (%)	Trypsin Inhibitor (TIU /mg)
A	0.28±0.01 ^b	0.11±0.03 ^c	2.09±0.04 ^b	2.23±0.01 ^c	7.82±0.02 ^a
M	0.27±0.01 ^b	0.31±0.11 ^a	7.42±0.01 ^a	10.21±0.01 ^a	1.03±0.01 ^b
C	0.50±0.04 ^a	0.27±0.01 ^b	0.25±0.03 ^c	7.21±0.04 ^b	0.95±0.00 ^c

Values are means ± standard deviation of triplicate determinations. Means on the same column with different superscript are significantly different at $p < 0.05$. A = Dehulled African breadfruit seed flour, M = maize flour, C = coconut grits.

Starch fractions of snack bars developed from dehulled African breadfruit seed flour, maize flour and coconut grits

Table 5 shows the rapidly digestible starch (RDS), slowly digestible starch (SDS), resistant starch (RS) and total starch (TS) content of snack bars produced with dehulled African breadfruit seed flour, maize flour and coconut grit blends. RDS content ranged from 26.32 to 34.62 % for the dehulled African breadfruit-based snack bars, while the control recorded the lowest value (23.43 %). TS content was between 62.44 and 72.42 %, with 20 % African breadfruit-based snack bar showing the highest value. RDS and TS decreased significantly ($P < 0.05$) with increasing addition of dehulled African breadfruit seed flour and decreasing amount of maize flour in the blend. SDS and RS increased with increasing addition of dehulled ABS in the blend. RS content of snack bars produced with dehulled African breadfruit flour was between 3.15 to 9.24 %. SDS content ranged from 34.46 to 38.71 %. Sample T₅ (95:0:5) had the highest SDS (38.71 %) and RS (9.24 %).

RS are starches that are resistant to digestion and absorption in the human small intestine. This resistance according to AACC (2001) can provide benefits by reducing the caloric value of the food while providing energy to the bacteria of the colon, thus enhancing healthy fermentation there. RS are found in retrograded amylose, physically trapped starch, digestion-resistant starch granules, and fragments of chemically and thermally modified starches. As prebiotic, RS can promote the growth of beneficial microorganisms such as bifidobacteria, which exert a lot of beneficial effects on human body. Sajilata *et al.* (2006), in their study reported that, butyrate, a short chain fatty acid (SCFA) produced as a result of fermentation of RS has been hypothesized to reduce the risk of colon cancer and inflammatory bowel diseases. These properties make RS an important functional fibre component of foods, which can be exploited in the prevention and management of chronic non-communicable diseases.

Table 5: Starch fractions of snack bars developed with different levels of dehulled African breadfruit seed flour, maize flour and coconut grits

Snack bar	RDS (%)	SDS (%)	RS (%)	TS (%)
T ₀	23.43 ± 0.02 ^f	34.24 ± 0.00 ^e	6.49 ± 0.02 ^c	64.36 ± 0.02 ^e
T ₁	34.62 ± 0.00 ^a	34.46 ± 0.01 ^f	3.15 ± 0.01 ^f	72.42 ± 0.01 ^a
T ₂	33.22 ± 0.01 ^b	34.96 ± 0.01 ^d	4.06 ± 0.01 ^e	71.81 ± 0.00 ^b
T ₃	31.60 ± 0.01 ^c	35.62 ± 0.01 ^c	5.25 ± 0.01 ^d	68.54 ± 0.00 ^c
T ₄	29.86 ± 0.02 ^d	36.92 ± 0.01 ^b	6.85 ± 0.01 ^b	67.29 ± 0.08 ^d
T ₅	26.32 ± 0.02 ^e	38.71 ± 0.00 ^a	9.24 ± 0.01 ^a	62.44 ± 0.00 ^f

Means in the same column with different superscript are significantly different at $p < 0.05$.

RDS = Rapidly Digestible Starch, SDS = Slowly Digestible Starch, RS = Resistant Starch, TS = Total Starch.

T₀ = 0:95:5, T₁ = 20:75:5, T₂ = 25:70:5, T₃ = 30:65:5, T₄ = 35:60:5, T₅ = 95:0:5 of Dehulled African breadfruit seed: Maize: Coconut

***In-vitro* starch digestibility and *in-vitro* glycemic index of snack bars developed from dehulled African breadfruit seed, maize and coconut flours**

Results of *in-vitro* starch digestibility (IVSD) and *in-vitro* glycemic index of snack bars produced using dehulled African breadfruit seed, maize and coconut flour blends are presented in Table 6. IVSD of snack bars ranged from 34.29 – 57.48 %, showing significant decrease with increased level of dehulled African breadfruit seed flour. Same range of IVSD of 34 – 57 % was reported by Azzollini *et al.* (2018) in extruded snacks enriched with insects. Edima-Nyah *et al.* (2022) reported lower values (31.44 – 51.70 %) of ISVD in malted African breadfruit-based snack bars.

In vitro glycemic index (IVGI) of snack bars (as shown on Table 6) decreased with increased with 25 to 95 % dehulled African breadfruit flour substitution. Snack bars containing 25 – 95 % dehulled African breadfruit (T₂ – T₅) had low glycemic index (47.32 – 54.26), while 0 – 20 % (T₀ and T₁) had medium glycemic index (57.34 – 55.83). As glycemic index describes blood glucose absorption rate, these snack bars could be rated as 'low – medium glycemic index foods', according to standard classification (EFSA, 2011) and could be considered as healthy alternatives for consumers seeking to control body weight and healthier eating habits. Snack bars formulated with malted African breadfruit flour were reported by Edima-Nyah *et al.* (2022) to have lower glycemic index (45.65 – 53.42).

Table 6: *In-vitro* Starch digestibility and Glycemic index of Snack Bars developed from dehulled African breadfruit seed flour, maize flour and coconut grits

Snack Bars	IVSD (%)	IVGI (%)
T ₀	57.48 ± 0.00 ^a	57.34 ± 0.00 ^a
T ₁	53.57 ± 0.01 ^b	55.83 ± 0.01 ^b
T ₂	49.32 ± 0.02 ^c	54.26 ± 0.01 ^c
T ₃	47.52 ± 0.00 ^d	53.53 ± 0.01 ^d
T ₄	41.61 ± 0.01 ^e	51.46 ± 0.00 ^e
T ₅	34.29 ± 0.01 ^f	47.32 ± 0.01 ^f

Means $\pm$ SD of triplicate determination, means with different superscript in the same column are significantly ($p < 0.05$) different. $T_0 = 0:95:5$, $T_1 = 20:75:5$, $T_2 = 25:70:5$, $T_3 = 30:65:5$, $T_4 = 35:60:5$, $T_5 = 95:0:5$ of Dehulled African breadfruit seed: Maize: Coconut flour respectively

IVSD = *In vitro* starch digestibility, IVGI = *In vitro* glycemic index.

Soluble (SDF), insoluble (IDF) and total dietary fibre (TDF) content of dehulled African breadfruit seed flour, maize flour and coconut grits and the snack bars developed with the flour blends

Table 7 shows the soluble dietary fibre, insoluble dietary fibre and total dietary fibre content of dehulled African breadfruit seed, maize and coconut flours and snack bars produced with different levels of these materials. The SDF content of coconut (7.94%) was higher than that of African breadfruit (4.82%) and maize (3.86%). Dehulled African breadfruit seed flour had the lowest IDF and TDF. There was no significant difference between maize and dehulled African breadfruit seed in TDF. The dietary fibre content of snack bars ranged from 10.72 to 17.18 % TDF and 6.66 to 13.72 % IDF respectively. The SDF content ranged from 3.46 to 5.18 % and showed significant ($P < 0.05$) decrease with increasing addition of dehulled African breadfruit flour in the snack bars. The highest value of SDF (5.18 %) was from the control (T_0), while the lowest (3.46 %) was from T_5 (95:00:5). TDF and IDF increased significantly ($P < 0.05$) with increasing addition of dehulled African breadfruit seed flour in the snack bars. A range of 3.15 – 5.15 % for SDF, 7.23 – 19.23 % for IDF, and 12.33 – 22.39 % for TDF was reported by Edima-Nyah *et al.* (2022) in snack bars from maize-malted African breadfruit-coconut blend. Faber and Yuyama (2015) reported lower dietary fibre: 7.41 % TDF, 5.44 % IDF and 1.97 % SDF, for Amazon cereal dietary functional bar, compared to the snack bars. Flores-Silva *et al.* (2015) reported TDF range of 13.7 – 18.3 g/100g for gluten-free snacks from unripe plantain – chickpea and maize blends, which is within the range of the TDF of snack bars. These snack bars from dehulled African breadfruit flour could be referred to as “high fibre snack bars” since they contain more than 6 g/100g of dietary fibre (EFSA, 2010). This is important because fibre acts like a broom, sweeping through the intestinal contents and causing timely expulsion of parasites, toxins and carcinogens from the human system (Ramaswamy, 2014).

Table 7: Soluble, insoluble and total dietary fibre content of dehulled African breadfruit seed, maize and coconut flours and the Snack Bars produced with the flour blends.

Samples	SDF (%)	IDF (%)	TDF (%)
Flour samples			
A	4.82 $\pm$ 0.01 ^c	12.34 $\pm$ 0.00 ^c	17.77 $\pm$ 0.02 ^b
M	3.86 $\pm$ 0.02 ^{cd}	13.76 $\pm$ 0.02 ^b	17.63 $\pm$ 0.04 ^b
C	7.94 $\pm$ 0.01 ^a	30.16 $\pm$ 0.01 ^a	38.10 $\pm$ 0.02 ^a

Snack bars			
T ₀	5.18 ± 0.00 ^b	7.25 ± 0.01 ^e	12.43 ± 0.02 ^c
T ₁	4.05 ± 0.00 ^c	6.66 ± 0.03 ^f	10.72 ± 0.04 ^e
T ₂	3.85 ± 0.01 ^{cd}	7.25 ± 0.01 ^e	11.10 ± 0.02 ^d
T ₃	3.67 ± 0.01 ^d	7.85 ± 0.01 ^e	11.52 ± 0.02 ^d
T ₄	3.51 ± 0.01 ^e	9.26 ± 0.01 ^d	12.76 ± 0.01 ^c
T ₅	3.46 ± 0.02 ^f	13.72 ± 0.01 ^b	17.18 ± 0.03 ^b

Means in the same column with different superscript are significantly different at $P < 0.05$.

A = dehulled African breadfruit seed flour, M = maize flour, C = coconut grits, T₀ = 0:95:5, T₁ = 20:75:5, T₂ = 25:70:5, T₃ = 30:65:5, T₄ = 35:60:5, T₅ = 95:0:5 for dehulled African breadfruit: maize: coconut flour respectively.

SDF = Soluble Dietary fibre, IDF = Insoluble Dietary Fibre, TDF = Total Dietary Fibre

Influence of Total Dietary Fibre on the Glycemic Index of Snack Bars

Influence of the total dietary fibre on the glycemic index of snack bars was studied. A negative correlation was observed (Fig.1) between the *in vitro* glycemic index and the total dietary fibre of the dehulled African breadfruit seed-based snack bars. The correlation was expressed in the equation:

$$y = -0.554x + 42.14 \dots \dots \dots \text{Eqn. 1.}$$

This implies that, the higher the dehulled African breadfruit substitution and total dietary fibre (TDF) content, the lower the in-vitro glycemic index (IVGI) of the snack bar.

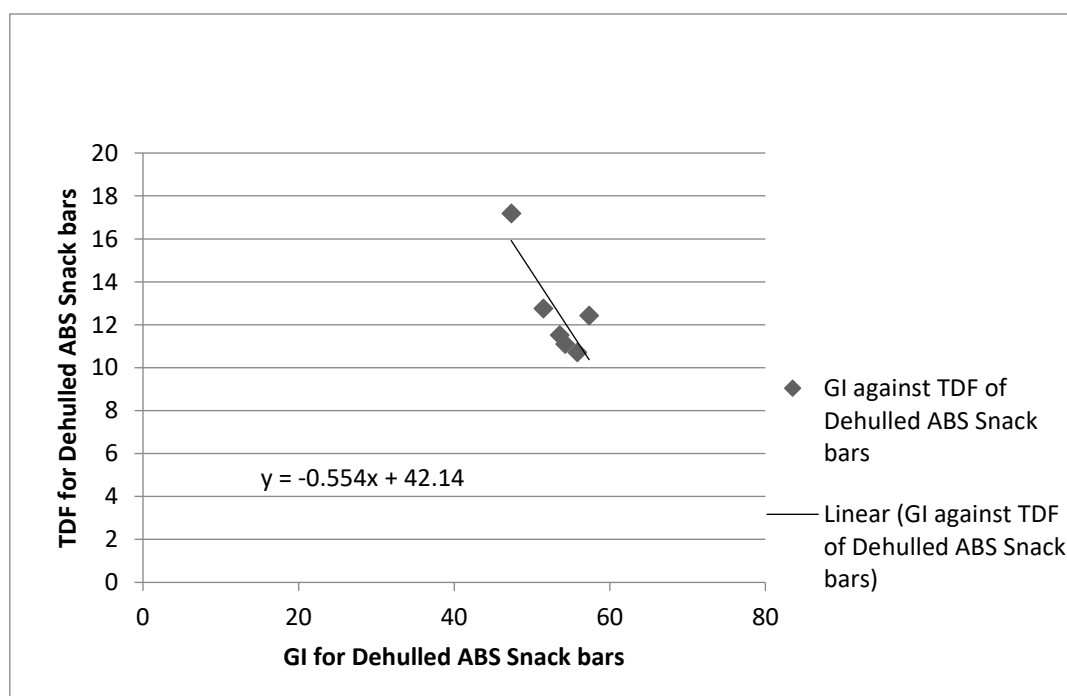


Fig.1: A graphical plot showing the correlation between in vitro Glycemic index and Total Dietary Fibre for Snack bars from dehulled ABS, maize and coconut grits.

TDF – Total Dietary Fibre, ABS – dehulled African breadfruit seed flour, GI – *In Vitro* Glycemic Index

Conclusion

The study showed that dehulled African breadfruit seed flour is a nutritious food material, with high protein, ash, and fibre content, with great potentials in high-fibre snack bars formulation. Increasing substitution of dehulled African breadfruit seed flour resulted in increased slowly digestible starch and soluble dietary fibre, and decreased *in-vitro* starch digestibility and glycemic index of the snack bars. All developed snack bars recorded high fibre content and low - medium Glycemic index. Dietary fibre, among other benefits, increases food volume without increasing caloric content to the same extent as digestible carbohydrates (making you feel full faster), and creates a state of satisfaction, thereby reducing appetite. Snacks bars could be useful for people looking for healthier eating habits and snack alternatives, and may equally be useful for those managing body weight.

Recommendations

Based on the research findings, it is recommended that;

- Individuals or Food industries seeking healthier snack alternatives should adopt and utilize this raw materials combination in production of snack bars with benefits of slowly digestible starches, high dietary fibre and low – medium glycemic index.
- Extrusion technology should be used in the production of the snack bars, since it has been reported to have numerous advantages over conventional baking process.

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