

Development and Quality Evaluation of Granola Bars from Yellow Maize, Tropical Almond Nut and Groundnut Flour Blends

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Abstract

In this study, five samples of the granola were produced from a standard method with yellow maize, tropical almond and groundnut grit composite flour blend in the ratio of 95:0:5 (A), 90:5:5 (B), 85:10:5 (C), 80:15:5 (D), 75:20:5 (E) with other baking ingredients. The granola bar samples were subjected to, functional properties, proximate, in-vitro digestibility, amino acid profile, following standard methods. Functional properties of flour blends such as water absorption capacity (1.33– 1.60 ml/g), oil absorption capacity (0.50 – 1.33 ml/g), swelling capacity (32.32 – 50.00 %) decreased significantly ($p < 0.05$), while foaming capacity (5.76 – 17.72 %), bulk density ($0.91 - 1.04 \text{ g/cm}^3$) and gelatinization temperature ($70.00 - 86.33 \text{ }^\circ\text{C}$) increased significantly ($p < 0.05$) with increasing levels of tropical almond nut flour in the blend. Proximate analysis showed significant ($p < 0.05$) decrease in carbohydrate (61.08 – 67.79 %) and significant ($p < 0.05$) increase in protein (9.30 – 13.65 %), fat (8.84 – 9.38 %), fibre (3.24 – 4.91 %) and ash (2.76 – 3.12 %) with increase in tropical almond nut in the blends. *In-vitro* protein digestibility (40.22 – 72.64 %) increased, while *in-vitro* starch digestibility (60.26 – 43.26 %) and glycemic index (57.20 – 39.84 %) decreased significantly ($p < 0.05$) with increasing level of tropical almond nut flour substitution. Amino acid profile of granola bars showed that they increased significantly ($p < 0.05$) with increasing level of tropical almond nut flour substitution in the blends. Leucine, isoleucine, phenylalanine, tryptophan, valine and threonine met the recommended dietary allowance (RDA) for adults. Acceptable granola bars could be produced with up to 20% tropical almond nut, with 75% yellow maize and 5% groundnut composite flour blends.

Keywords: Granola Bars, Tropical Almond Nut, Groundnut Grit, Yellow Maize Flour, Sensory Evaluation.

Introduction

The revolution of introducing innovative food is at the forefront of the world today. Functional foods are foods that offer health benefits beyond their nutritional value. In addition to nutrient-rich ingredients like fruits and nuts. The category also includes foods fortified with vitamins, minerals and probiotics. Functional foods are used to describe foods or food ingredients that provide health benefits beyond meeting basic nutrition needs due to their physiologically active food components (Gibson and Williams, 2000). Granola bars stand out among the numerous fast foods in the market due to their balanced nutritional content and convenience. The ingredients mainly used in granola bars development are

oats, grains, nuts, raisins and other cereals. With its high nutritional value, a granola bar can be a good choice for a quick meal (Edima-Nyah *et al.*, 2019a).

High-fibre cereals and snacks has gained more interest in the food industry. The dietary benefits of this type of food are outstanding and well documented. According to recent researches, a high fibre diet benefits the heart, prevents heart attack, lowers the risk of blocked arteries and strokes, lowers sugar and insulin levels in the blood, and blood cholesterol. In addition to reducing the risk of certain chronic diseases, high fibre diets fill the stomach and thereby reduces appetite. Thus, high fibre diets protect against obesity (Schill and Munz, 2013). Therefore, the consumption of dietary fibre plays an important role in preventing some diseases, including colon cancer, coronary heart disease, obesity, diabetes, and gastrointestinal disorders. Insoluble fibre, which is often found in cereals, is mainly related to intestinal regulations, whereas soluble fibre, mainly found in fruits and vegetables is involved in lowering blood cholesterol and glucose adsorption (Leoro *et al.*, 2010).

Cereals are members of a large monocotyledonous grass family, the Gramineae, which mainly consists of wheat, maize, barley, oats, rice, and sorghum (Anderson *et al.*, 2000). Cereal-based foods have been a staple dietary source for the world's population for centuries.

Yellow Maize (*Zea mays Linn*) is one of the important cereal crops with diverse uses as food, feed and industrial applications. As a food crop, it provides about 30% of the calories for approximately 4.5 billion people in 94 developing countries (Gwaritz and Gracia-Casal, 2014).

Tropical almond (*Terminalia catappa*) is a large tree that grows mainly in the tropical regions like, Asia, Africa and Australia. It is one of the underutilized tree species found in the tropics including Nigeria (Akpakpan and Akpabio, 2012). The fruit of the tree is a drupe about 5-7cm long and 3-5-5cm broad, green at first, then yellow and red when ripe. It contains a single fruit with edible fibrous pulp which is eaten by children as forage snack. Scientifically, the fruit has demonstrated anti-diabetic activity (Nagappa *et al.*, 2003).

Groundnut (*Arachis hypogaea L.*) is a leguminous oil seed crop cultivated in the semi-arid and tropical regions of the world. It is an important oil seed and food crop, a good source of protein, cooking oil and vitamins (Nautiyal, 2009).

Statement of Research Problem

In today's world, the busy lifestyle and desire for convenience has caused many to depend on convenient foods such as snacks, cereal bars/ granola, breakfast cereal, ready-to-eat foods which can be eaten directly or reconstituted with warm or cold milk or water. Snacks available in the market today are high in calories and fat and low in proteins, vitamins and micronutrients (Ranhotra and Vetter, 1991). The awareness of the importance of food fibers has led to the demand and subsequent development of a large market for fiber-rich products and ingredients (Rodriguez *et al.*, 2006). The raw material used for this research are possible sources of nutrients which some snacks lack.

Tropical almond, a native nut found in Akwa Ibom State, is grown as shade trees at the University of Uyo's town and annex campuses. Despite their availability, these trees are underutilized since many people are unaware that the flesh, pulp, or fruits are edible, and the hard nuts can be cracked open to access the edible seeds inside.

These fruits and nuts, when effectively utilized, can provide nutritional value as snacks or, if processed, can be integrated into food formulations to create healthy and nutritious products for consumers. Most market snacks are primarily wheat-based; however, wheat is not grown domestically, leading to reliance on costly imports, which in turn elevates snack prices. Thus, it is essential to design and manufacture granola bars that serve as a comprehensive or nearly comprehensive nutritious and healthy snack.

Objectives of the Study

General Objective

The main objective of this study is to develop and evaluate the quality characteristics of granola bars from blends of yellow maize flour, tropical almond nuts and groundnut.

Specific Objectives

The specific objectives of the study are to;

- i. Produce yellow maize flour, tropical almond nut and groundnut grits, and formulate blends for preparation of granola bars.
- ii. Determine functional properties of formulated blends.
- iii. Assess the proximate composition and energy value of granola bars.
- iv. Determine the invitro starch digestibility and glycemic index of granola bars.
- v. Assess invitro protein digestibility and amino acid profile of granola bars, and
- vi. Evaluation the sensory qualities of the granola bars.

Literature Review

Granola Bar

Granola bar is a highly nutritious product classified as a snack food and can be prepared using numerous ingredients. It is a bar-shaped food product, made by pressing cereals and dried fruit or berries, which are in most cases held together by glucose syrup (Asif, *et al.*, 2017). Consumers choose granola bars as an alternative to the less-healthy snacks, a quick source of energy before a workout, or a substitute for a meal (Sharma *et al.*, 2014). Composite flours are combinations of different grains, legumes, root, tubers with or without the addition of wheat flour with other flour sources to satisfy specific functional characteristics and nutrient composition (Bolarinwa *et al.*, 2015) and functional properties of composite flour includes water absorption capacity which measures the amount of water flour can absorb, affecting dough consistency and baking, oil absorption capacity, bulk density, swelling capacity and gelatinization temperature. According to the USDA, 100g of yellow maize contains 10.37g of water, 365Kcal of energy, 9.42g of protein, 74.26g of

carbohydrate and 4.74g of fat. Tropical almond nut (*Terminalia catappa*) nutritional value per 100g according to USDA nutritional data base has the following. Energy-575Kcal, carbohydrate-21.67g, protein-21.22g, total fat-49.42g, dietary fibre-12.20g, folates-50g, niacin-3.385mg, panthotenic acid-0.47mg, pyridoxine-0.143mg, riboflavin-1.014mg, thiamin-0.211mg, vitamin A-1 IU, vitamin E- 26mg, sodium-1mg, potassium-705mg, calcium-264mg, copper-0.996mg, iron-0.20mg, magnesium-268mg, manganese-2.285mg, phosphorous-484mg, selenium-2.5g, zinc-3.08mg, carotene-1g and lutein-zeaxanthin-1g. Nutritional composition of 100g of groundnut by USDA Food Data Central, April 2018 has the following. Water-6.5g, energy-567Kcal, protein-25.8g, fat-49.2g, ash-2.33g, carbohydrate-16.1g, fibre-8.5g, calcium-92mg, iron-4.58mg, magnesium-168mg, phosphorus-376mg, potassium-705mg, sodium-18mg, zinc-3.27mg, copper-1.14mg, manganese-1.93mg, selenium-7.2µg, thiamine-0.64gmg, riboflavin-0.135mg, niacin-12.1mg, pantothenic acid-1.77mg, vitamin B6-0.348mg, folate-240µg, choline-52.5mg, betaine-0.6mg, vitamin E-8.33mg. Granola bar studies in Africa shows that over the years, snacking has become a regular habit for majority of the population with increased need for food manufactures to meet consumers demand through product development. According to Eke-Ejiofor and Okoye (2018), the habit of snacking irresponsibly could lead to weight gain and nutrition deficiency. Sensory evaluation of high fibre snacks would investigate the acceptability and sensory attributes of the granola bars like taste, texture, appearance and overall acceptability.

Materials and Methods

Sources of Materials

The principal raw materials used for this research were yellow maize, tropical almond nuts, groundnuts and date fruit. Yellow maize was purchased from International Institute of Tropical Agriculture (IITA), Umudike, Abia State and was identified as Pro-vitamin 52 - yellow maize variety. Tropical almond nuts were sourced from tree growing around University of Uyo town campus and was identified and authenticated as *Terminalia catappa* L., Family: *Combretaceae*, under the Herbarium No: Emmanuel UUYH4549 (Uniuyo) by Professor, Margaret Bassey, a taxonomist from University of Uyo Herbarium. Groundnut and dried date palm fruit was purchased from Nassarawa Market, Mbak Itam III, Akwa Ibom State, Nigeria, and was identified as *Phoenix dactylifera* L. species (Dabinoin Hausa Variety) under the Voucher Number: UUPH8(h) by Dr. Johnny Imoh, a botanist from University of Uyo Pharmacy Herbarium. Baking ingredient such as milk powder, date paste, margarine, egg, vanilla essence and salt were purchased from Akpanandem Market in Uyo metropolis. All the reagents used throughout the study were of analytical grade.



Plate 1.1: Photograph of raw materials

A= Yellow maize grains (Pro- vitamin 52 yellow maize), B = Tropical almond nut (*Terminalia cattappa* L), C= Groundnut

Preparation of Raw Materials

Preparation of Yellow Maize Grains

The method used was the method stated by Kumar and Jhariya (2013). About 2kg of cleaned and sorted yellow maize grains were washed using portable water to remove dirt. The washed grains were dried in a hot air oven (NAAFCO BS OVEN OVH-102) at 60°C for 24 hours in Food Science and Technology processing Laboratory, University of Uyo, Akwa Ibom State, Nigeria. It was milled into flour using attrition milling machine with model number Panasonic MX-mixer grinder AC2105 made in China and sieved with USA standard testing sieve (0.16mm) to obtain a fine maize flour then packaged in an air-tight container. The flow diagram for the preparation of maize flour is shown in Fig. 3.1

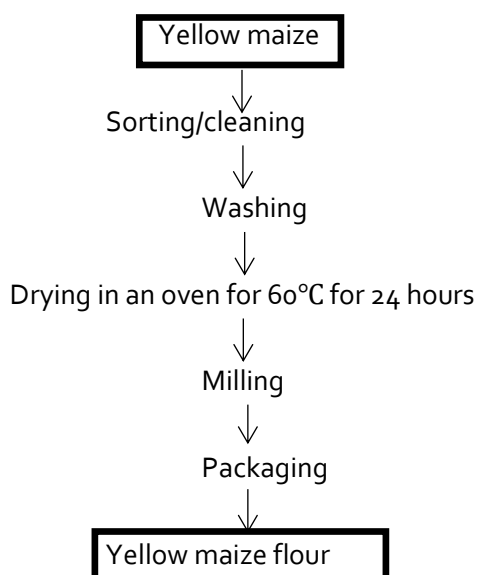


Figure 1: Flow chart showing the production of yellow maize flour

Source: Kumar and Jhariya (2013).

Extraction of Tropical almond nut and Preparation of flour

The method of Mbah *et al.*, (2013) was adopted in the extraction and milling of the tropical almond nut from the fruit seeds. The tropical almond fruits were sundried for 3 days to prevent rancidity and to ease dehulling. The dried seed pod was dehulled by cracking along margins with a non-sparking hammer to obtain the brown spindle shaped kernel. The kernel was dried in an oven at 60°C for 15 minutes, cooled and gritted using Corona landers & Cia S.A.I.U manual grinder. The grit obtained were packaged in an airtight container.

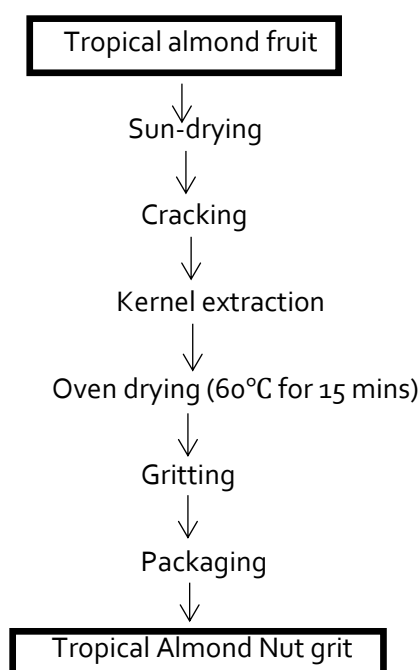


Figure 2: Flow chart showing the production of Tropical Almond Nut grit

Source: Mbah *et al.*, (2013)

Preparation of Groundnuts

The method of Polouse *et al.*, (2014) was adopted in this preparation. Groundnut grains were cleaned, sorted, to remove dirt, stones and extraneous particles. The cleaned nuts were roasted and dehulled. It was packaged for further analysis.

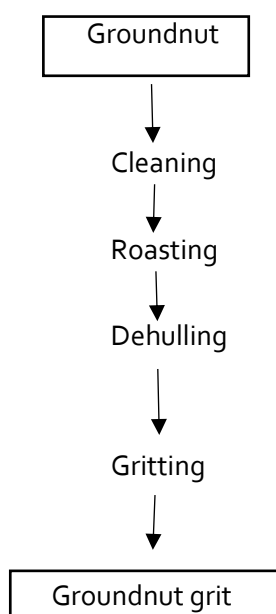


Figure 3: Flow chart showing the production of Groundnut grit

Source: Poulose *et al.*, (2014)

Formulations for Granola

Flours from yellow maize, tropical almond nut and groundnut grit were blended in the ratio of: 95:0:5 = A, 90:5:5 = B, 85:10:5 = C, 80:15:5 = D, 75:20:5 = E as shown in Table 1. The recipe of Edima-Nyah *et al.* (2023) was modified and used for granola formulations (Table 2) which consist of dry ingredients (solid phase) and the liquid ingredients. The dry ingredients included the yellow maize flour, tropical almond grit, groundnut grit, salt, baking powder, milk powder, margarine and date paste. The liquid ingredients were egg and vanilla essence.

Table 1: Blending Ratio of Flour Formulation

Samples	Yellow maize flour	Tropical almond nut grit	Groundnut grit	Total
A	95	0	5	100
B	90	5	5	100
C	85	10	5	100
D	80	15	5	100
E	75	20	5	100

Source: Modified method of Edima - Nyah *et al.*, (2023)

Table 2: Recipe for granola preparation

Ingredients	Formulations				
	A	B	C	D	E
Dry ingredients (g/100g of flour)					
YMF	95	90	85	80	75
TAG	0	5	10	15	20
GNG	5	5	5	5	5
Salt	0.2	0.2	0.2	0.2	0.2
Baking powder	2	2	2	2	2
Milk powder	5	5	5	5	5
Margarine	50	50	50	50	50
Date paste	50	50	50	50	50
Liquid ingredients (g/100g of flour)					
Egg	23	23	23	23	23
Vanilla essence	5	5	5	5	5

Source: Modified method of Edima - Nyah *et al.*, (2023)

Production of Granola Bar

Granola bars were produced according to the method described by Edima-Nyah *et al.*, (2023). The dry ingredients were manually mixed together in a stainless-steel bowl for about 3min to obtain a uniform mixture. The liquid ingredients (vanilla essence and egg) were added and mixed for 3min. Egg was incorporated slowly and the entire dough was mixed thoroughly for about 2min to obtain a uniform mixture. After mixing, the dough was transferred into greased aluminum pans. The dough was 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 bars were baked in an oven at 130°C for 25min. The pans were cooled to about 60°C, de-panned and cut into uniform bars and packaged in an air-tight polyethylene bags for sensory evaluation.

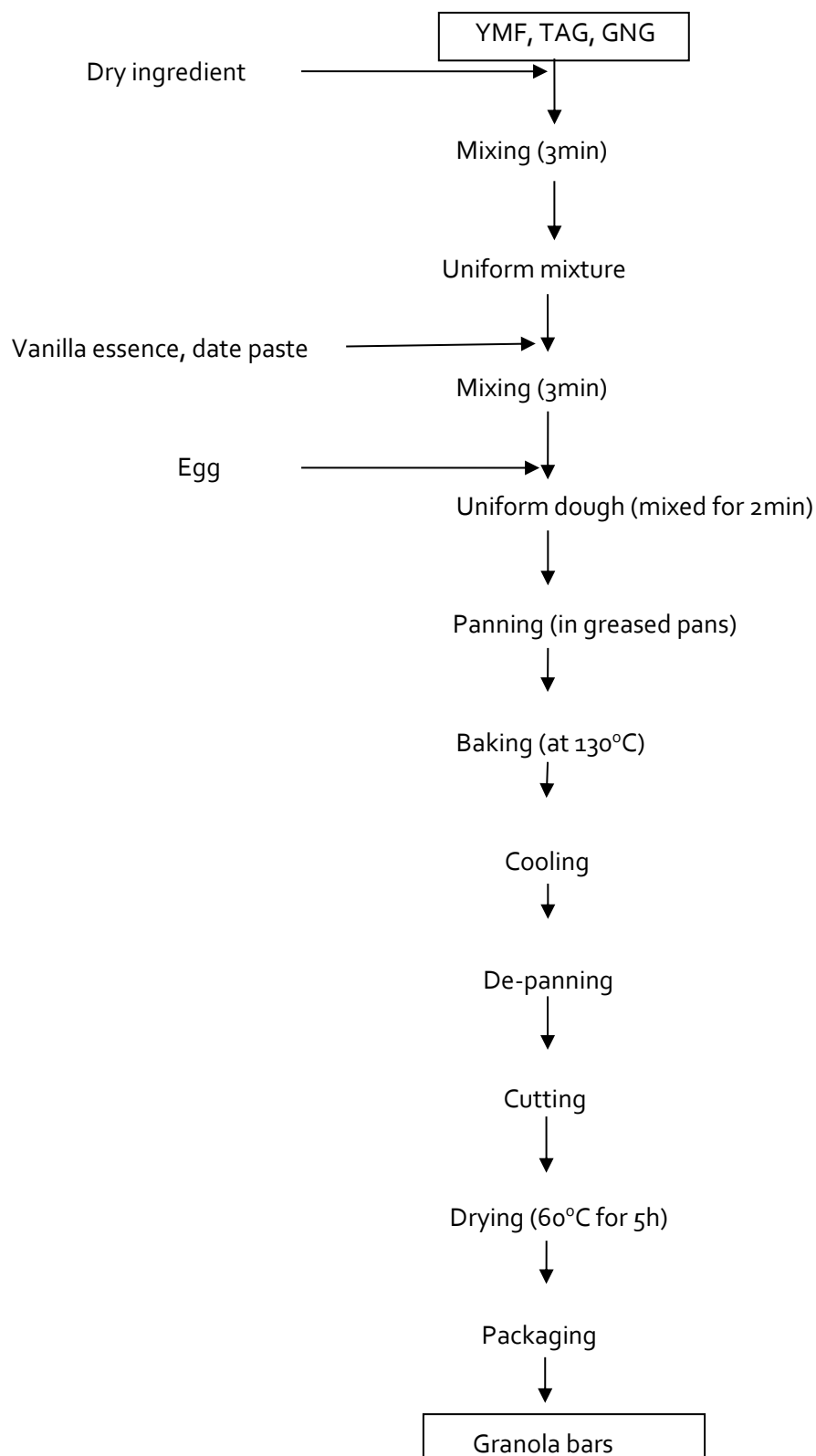


Figure 4: Flow diagram for the production of granola bars.

Source: Edima-Nyah *et al.*, (2023).



Plate 1.2: Photographs of granola bars produced

CBS₁ = 95:0:5, CBS₂ = 90:5:5, CBS₃ = 85:10:5, CBS₄ = 80:15:5, CBS₅ = 75: 20: 5 of yellow maize: tropical almond nut: groundnut blends.

Functional Properties Determination

Functional properties determined included: Bulk density, water absorption capacity, oil absorption capacity, foaming capacity, swelling capacity and gelatinization temperature

Bulk density

This was determined using the method described by Onwuka (2005). Two grams (2g) of sample was filled on a 10ml graduate cylinder and its bottom tapped on the laboratory bench until there was a decrease in volume of the sample.

The volume was recorded.

$$\text{Bulk density} = \frac{\text{Weight of Sample (g)}}{\text{Volume of Sample (cm}^3\text{)}}$$

Water Absorption Capacity

The method described by Onwuka (2005) was used. Two grams (2g) of the flour sample was weighed into a 15ml centrifuge tube and suspended in 10ml of water. It was shaken on a plate form tube rocker for 1 min at room temperature. The sample was allowed to stand for 30mins and centrifuged at 120°C for 30 mins. The volume of free water was read directly from the centrifuge tube.

$$\text{WAC (\%)} = \frac{\text{Amount of water added} - \text{Free water}}{\text{Weight of Sample}} \times \text{Density of water} \times 100$$

Oil Absorption Capacity

The method by Onwuka (2005) was used. Two grams (2g) of the flour was mixed with 10ml refined corn oil in a centrifuge tube and allowed to stand at room temperature ($30 \pm 2^\circ\text{C}$) for 1 hr. It was centrifuged at 160°C for 20min. The volume of the free oil was recorded and decanted. Fat absorption capacity was expressed as ml of oil bound by 100g dried flour.

$$\text{OAC (\%)} = \frac{\text{Amount of Oil added} - \text{Free Oil}}{\text{Weight of Sample}} \times \text{Density of Corn oil} \times 100$$

Swelling Capacity

Swelling capacity was determined according to the method given by Robertson *et al.*, (2000). Two grams (2g) of flour sample was mixed with 10ml of distilled water in a calibrated cylinder at room temperature. After equilibration for 18hrs; the bulk volume was recorded and swelling capacity expressed as volume occupied by sample per gram of original sample dry weight.

$$\text{Swelling capacity \%} = \frac{\text{Change in volume of sample}}{\text{Original weight of samples}}$$

Foaming Capacity Determination

Foaming capacity (FC) was determined according to the method described by Onwuka (2005). Two grams (2g) of flour sample was weighed and added to 50ml distilled water in a 100ml measuring cylinder. The suspension was mixed and properly shaken to foam and the total volume after 30 seconds was recorded. The percentage increase in volume after 30 seconds is expressed as foaming capacity.

$$\text{Foaming capacity (\%)} = \frac{\text{Volume after whipping} - \text{Volume before whipping}}{\text{Volume before whipping}} \times 100$$

Gelatinization Temperature

Gelatinization temperature was determined by Shinde (2001). Two grams (2g) of flour sample was weighed accurately in triplicate and transferred to 20ml screw capped tubes. Ten (10) ml of water was added to each sample. The samples were heated slowly in a water bath until they formed a solid gel. At complete gel formation, the respective temperature was measured and taken as gelatinization temperature.

Proximate Composition Analysis

Moisture Content Determination

The standard method of AOAC (2010) was followed for the determination of moisture content. Cleaned crucibles were dried in a hot air oven at 100°C for an hour to obtain a constant weight and then cooled in a desiccator. 1g of each of the samples was then weighed into the crucibles and dried at 100°C so as to obtain a constant weight.

$$\% \text{ Moisture content} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

Where, W_1 = Initial weight of the empty crucible in gram

W_2 = weight of crucible + sample before drying

W_3 = weight of crucible + sample after drying.

Determination of Crude Fat Content

Fat content was determined using the Soxhlet extraction method as described by AOAC (2010). A Soxhlet extractor with a reflux condenser and a round bottom flask was fixed. 1g of the sample was weighed into a labeled thimble. Petroleum ether was filled into the round bottom flask and the extractor thimble seal. The Soxhlet apparatus was in reflux for several hours before the thimble was removed. Petroleum ether collected from the flask was dried at 105°C for an hour in an oven cooled in a desiccator and weighed. This procedure was carried out for all the samples.

$$\% \text{ Fat} = \frac{\text{weight of fat}}{\text{weight of sample}} \times 100\%$$

Where weight of fat = (weight of thimble with sample – weight of empty thimble).

Determination of Crude Protein

Crude protein was determined using the Kjeldahl method described in (AOAC, 2010). Exactly 1g of each of the sample was weighed into an 100ml Kjeldahl flask. 1grams of anhydrous Na_2SO_4 , 1g of CuSO_4 and 5ml of concentrated H_2SO_4 was added and allowed for 2-3 hours. The flask was heated in a flame chamber till the solution was clear. This process is called digestion. After cooling, the content was transferred into an 100ml volumetric flask and made up to the mark with repeated washing using distilled water. Distillation was done by mixing the digest with 5ml of boric acid and 3 drops of methyl red indicator in a 100ml conical flask. 100ml of 60% NaOH was added to neutralize it. Distillation was done for few minutes until there was a colour change. Titration was done using 5ml distillate against 0.01N HCl until a purple-pink endpoint was observed

The percentage protein was calculated using the expressions below:

$$\% \text{ Protein} = \% \text{ Nitrogen} \times 6.25 \text{ (where 6.25 = Conversion factor of protein).}$$

$$\% \text{ Nitrogen} = \frac{T \times A \times N \times 20}{W \times 100} \times 100$$

Where T = Titre value

W = Weight of the sample (1g)

20 = Dilution factor

N= Normality of HCl = 0.01

A = Atomic mass of nitrogen.

Determination of Total Ash

Determination of the ash content was done using the procedure stated by AOAC (2010). Exactly 1g of the samples was weighed into four different crucibles. The crucibles were ignited, cooled and weighed to get the initial weight of the crucible without the content. Both the crucibles and their content were transferred into a muffle furnace ignited at 550°C. Ashing was done for 7-8 hours. The un-ashed sample were expose by adding a few drops of water in the crucible. It was dried in the oven for 2 hours and re-ashed at 550°C. After ashing, the sample was removed from the furnace, cooled in a desiccator and was weighed. Percentage ash was calculated using this expression below

$$\% \text{ Ash} = \frac{(\text{Weight of crucible and ash}) - (\text{weight of crucible})}{(\text{Weight of crucible and sample}) - (\text{weight of crucible})} \times 100\%$$

Determination of Crude Fiber

Crude fiber was determined using the method described by AOAC (2010). Exactly 1g of the sample was weighed and put in a boiling 200ml of 1.25% H_2SO_4 and allowed to boil for 30minutes. When cooled, the solution was filtered using a muslin cloth fixed to a funnel, it was washed with boiling water until it was completely free from acid. Filtration was done in less than 10 minutes. The residue was returned into 200ml boiling NaOH and allowed to boil for 30 minutes. This is to analyze the part of nitrogen in protein and making saponification

with the fat. It was then pre-heated with boiling water and carefully filter the hydrolysed mixture before letting it rest for 1 minute. The residue was washed with boiling water, with HCl acid solution and then washed again with boiling water. The final residue was placed in a crucible and in an oven set at 105°C for 12 hours and then cooled. The final weight of the crucible was taken. Percentage crude fiber was calculated thus:

$$\% \text{ Crude fiber} = \frac{(\text{weight of crucible with dry residue}) - \text{weight of crucible with ash}}{\text{Weight of sample}} \times 100$$

Determination of Carbohydrate Content

The total carbohydrate content was estimated as the difference between 100 and the total sum of moisture, fat, protein, crude fiber and ash as described by AOAC (2010). It was calculated as follow:

$$\% \text{ Total carbohydrate} = 100 - (\text{moisture} + \text{protein} + \text{fat} + \text{ash} + \text{crude fibre})$$

Determination of Total Energy

The Atwater system described by Merrill *et al.*, (1973) was used to determine the total calorific value employing the 4-9-4 method. This system applies energy conversion factors to the macronutrients carbohydrate, fat and protein. The average value of energy was expressed as the number of kilo-calories per 100g of the macronutrient, and it was calculated thus:

$$\text{Caloric value} = \text{crude protein} \times 4 + \text{crude fat} \times 9 + \text{carbohydrate} \times 4$$

In vitro Digestibility Analysis

Determination of in vitro protein digestibility (IVPD)

The method of Kanu *et al.*, (2009) was used with slight modifications. The formulations (5 g each) were placed in a 50 ml centrifuge tube, to which 15 ml of 0.1N HCl containing 1.5 mg pepsin-pancreatin was added and the tube was incubated at 37°C for 3 hours. The suspension was then neutralized with a phosphate buffer (pH 8.0), containing 0.005 M sodium azide. 1 ml of toluene was added to prevent microbial growth and the mixture was gently shaken and incubated for an additional 24 h at 37°C. After incubation the sample was treated with 10 ml of 10% Trichloroacetic Acid (TCA) and centrifuged at 5000 rpm for 20 min at room temperature. The protein in the supernatant liquid was estimated using the Kjeldahl method. The percentage of protein digestibility was calculated using the following formula:

$$\text{Protein Digestibility (\%)} = \frac{\text{protein in supernatant}}{\text{protein in sample}} \times 100$$

Determination of in vitro- Starch Digestibility

Digestibility of starch was determined following the method of Singh *et al.*, (2012). A suitable amount of defatted meal (50 mg) was dispersed in 1.0 ml of 0.2 M phosphate buffer, PH 6.9. Pancreatic amylase (40000 U/ml,) was added to the sample suspension and incubated at 37°C for 2 hours. 2 ml of 3,5 dinitrosalicylic acid reagent was quickly added

and the mixture was heated for 5 min in a boiling water bath. After cooling, the solution was made up to 25 ml with distilled water. After sample titration, absorbance was read at 550 nm using UV Spectrophotometer (T6 ultraviolet Spectrophotometer, Beijing General instrument company Ltd). The blank was run simultaneously by incubating sample with 3,5 dinitrosalicylic acid before addition of the enzyme solution. Maltose will be used as standard, and results will be expressed as mg of maltose released per gram of sample.

Determination of In-Vitro Glycemic Index

The invitro glycemic index (GI) of the granola bars were determined according to the method described by Gõni et al, (1997) with modification by Leoro et al (2010). Approximately 500mg samples were combined with 10ml HCl-KCl BUFFER (pH 1.50). The samples were homogenized for 2 minutes using a vortex (Black Scientific Limited, Lv, USA). About 0.20ml pepsin solution containing 1mg pepsin in 10ml HCl-KCl buffer (pH 1.50) was added to each sample. Samples were incubated at 40°C in a water bath for 60 min, with constant shaking. The digest was diluted to 25ml by adding 15ml tris-maleate buffer (Ph 6.9). Starch hydrolysis was initiated by adding 5ml tris-maleate buffer containing 2.60µl porcine pancreatic α-amylase. The mixture was incubated in a 37 °C water bath with moderate agitation. Approximately 1ml sample was taken from each flask every 30mins from 0 to 3 hours. The α-amylase was inactivated immediately by holding the flask in a boiling water bath for 5min. then, 3mls of 0.40N Sodium acetate buffer (pH 4.75) followed by 60µ amyloglucosidase for *Aspergillus niger* was added and the mixture was incubated at 60°C for 45min. The glucose concentration was determined using a glucose oxidase peroxidase kit (Baloworld Scientific G3254-ACap 01). The role of starch digestion was expressed as a percentage of the total starch hydrolyzed at times (30, 60, 90 and 120mins). A non-linear model was applied to describe the kinetics of the starch hydrolysis (Gõni et al., 1997)

The first order equation had the form

$$C = C_{\infty} (1 - e^{-kt}) \quad \text{Equation 3.1}$$

And the areas under the hydrolysis curve (AUC) were calculated using the following equation:

$$AUC = C_{\infty} (t_f - t_0) - (C_{\infty}/k) [1 - \exp(t_f - t_0)] \quad \text{Equation 3.2}$$

C = Percentage of starch hydrolyzed at time, t.

C_{∞} = Equilibrium percentage of starch hydrolyzed after 120min.

K = Kinetic constant

t = Time

t_f = Final time (120min)

t_0 = Initial time (0min)

The hydrolysis index (H_i) was obtained by dividing the area under the hydrolysis curve of each sample by the corresponding area of a reference sample (glucose)

$$HI = \frac{\text{AUC of sample}}{\text{AUC of glucose}} \quad \text{Equation 3.3}$$

The glycemic index (GI) was calculated using this equation:

$$GI = 39.71 + (0.549 \times HI) \quad \text{Equation 3.4}$$

Glucose concentration was determined using a GOD-PAD glucose kit and the colour reaction was measured in a UV/VIS spectrophotometer (Leoro *et al.*, 2010).

Determination of Amino Acid Profile

The amino acid profile of the granola bar produced was determined using the method described by Benitez (1989). The samples were dried to constant weight, defatted, hydrolyzed, evaporated in a rotary evaporator and loaded into the Applied Bio-systems PTH Amino Acid Analyzer (model: 120A PTH, England)

Amino Acid Quantification Methodology

There are different approaches to analyze the amino acid content of a sample, typically involving sequential steps of cleaving the peptide bonds to obtain the respective amino acid, followed by separation and the final stages of detection and quantification of each chemical process. Chemical hydrolysis emerges as a consolidated method among the common approaches used to extract amino acid from food containing proteins (AOAC methods). This approach typically involves the hydrolysis of protein peptide bonds using hydrochloric acid at high temperature for an extended period, often up to 72h. It is effective for most amino acids except for cysteine and methionine (Sulphur containing amino acid) that requires a pre-oxidation step and tryptophan, that requires an alkaline hydrolysis to be recovered quantitatively.

Defatting of sample

The samples were defatted using the AOAC method (2005), where a 4g sample each and chloroform/methanol mixture of 2:1 ratio, was put in an extraction thimble and extracted for 15 hours in a soxhlet extraction apparatus.

Nitrogen determination

The ground sample was weighed, 200mg, wrapped in Whatman filter paper (No.1) and put in the Kjeldahl digestion flask. Concentrated sulphuric acid (10ml) was added. About 0.5g catalyst mixture containing sodium sulphate (Na_2SO_4), copper sulphate (CuSO_4) and selenium oxide (SeO_2) in the ratio of 10:5:1 was added into the flask to facilitate digestion. Four pieces of anti-bumping granules were added. The digestion was carried out in the digestion apparatus for 3h until the liquid turned light green. The digested samples were cooled and diluted with distilled water to 100ml in standard volumetric flask. Aliquot (10ml) of the diluted solution and 10ml of 45% sodium hydroxide was put into Markham distillation apparatus and distilled into 10ml of 2% boric acid containing 4 drops of bromocresol green/methyl red indicator until about 70ml of distillate was collected.

The distillate was then titrated with standardized 0.01N hydrochloric acid to grey coloured end point.

$$\% \text{ Nitrogen} = \frac{(a-b) \times 0.01 \times 14 \times V \times 100}{W \times C}$$

Where: a= Titre value of the digested sample, b= Titre value of blank sample, v=volume after dilution (100ml), w= weight of dried sample (mg), c= aliquot of the sample used (10ml), 14= Nitrogen constant in mg.

Hydrolysis of sample:

The defatted sample was weighed into a glass ampoule and 7ml of 6N HCl was added and oxygen was expelled by passing nitrogen into the ampoule (this is to avoid possible oxidation of some amino acids during hydrolysis e.g. methionine and cystine).the ampoule was then sealed with a bunsen burner flame and put in an oven, preset at $105^{\circ}\text{C} \pm 5^{\circ}\text{C}$ for 22h. The ampoule was allowed to cool, break-opened at the tip and the content filtered to remove the humins. It is worthy to note here that tryptophan is destroyed by 6N HCl during hydrolysis. The filtrate was then evaporated to dryness using rotary evaporator. The residue was dissolved with 5ml acetone buffer (pH 2.0) and stored in plastic specimen bottles in the freezer.

Loading the hydrolysate into the analyzer

Sixty microlitre (60µl) was dispensed into the cartridge of the analyzer. The analyzer is designed to separate and analyze free acidic, neutral and basic amino acids of the hydrolysate.

Method of calculating amino acid values from the chromatogram peaks:

An integrator attached to the analyzer calculates the peak area proportional to the concentration of each of the amino acids.

Ethical Considerations

Before conducting the sensory evaluation, panelist were drawn from within the Department of Food Science and Technology where they were trained on how to rate products using sensory evaluation questionnaire. The thirty (30) member panelists willingly participated in the evaluation. They were provided with the necessary tools that aided their rating. The privacy of the panelist was respected and was given right of anonymity. The information was regarded with intention of the research being conceded from the panelist. In terms of data collection, the data was collected in triplicates from different experimental procedures and questionnaires were carefully analyzed using a statistical tool known as Statistical Package for Social Science (SPSS, version 22). I ensured that the information conducted from the panelists and the experiments were not tampered with. There was no conflict of interest. My research was on development of granola bars from yellow maize, tropical almond nut and groundnut blends. Plagiarism was totally avoided and the benefits of this research are not exaggerated.

Sensory Evaluation of Granola Bars

Sensory characteristics of the granola bars were evaluated for different sensory attributes by thirty (30) semi trained panelist drawn from the Department of Food Science and Technology, University of Uyo. All the panelist were briefed before the commencement of the evaluation process. Sensory attributes evaluated were appearance, taste, aroma, texture and overall acceptability. The nine (9) point hedonic scale described by Ihekoronye and Ngoddy (1985) was used to carry out the sensory evaluation. All panelist were conversant with the attributes of the granola bars. Water at room temperature was provided to rinse the mouth between evaluations. Data obtained were statistically analyzed to determine the level of significance.

Statistical Analysis

All the data were subjected to statistical analysis using Analysis of Variance (ANOVA). The means were then separated with the use of New Duncan Multiple Range Test (NDMRT) using the Statistical Package for the Social Sciences (SPSS) 23.0 software.

Results and Discussion

Functional properties of blends of yellow maize, tropical almond nut flours and groundnut for formulation of granola

Table 1 shows the functional properties of the flour blends for production of granola bars. Bulk density of the flour ranged from 0.91 to 1.04 g/ml. Samples A, B, C were significantly ($p < 0.05$) different, while samples D and E were statistically ($p > 0.05$) the same. Bulk density increased with increasing levels of tropical almond nut flour addition. Water absorption capacity of flour blends ranged from 1.33 – 1.60g/ml, and decreased with increasing addition of tropical almond nut flour in the blends. Sample A (without tropical almond nut flour) was significantly ($p < 0.05$) different from sample E, there was no significant ($p > 0.05$) difference among samples B, C and D. Oil absorption capacity of the flour blends ranged from 0.50-1.30ml/g for samples E and A respectively and a significant ($p < 0.05$) difference was observed in samples A and E. Swelling capacity of the flour blends ranged from 32.32-50% and it decreased significantly ($p < 0.05$) with increased addition of tropical almond nut and decrease in maize in the flour blend.

Foaming capacity of the flour blends showed significant ($P < 0.05$) difference between the flour samples ranging from 5.76 – 17.72%. Gelatinization temperature of the flour showed significant difference ($p < 0.05$) among the samples and ranged from 70.00 for sample A to 86.33 for sample E.

Table 1: Functional properties of blends of yellow maize, tropical almond nut flours and groundnut flour for formulation of granola

Samples	Bulk density (g/ml)	WAC (g/ml)	OAC (ml/g)	Swelling capacity (%)	Foaming Capacity (%)	Gelatinization. Temperature °C
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A	0.91 ^d ±0.09	1.60 ^a ±1.70	1.30 ^a ±1.30	50.00 ^a ±0.04	5.76 ^d ±0.70	70.00 ^d ±0.02
B	0.94 ^c ±0.01	1.50 ^{ab} ±0.17	0.96 ^b ±0.05	44.46 ^b ±0.58	12.94 ^c ±0.28	74.66 ^c ±1.15
C	0.97 ^b ±0.00	1.43 ^{ab} ±0.05	0.83 ^b ±0.05	41.72 ^c ±0.12	14.19 ^c ±0.88	77.66 ^c ±1.52
D	1.02 ^a ±0.01	1.46 ^{ab} ±0.05	0.76 ^b ±0.05	37.28 ^d ±0.40	15.96 ^b ±0.32	82.33 ^b ±0.57
E	1.04 ^a ±0.11	1.33 ^b ±0.05	0.50 ^c ±0.10	32.32 ^e ±1.10	17.72 ^a ±0.43	86.33 ^a ±0.57

Values are means of the triplicate determination ± standard deviation. Means with different superscript in the same column are significantly ($p < 0.05$) different. A= 95% yellow maize, 0% tropical almond and 5% groundnut grit; B=90% yellow maize, 5% tropical almond and 5% groundnut grit; C=85% yellow maize, 10% tropical almond and 5% groundnut grit; D= 80% yellow maize, 15% tropical almond and 5% groundnut grit and E=75% yellow maize, 20% tropical almond and 5% groundnut grit.

Functional Properties of Blends of Yellow Maize, Tropical Almond Nut and Groundnut Flours

Bulk density (BD) is a measure of heaviness of a flour sample, thus giving an indication that the relative volume of the composite flour in a package would not reduce excessively during storage (Alawode *et al.* 2017). The bulk density of the blends of yellow maize, tropical almond nut and groundnut flours increased from 0.91 to 1.04 g/ml with increasing amount of tropical almond nut. The bulk density of this study is higher than (0.12- 0.27g/ml) for granola produced from different cereals (maize, millet, guinea corn) and processing methods by (Eke-Ejiofor *et al.*, 2017). (Adepeju *et al.*, 2024) recorded lower values of (0.39- 0.45g/ml) for breakfast cereals made from yellow maize, sorghum and date. (Eke-Ejiofor *et al.*, 2016) recorded lower values of (0.40-0.47g/ml) for granola produced from maize and coconut blend. Higher values for water absorption capacity of (1.69-4.43g/ml) was recorded by (Adepeju *et al.*, 2024) for breakfast cereals using yellow maize, sorghum and date. A higher range value of (0.97-1.95g/ml) was reported by (Eke-Ejiofor *et al.*, 2017) for granola produced from different cereals (maize, millet, guinea corn) Water absorption capacity of the flour blends was higher than the range 1.14 (114%) – 1.99 (199%) reported for cassava-bambara groundnut flour blends by Olapade *et al.* (2014). Water absorption capacity (WAC) is an index of the maximum amount of water that a food product would absorb and retain (Marero *et al.* 1988). It is also the ability of a product to associate with water under a limiting water condition. It helps in bulking and consistency of products (Osundahunsi *et al.*, 2003). The water absorption capacity (1.33 -1.60 ml/g) in the present study was increased with increasing tropical almond flour. The result of the WAC of the present study was similar to the report of 1.00 – 2.90 by Obinna-Echem *et al.* (2020) for cowpea tiger-nut flour blends. Oil absorption capacity (OAC) of the flour blend is the ability of its protein to physically bind fat by capillary attraction and it is of great importance since fat is well known as flavour retainer to increase the mouth-feels of foods (Omueti *et al.* 2009). Adesanmi *et al.* (2020) reported a higher range value of (150.00-350.00 ml/g) for blends of maize and almond flour, although the result for OAC in the present study was similar to (1.70 - 1.90 g/g) reported by Bello *et al.* (2020) for flour blends of sorghum, African yam bean and soybean.

The swelling capacity is an important factor used to determine the amount of water that food samples would absorb as well as the degree of swelling within a given time (Ijarotimi and Keshinro, 2012a). The swelling capacity of the flour decreased with increase in almond flour due to its low starch content and higher fat content. The swelling capacity of this study is higher than the range value (2.50-3.10) and 6.05-8.84) for blends of maize flour, almond and yellow maize, and soybeans and jackfruit as reported by Adesanmi *et al.* (2020) and Meka *et al.* (2019).

The foaming capacity of the flour increased (5.76 – 17.72%) with increasing amount of tropical almond. The increase in the foaming capacity could be due to the protein content of the almond. James and Nwabueze (2013) reported values (1.90 – 2.40 %) that were lower than those reported in this study for African breadfruit flour, soybean-corn snack bars. The range of (5.76 – 17.72 %) for foaming capacity in the present study differs from 9.11 - 12.92% reported by Nawaz *et al.* (2015).

Gelatinization temperature is the temperature at which starch in food absorbs water and swell, breaking down their crystalline structure and becoming a gel (Sandhu *et al.*, 2017). A gel is a phase in between the solid and liquid state. The gelatinization temperature of this study increased with increasing incorporation of tropical almond in the blend. The trend in this study was in line with the values (75.00 – 84.00 °C) reported by Bello *et al.* (2020) for wheat, plantain and germinated fluted pumpkin seed composite flour used in the production of cookies.

Table 2: Proximate Composition (%) and Energy Value (Kcal/100g) of Granola produced from yellow maize, maize, tropical almond nut and groundnut flour blends

Samples	Moisture%	Fat%	Protein%	Ash%	Fibre%	Carbohydrate %	Energy Kcal/100g
A	8.07 ^a ±0.02	8.84 ^e ±0.07	9.30 ^e ±0.05	2.76 ^e ±0.02	3.24 ^e ±0.04	67.79 ^a ±0.17	387.92 ^a ±0.20
B	7.93 ^b ±0.03	8.94 ^d ±0.04	10.70 ^d ±0.02	2.92 ^d ±0.02	4.46 ^d ±0.01	65.05 ^b ±0.12	383.46 ^c ±0.09
C	7.80 ^d ±0.05	9.11 ^c ±0.03	11.91 ^c ±0.03	3.01 ^c ±0.02	4.62 ^c ±0.02	63.75 ^c ±0.01	384.63 ^b ±0.40
D	7.81 ^c ±0.02	9.24 ^b ±0.04	12.81 ^b ±0.03	3.09 ^b ±0.01	4.81 ^b ±0.01	62.24 ^d ±0.01	383.36 ^d ±0.28
E	7.34 ^e ±0.04	9.38 ^a ±0.04	13.67 ^a ±0.05	3.12 ^a ±0.02	4.91 ^a ±0.01	61.08 ^e ±0.06	383.42 ^c ±0.16

Values are means of the triplicate determination ± standard deviation. Means with different superscript in the same column are significantly (p<0.05) different. A= 95% yellow maize, 0% tropical almond and 5% groundnut grit; B=90% yellow maize, 5% tropical almond and 5% groundnut grit; C=85% yellow maize, 10% tropical almond and 5% groundnut grit; D= 80% yellow maize, 15% tropical almond and 5% groundnut grit and E=75% yellow maize, 20% tropical almond and 5% groundnut grit.

Proximate composition of granola bars produced from yellow maize, tropical almond nut and groundnut flour blends

The proximate composition of granola bar prepared from yellow maize, tropical almond and groundnut grits are presented in Table 2. Moisture content is associated with the shelf life of food products. Ordinarily, food products with a low moisture content (low water activity) have an extended shelf life (Ahaotu *et al.*, 2022). The moisture content of the granola bar in this study was within the range recommended as safe limit which validates with the finding of James (1995) who reported that the moisture content of snack bars (below 10%) is within the range of standard category, suitable for suppressing the growth of microorganisms favourable for storability. Edima-Nyah *et al.* (2019b) reported a lower range value (3.76-4.62%) for snack bar from African bread fruit, maize and coconut blends. (Gbolagade *et al.*, 2024) reported a range value of (5.37-7.14%) for plantain flour, soy cake and oat bran which were within the range in this study. Granola bars from indigenous available cereals and nuts by Eke-Ejiofor and Okoye (2018) had values of (5.09 to 6.78%). (Ahaotu *et al.*, 2022) recorded higher moisture content of about (11.47 to 17.45%) in snack bar developed from maize and bambara groundnut flour blends. (Deedam and Mbah, 2020) recorded a lower value of (5.21-7.22%) in granola bars made from soursop and wheat flour. The fat content increased with increasing amount of tropical almond. The range in this study were within the range (10.10-10.80 %) for snack bar from gude bean, kratok and red bean reported by Widnyani and Rabani (2021) and a range (7.31-8.46%) for African bread fruit, maize and coconut blends reported by Edima-Nyah *et al.* (2019a). (Gbolagade *et al.*, 2024) reported a higher range value (12.94-21.84%) for plantain flour, soy cake and oat brans. Also, the findings of (Oluwajuyitan *et al.*, 2020) showed a lower range (2.00-8.5 %) of fat content for granola bar made from plantain, defatted soybean, rice bran and oat bran flour blends. Given the Dietary Reference Intake (DRI) and Acceptable Macronutrients Distribution Range (AMDR) recommendation of 25 to 35 % total fats for adults (Ire *et al.*, 2020), it was observed that all the samples of the granola bars did not meet the requirement. But values of 23.27 to 29.38% was in line with this requirement as recoded by Eke-Ejiofor and Okoye (2018).

The protein content of the granola bar increased with increasing amount of tropical almond nut which corresponds with the finding of Aremu *et al.*, (2015) and Oduro *et al.*, (2009) who reported that tropical almond contains a significant amount of protein. Protein functions to regulate metabolic processes in the form of enzymes, hormones, and as a body defense mechanism to fight foreign infections into the body, as well as maintain cells and body tissues (Winarno, 2008). Higher protein range (13.81-26.10%) and (3.98-25.24%) was reported by Edima-Nyah *et al.*, (2019a) and (Gbolagade *et al.*, 2024) for snack bars from African bread fruit, maize and coconut blends and plantain flour, soy cake and oat brans respectively. The findings of (Oluwajuyitan *et al.*, 2020) with a protein content range of (16.2-19.4 %) for granola bar produced from plantain, defatted soybean, rice bran and oat bran flour blends was higher than the report for protein content of this study. All the granola bars fell within the Dietary Reference Intake (DRI) and Acceptable Macronutrient Distribution Range (AMDR) of (10 to 35%) specifically for adults (Ire *et al.*, 2020). They also

play a vital role in the synthesis of plasma proteins, hemoglobin, hormones, enzymes, coagulation factors and antibodies. Protein content of (9.94%-10.67%) similar to this present study was recorded by Foyinsade and Abiodun (2020) obtained from malted quality protein maize breakfast cereal. The value of (21.3 to 23.9%) is documented by Eke-Ejiofor and Okoye (2018) from cereal bars produced from cereals and nuts and is higher than the value in this study.

The ash content showed a considerable increase with increasing amount of tropical almond which is a good source of mineral. The range in this study is higher than the range (0.70-1.34%) for snack bar from gude bean, kratok and red bean reported by Widnyani and Rabani (2021) but lower than the range value of (2.83-4.57%) and (1.88-6.68%) for snack bar from African bread fruit, maize and coconut blends and plantain flour, soy cake and oat bran respectively as reported by Edima-Nyah *et al.* (2019a) and (Gbolagade *et al.*, 2024) respectively. The ash content of the study was found to be significantly higher than ash content of cereal bars reported by Eke-Ejiofor and Okoye (2018) obtained from grains and nuts which was within the range of (1.54 to 1.90 %).

The fibre content of the granola bar increased with increasing amount of tropical almond. The increase in the fibre content could be due to the lignin, cellulose and pectin which is contained in the tropical almond nut. Higher range value (5.09-8.43%) and (3.31-6.68%) for snack bar from African bread fruit, maize and coconut blends and plantain flour, soy cake and oat bran were reported by Edima-Nyah *et al.* (2019a) and Gbolagade *et al.*, (2024) respectively. Although it was noticed that the range of crude fibre content observed from the granola bars in this study was higher than the findings of (2.58 - 3.70 %) for granola bar produced from maize and coconut flour blends as reported by (Joy *et al.*, 2016). To prevent constipation and other health challenges associated with inefficient waste removal from the body, regular consumption of diets rich in crude fiber is recommended. There are indications that consumption of vegetable fiber reduces the level of cholesterol in the body (Soliman, 2019). It could also reduce the risk of coronary heart diseases. The risk of developing hypertension, colon and breast cancer is also reduced by eating diets rich in vegetable fiber. Glucose tolerance is enhanced by vegetable fiber consumption which also increases insulin sensitivity (Edima-Nyah *et al.*, 2019b).

The carbohydrate content (61.08-67.79%) was higher than the value (38.25 – 65.65%) reported by Edima-nyah *et al.*, (2019a) in snack bars developed from African bread fruit seed flour, maize and coconut and the values (43.06 – 62.54%) reported by (Gbolagade *et al.*, 2024) for plantain flour, soy cake and oat brans. Similar trend with (56.05- 70.37 %) reported by (Ahaotu *et al.*, 2022) for snack bar produced from bambara groundnut and maize flour blends. In contrast, the carbohydrate content of five samples of cereal bars prepared by Eke-Ejiofor and Okoye (2016) using rolled oat, yellow maize, white maize, millet and guinea corn had a range of (36.64 - 41.42%) which is lower than the result observed in this present study. Worthy to note is that carbohydrate content of the granola bar samples in this study was within the recommended Dietary Reference Intake's (DRI) and Acceptable Macronutrient Distribution Range (AMDR) of (45 - 65%) of energy obtained

from carbohydrate for adults (Ire *et al.*, 2020). The potential reason for discrepancies in the various results is basically due to use of different raw materials in processing.

The energy value of granola bars (383.36 – 387.92 Kcal/100g) was higher than the range value (333.27-386.33 Kcal/100g) for snack bars produced from African bread fruit, maize and coconut blends reported by Edima-Nyah *et al.* (2019) but within the range value (396.12-471.67 Kcal/100g) for and plantain flour, soy cake and oat brans reported by (Gbolagade. *et al.*,2024). The energy value of this present study was higher than (293-380 Kcal/100g) recorded by Foyinsade and Abiodun (2020) and lower than the values (452.6 to 505.2 Kcal/100g) as recorded by Eke-Ejiofor and Okoye (2018) in cereals and nut cereal bars.

Table 3: *In-vitro* protein and starch digestibility and glycemic index of granola produced from yellow maize, tropical almond nut and groundnut blends

Sample	IVPD (%)	IVSD (%)	IVGI (%)
A	40.22 ^e ±0.01	60.26 ^a ±0.02	57.20 ^a ±0.00
B	65.34 ^d ±0.01	58.45 ^b ±0.01	49.38 ^b ±0.00
C	67.40 ^c ±0.01	51.17 ^c ±0.01	42.25 ^c ±0.01
D	70.14 ^b ±0.00	47.22 ^d ±0.01	41.00 ^d ±0.01
E	72.64 ^a ±0.01	43.62 ^e ±0.00	39.84 ^e ±0.00

Values are means of the triplicate determination ± standard deviation. Means with different superscript in the same column are significantly (p<0.05) different. A= 95% yellow maize, 0% tropical almond and 5% groundnut grit; B=90% yellow maize, 5% tropical almond and 5% groundnut grit; C=85% yellow maize, 10% tropical almond and 5% groundnut grit; D= 80% yellow maize, 15% tropical almond and 5% groundnut grit and E=75% yellow maize, 20% tropical almond and 5% groundnut grit.

However, Sajilata *et al.* (2002) recommends a range of (400- 435 Kcal/100g) and (350- 400 Kcal/100g) for men and women respectively.

In-Vitro Protein, Starch Digestibility and In-Vitro Glycemic Index of granola bar produced from blends of yellow maize, tropical almond and groundnut

Protein digestibility is an important measure of the susceptibility of protein proteolysis. A protein with high digestibility is potentially of better nutritional value than one with low digestibility (Pushparaj and Urooj, 2011). The invitro protein digestibility increased significantly with increase in tropical almond nut flour due to the protein content of the tropical almond which is more digestible than maize. The range value of (40.22-72.64 %) in this study is within the range (63.93-88.19 %) for African bread fruit, maize and coconut reported by Edima-Nyah *et al.* (2019). Research has demonstrated that *in-vitro* (starch and protein) digestibility tests are necessary since the nutritional composition of food alone is insufficient to predict nutrient bioavailability (Anuonye *et al.*, 2007). Kumar *et al.* (2020) recorded higher values of protein digestibility (80.1- 85.2 %) than this study in the effect of different types of fiber on in vitro digestibility and glycemic index of a snack bar produced from millet flour and pulses. Sharma *et al.* (2019) recorded (88.5 %) for protein digestibility

of snack bar produced with ancient grains, pulses like mung bean, cowpea, chick and pigeon peas.

The invitro starch digestibility decreased with increase in tropical almond which is due to amylose and amylopectin in the maize which would require more time and temperature for the starch to be gelatinized. The values observed in this study (43.62-60.26) is within the range (29.59-57.48%) recorded in snack bar from African bread fruit, maize and coconut reported by Edima-Nyah *et al.* (2019). The IVSD of this study was significantly higher (43.62 – 60.26 %) than (29.06 - 43.93 %) reported by Edet *et al.*, (2023) obtained from cookies made from breadnut seed, rice flour and pineapple pomace flour. Soluble dietary fiber interacted with the starch, enveloping the starch and thereby limiting the interaction between starch and enzymes resulting to low starch digestibility in food products, which was evident in the IVSD range of this study (Giuberti *et al.*, 2018). Singh *et al.*, (2018) recorded a higher value (61.4 – 70.5 %) for snack bar made from oats, nuts, and dried fruits. Kumar *et al.* (2020) recorded (60.5%), a higher value than the value obtained in this study.

Glycemic index (GI) is a property of starchy food, which describes the rate of blood glucose absorption after consumption (Odenigbo *et al.*, 2013). The *in-vitro* glycemic index decreased progressively with increased in tropical almond which is due to the carbohydrate content and starch composition of the yellow maize consequently raising the glycemic index. The low glycemic index observed in this study is preferable for overall health, promoting better blood sugar control and energy, and correspond with the finding of (Henry *et al.*, 2005) who reported that the consumption of a low GI food has been shown to have positive health benefits in a variety of chronic diseases including insulin resistance, diabetes, cardiovascular disease, obesity and cancer. Bao *et al* (2019) and Kumar *et al.*, (2020) recorded value ranges from (55.1 – 71.4 %) and (58.2 – 78.2%) respectively. These values were higher than the values in this study. Health implication of low glycemic index foods causes a slower and lower blood sugar levels after eating and can offer improved blood sugar control particularly for individuals with diabetes, potential weight management and a reduced risk of certain chronic diseases like heart diseases and type 2 diabetes (David *et al.*, 2002). It also helps in lowering LDL cholesterol. Limitations for determining the invitro assay for glycemic index is primarily due to inability to perfectly replicate the complex conditions of the human digestive system in accurately predicting how foods will affect blood glucose levels in individuals.

Amino acid composition of granola bars produced from yellow maize, tropical almond and groundnut grit blends

Amino acid composition of granola from yellow maize, tropical almond and groundnut grit are presented in Table 4. The amino acid with the highest concentration was glutamic acid with values 7.45, 9.89, 10.16, 11.25 and 12.58 protein for A, B, C, D and E. Leucine had the second abundant amino-acid (5.20-7.95g/100g) followed in decreasing order by aspartic acid (5.12-7.84g/100g) and phenylalanine (4.21-5.87g/100g). The amino-acids with least contents in all the samples were tryptophan and methionine with values of 0.79-1.24g/100g

and 1.26-1.51g/100g, respectively. The total non-essential amino-acid (TNEAA) was higher (27.05-45.46g/100g) than the total essential amino-acids (TEAA: 25.14-38.36g/100g).

Table 4: Amino acid composition (g/100g protein) of granola bar produced from yellow maize, tropical almond nut and groundnut grit blends

SAMPLES	A	B	C	D	E	RDA (adult- FAO/W HO/UN U, 2007)	RDA (Children- FAO/WHO/U NU, 2007)
Essential Amino acids							
Leucine	5.20 ^e ±0.23	6.98 ^d ±0.12	7.23 ^c ±1.17	7.49 ^b ±0.16	7.95 ^a ±1.34	3.90	7.30
Lysine	2.94 ^e ±1.12	3.55 ^d ±0.13	4.17 ^c ±1.16	4.52 ^b ±0.15	4.86 ^a ±1.23	3.00	6.40
Isoleucine	2.68 ^e ±0.02	3.58 ^d ±0.14	3.69 ^c ±1.52	4.09 ^b ±0.13	4.26 ^a ±0.13	2.00	3.10
Phenylalanine	4.21 ^e ±0.03	5.28 ^d ±0.15	5.54 ^c ±1.64	5.73 ^b ±0.23	5.87 ^a ±0.01	2.50	6.90
Tryptophan	0.79 ^e ±0.01	0.87 ^d ±0.16	0.99 ^c ±1.65	1.12 ^b ±0.01	1.24 ^a ±1.23	0.40	1.25
Valine	2.93 ^e ±0.03	3.94 ^d ±0.14	4.13 ^c ±1.23	4.38 ^b ±0.14	4.64 ^a ±1.23	2.60	3.80
Methionine	1.26 ^e ±0.01	1.29 ^d ±0.14	1.38 ^c ±0.14	1.42 ^b ±1.23	1.51 ^a ±1.34	1.50	2.70
Histidine	1.38 ^e ±0.06	2.15 ^d ±0.03	2.38 ^c ±0.13	2.52 ^b ±1.14	2.97 ^a ±1.29	-	1.00
Cystine	1.28 ^e ±0.07	1.37 ^d ±0.05	1.39 ^c ±0.13	1.48 ^b ±2.24	1.60 ^a ±1.45	-	-
Threonine	2.47 ^e ±0.01	3.09 ^d ±0.19	3.17 ^c ±0.60	3.28 ^b ±1.20	3.46 ^a ±1.15	1.50	-
ΣEAA	25.14	32.01	34.21	36.03	38.36		3.70
Non-Essential Amino acids							
Proline	2.55 ^e ±0.04	3.26 ^d ±0.12	3.59 ^c ±0.14	3.88 ^b ±1.29	4.11 ^a ±0.14		
Arginine	1.38 ^e ±0.05	2.43 ^d ±0.01	2.66 ^c ±1.13	3.42 ^b ±0.22	3.81 ^a ±1.06		
Tyrosine	2.19 ^e ±0.05	3.14 ^d ±0.06	3.38 ^c ±1.56	3.51 ^b ±1.27	3.92 ^a ±0.04		
Alanine	3.19 ^e ±0.01	4.38 ^d ±0.01	4.51 ^c ±0.14	4.64 ^b ±1.34	4.82 ^a ±1.23		
Glutamic acid	7.45 ^e ±0.03	9.89 ^d ±0.010	10.16 ^c ±0.04	11.25 ^b ±1.10	12.58 ^a ±1.12		
Glycine	2.83 ^e ±0.09	3.71 ^d ±0.15	3.84 ^c ±0.16	3.99 ^b ±1.29	4.20 ^a ±1.14		
Serine	2.34 ^e ±0.07	3.45 ^d ±0.09	3.82 ^c ±0.01	3.91 ^b ±1.11	4.18 ^a ±1.16		
Aspartic acid	5.12 ^e ±0.01	6.83 ^d ±0.02	7.01 ^c ±0.14	7.24 ^b ±1.11	7.84 ^a ±1.11		
ΣNEAA	27.05	37.09	38.97	41.84	45.46		
ΣAA	52.19	69.01	73.18	77.87	83.82		
Values are means of the duplicate determination ± standard deviation. Means with different superscript in the same row are significantly (p<0.05) different. A= 95:0:5; B=90:5:5; C=85:10:5; D= 80:15:5 and E=75:20:5 for yellow maize:tropical almond nut:groundnut blends. ΣEAA = Summation of Essential Amino acids, ΣNEAA = Summation of Non-essential Amino acids, ΣAA = TAA= Summation of Total Amino acids							

Amino acid Composition of Granola bar Produced from yellow maize, tropical almond nut and groundnut blends

Amino acids are component subunit of proteins that support growth of a living system (Brosnan, 2003). Results of this present study for essential amino acids was higher than the Recommended Dietary Allowance (RDA). Yenrinna *et al.*, (2016) reported higher values for essential amino acids in snack bar made from mixed whole wheat variety flour with soy flour. The high value could be as a result of the quality of protein present in whole wheat and soy flour. Glutamic acid is an acidic amino acid that is essential for cell proliferation (Zhao *et al.*, 2006). Glycine is a major component of human skin collagen together with other amino acids such as proline, serine and phenylalanine form of polypeptides that promotes re-growth and tissue healing (Witte *et al.*, 2002).

The most abundant essential amino acids in the granola bars were leucine, lysine, isoleucine, phenylalanine and valine with contents ranging from (5.20 to 7.95 g/100 g, 2.94 to 4.86 g/100 g, 2.68 – 4.26 g/100 g, 4.21 to 5.87 g/100 g and 2.93 to 4.64 g/100 g,) respectively and were significantly higher than their corresponding Recommended Dietary Allowance (RDA) for essential amino acid (3.90 g/100 g, 3.00 g/100 g, 2.00 g/100 g, 2.50 g/100 g, and 2.60 g/100 g) respectively. Lysine in this study was unusually high, this could be attributed to the fact that lysine is predominant in cereals. Lysine is important for children because it aids in bone formation, hormone production, and decreases serum triglyceride levels (Gersten, 2013). The main role of lysine is to participate in protein synthesis, thus it is important for growth and maintenance of the body. All essential amino acids are considerably present in all the samples. In this study, it was observed that tryptophan, methionine, and histidine were the essential amino acids with the lowest concentration in the granola bars. Leucine is recognized as a significant dietary amino acid capable of promoting the synthesis of muscle protein and is said to play a significant therapeutic function in stress-related illnesses like trauma and sepsis (FAO/WHO/UNU, 2007). The significant higher values recorded in the granola bars in the present study was not surprising, since the tropical almond nut and groundnut used to make them have a high protein content. It was reported that the presence and availability of essential amino acids, which are necessary for the growth, reproduction, and maintenance of the human body, are crucial factors in determining the protein quality of a diet. Since essential amino acids play a crucial role in achieving these functions, they are frequently used as indicators of the protein quality of food (Edet *et al.*, 2023).

(Edima-Nyah *et al.*, 2022) reported lower values for the following essential amino acids, lysine (2.45-4.26), phenylalanine (3.46-4.08), leucine (6.65-7.00) and a higher value for isoleucine (3.40-4.60) and the following range of values for non-essential amino acids. Higher values for glutamic acid (11.05-12.78) and glycine (3.80-4.42) and lower values for proline (3.25-3.65) and aspartic acid (6.64-7.63) respectively for maize -coconut snack bars from malted African breadfruit seed flour. Health implication of amino acid enhancement particularly with essential amino acids can offer benefits like improved muscle growth and repair, faster recovery and enhanced athletic performance (Furst and Stehle, 2004).

Improved muscle growth and repair especially after exercise and injury, enhanced athletic performance and endurance due to increased protein synthesis and improved energy production. Improved mood and cognition which involves which involves essential amino acids like tryptophan which are precursors to neurotransmitters like serotonin which influences mood and cognition function. Amino acids are involved in cell regeneration and collagen production which are vital for wound healing (Young, 1994).

Sensory qualities of granola bars produced from yellow maize, tropical almond nut and groundnut blends

The sensory qualities of the granola are presented in Table 5. Variation was observed among the samples. The appearance of the granola ranged from 6.93-7.70 and was not significantly different from each other. The taste of the granola varied from 6.40 to 7.90 and samples B and C was significantly different from sample A, D and E. The aroma ranged from 6.63-8.27. The texture of the granola ranged from 6.43-7.73 with sample A having the lowest value while sample B having the highest value. The general acceptability of the snack bar ranged from 6.60- 7.77 and sample B, C was significantly different from A.

Table 5: Sensory qualities of granola bars produced from yellow maize, tropical almond nut and groundnut blends

Sample	Appearance	Taste	Aroma	Texture	General acceptability
A	6.93 ^a ±1.04	6.40 ^b ±1.03	6.63 ^c ±1.15	6.43 ^b ±1.13	6.60 ^b ±1.16
B	7.70 ^a ±0.98	7.90 ^a ±1.37	8.27 ^a ±0.78	7.73 ^{ab} ±1.59	7.77 ^a ±1.13
C	7.60 ^a ±1.52	7.83 ^a ±1.17	7.83 ^{ab} ±1.26	7.43 ^{ab} ±1.16	7.70 ^a ±1.13
D	7.27 ^a ±1.20	6.83 ^b ±1.05	7.10 ^{bc} ±1.15	6.87 ^{ab} ±1.16	6.97 ^{ab} ±1.89
E	7.30 ^a ±1.78	6.53 ^b ±1.65	6.70 ^c ±1.64	6.47 ^b ±1.57	6.97 ^{ab} ±1.27

Values are means of the triplicate determination ± standard deviation. Means with different superscript in the same column are significantly (p<0.05) different. A= 95% yellow maize, 0% tropical almond and 5% groundnut grit; B=90% yellow maize, 5% tropical almond and 5% groundnut grit; C=85% yellow maize, 10% tropical almond and 5% groundnut grit; D= 80% yellow maize, 15% tropical almond and 5% groundnut grit and E=75% yellow maize, 20% tropical almond and 5% groundnut grit.

Sensory Qualities of Granola bar Produced from yellow maize, tropical almond nut and groundnut blends

From results on Table 5, sample B was most accepted although there was no significant difference between samples B and C in all sensory characteristics. Sensory characteristics of granola bars produced revealed value ranges of (6.93 – 7.70) for appearance, (6.40 – 7.90) for taste, (6.63-8.27) for aroma, (6.423-7.73) for texture and (6.60-7.77) for general acceptability. Eke-Ejiofor and Okoye (2018) also reported similar sensory scores for texture (5.60-7.20), taste (6.0-7.10), aroma (5.60-6.70) and overall acceptability (6.05-7.50) of cereal bars produced from rolled oat, yellow maize white millet and guinea corn compared with the result reported in this study.

Sensory analysis includes all and crucial characteristic as they are more distinct to consumers and the sensations that a person may experience when holding or eating food, Omoba *et al.*, 2013. It is also used to determine the texture of foods (Bello *et al.*, 2020). Alawode *et al.*, (2017) reported that the sensory characteristics of cereal snack bars go a long way to influence the acceptability of the product by consumers. Sample with 90% yellow maize, 5% tropical almond nut 5% groundnut blend (sample B) was best accepted in appearance, taste, aroma, texture and overall acceptability. Edima-Nyah *et al.* (2019) reported a sensory score for appearance (5.00-6.93), taste (5.36-7.56), texture (5.96-7.30) and overall acceptability (5.63-7.80) which was within the ranges observed in this study. Linking functional properties to sensory outcome shows that the higher the bulk density in this study, the lower the sensory score on texture of the granola bars and the higher incorporation of tropical almond nut flour, the higher the foam capacity. Limitation of sensory panel scope have inherent limitations like subjectivity of human perception, potential for panelist been fatigue and bias, limited availability of samples, and high cost of recruitment and training.

Conclusion

Acceptable granola bars were produced from blends of provitamin 52 yellow maize, tropical almond nut and groundnut grits. Inclusion of tropical almond nut flour in the granola bar formulation increased the nutrient content (protein, ash, fibre, essential amino-acids) and *in-vitro* protein digestibility of the products. A lower glycemic index was recorded with increased incorporated tropical almond nut, giving a more health friendly and nutritious snack product. The inclusion of tropical almond nut flour into yellow maize flour, fortified with groundnut grit in the production of granola bars would greatly enhance the utilization of these crops in developing countries like Nigeria in particular and West Africa in general. This help in improving the health of consumers by supplying bio-active and functional compounds.

Recommendations

It is therefore recommended:

- Provitamin 52 yellow maize be utilized in the production of snacks. The pro Vitamin 52 yellow maize flour could also be a substitute to wheat flour which could help reduce the cost of the conventional wheat flour importation, and expand its usage.
- Incorporating tropical almond flour into bakery items up to a concentration of 20% can serve as a nutritious enhancer and as a component in formulating nutrient-rich snack bars, given its potential utility in various food preparations.
- Also, employing advanced methods to produce premium granola bars is advised.

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