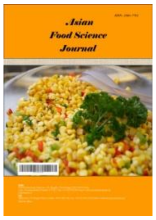

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Evaluation of Chemical, Physical and Functional Properties of Extruded Snacks from Blends of Acha Grain, Jackbean and Pawpaw Pormace Flours

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: To produce protein and fibre enriched extruded product that can be used as a protein supplement by combining legumes, cereal and fruits, evaluate the proximate properties of the snacks, evaluate anti-nutritional factors in the snacks, assess the functional properties of the flour blends, determine the physical properties of the extruded snacks, evaluate the quality and sensory properties of the snacks produced, carry out the mineral content analysis of the extruded products.
Methodology: Acha flour (A), Jack bean flour (J) and Pawpaw flour (P) were produced and blended to give various ratios of AAA (100% Acha, 0% jackbean, 0% pawpaw pomace), AJP (70% Acha, 20% Jackbean, 10% pawpaw), APJ (70% Acha,10% Jack bean, 20% pawpaw), AJN (70% Acha, 30% Jackbean, 0% Pawpaw), ANP (70% Acha, 0% Jack bean, 30% Pawpaw). These composite flour blends were used to produce extruded snacks and were analyzed for their proximate, minerals, anti-nutritional contents, and sensory properties, functional and physical properties. The analysis were carried out in triplicates for all the five formulations. The result obtained *from* the analysis were statistically analysed using SPSS 16.0 defined at ($P < 0.05$).
Results: Protein content ranged from 10.92% to 6.98% with ANP having the highest and low in AAA, Carbohydrate content also ranged from 83.76% to 79.40%, high in AJP and lower in ANP,

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AAA had the highest moisture content of 3.88% and low in AJP 2.66, Fat content was high ANP (4.41%) and low in AJN and AJP (3.00%), APJ has the highest fibre content of (3.60%) and lower in AJN (1.18%) Ash was high in AAA and low in AJP (2.89% and 1.59%) respectively. The tannin content ranged between 0.18 to 0.36mg/g with ANP to be the highest, phytate content ranged between 0.25mg/g to 0.63mg/g. Saponin content ranged from 0.35 to 0.73mg/g with ANP to be the highest among them. As for the functional properties, the bulk density ranged between 0.84 - 0.92g/ml with the control samples (AAA) having the highest value and the lowest value was observed in sample AJP. Water absorption capacity and Oil absorption capacity ranged between 0.88 – 3.5% and 1.33 – 2.33% respectively. Physical properties of the extruded snacks; bulk density ranges between 0.23 – 0.38% with sample AAA having the highest value and ANP being the lowest, Apparent density, Lateral expansion and Porosity ranged between 0.36 – 0.62%, 79 – 130% and 0.47 – 0.81% respectively. All the five formulations have no significant difference in there sensory attributes. Mineral content, Potassium content was high in ANP (203.75mg/100g) and low in AJP (148.75mg/100g), Calcium was high in ANP (576.25mg/100g) and low in AAA (435.50mg/100g), Magnessium was high in ANP (208.25mg/100g) and low in AAA (208.25mg/100g).

Conclusion: Inclusion of pawpaw pomace and Jackbean to the composite increased ($p<0.05$) the protein and Mineral content of the product, when compared with the control. Based on the nutritional values and sensory attributes, AJP and ANP snacks could be recommended as an appropriately enriched snack product.

Keywords: Acha; jackbean; pawpaw pomace; proximate composition; anti-nutritional factor.

1. INTRODUCTION

Food process industry is often challenged to develop convenience foods such as snacks, direct-expanded (puffed) and breakfast cereals of high nutritional value that will adequately meet the needs of the populace in developing countries using locally available food ingredients due to their snacking habits [1]. Snack foods are quick-to-eat foods that can be consumed in between meals. In Nigeria, a growing portion of the household food budget is spent on snack foods, where convenience and quality are viewed as the most important factors [2]. In developing countries, snacks are sometimes relied upon to meet the physiological needs of the populace particularly children. Children are growing rapidly, and as such, have increased needs for energy as well as other essential nutrients [3], they need to eat more frequently to meet this need. Snacks help to bridge the gap between meals. Healthy snacks can help to ensure that children are getting the nutrients they need to fuel their growth and development [3]. Proteins are a necessary component of the diet for both animals and humans to survive. One of their basic functions in nutrition is to supply adequate amount of needed amino acids [2].

Extruded snacks products are predominantly made of starchy food source and have a tendency to be low in protein and have low biological value as they have low amount of essential amino acids. A good deal of attention has been paid to fortifying extruded foods with cereals high in protein and lysine to enhance the essential amino acids content. Generally, cereals and legumes, such as red kidney beans, soy and corn, have been used to make highly nutritious products [4]. Consumers have expressed concern about the functional properties, as well as the nutritional quality of products. Acha (*Digitariaexilis*), also known as hungry rice, is an African cereal that is both indigenous and underutilized. The cereal is particularly high in methionine and cystine, and it has a low sugar content [5]. Its methionine content is thought to be twice as high as that of egg protein [6]. Because of the nutritional value, Acha is highly recommended for diabetic patients by doctors. Acha like other cereals lacks lysine. Jackbean *(Canavaliaensiformis)* belongs to the family of the Leguminosae. Also called Chickasaw Lima bean, sword bean (canavaliagladiatd), horsebean and gotani bean, it is a tropical climber producing long pendant green beans [7]. Young pods and beans of Jackbean are eaten as vegetables [8] but only after much preparation and cooking as they contain mild poison in the form of anti-nutritional factors (protease inhibitors, lectins, saponins and tannins). However, the Jackbean seeds coat is not to be eaten. The crude protein content (20-32%) and amino-acid profile of the mature Jackbean seed are both high [7]. It is rich in aspartic acid, glutamic acid and histidine, and its level of the essential amino acids isoleucine, leucine and tyrosine are higher compared to some common legumes; however, it is deficient in sulphur containing amino-acids [9].

Pawpaw (*Carica papaya*) a member of the family Caricaceae is one of the fruits enjoyed by most people in the world. When perfectly ripe, the fruit is a large edible berry with various seeds that is often eaten fresh without the skin or seeds. Brew, wine, or brandy may be made from the pulp after fermentation. Pawpaw has a unique flavor that resembles a variety of tropical flavors including banana, pineapple and mango. Pawpaw is a strong banana substitute in almost every recipe because of its taste and custard-like texture. Pawpaw is a good source of vitamin C, carotene, fiber, minerals like magnesium, iron, copper, manganese, potassium, and other amino acids, according to research [10,11]. Apples, grapes, and bananas are all richer in niacin, calcium, and potassium than pawpaw. Pawpaw have three times much vitamin C as apples, two times as much as bananas and one-third as much as oranges. Pawpaw is the only fruit that contains all of the essential amino acids as well as being high in antioxidants [12]. Apart from having protection against colon cancer, both of these nutrients improve cardiovascular health. Being a rich source of fiber, pawpaw consumption helps in lowering high cholesterol levels [13].

Blending of Acha, Jack bean and pawpaw would provide a wide range of high calories, protein, fibre and micronutrients if properly processed. Furthermore blending of jack bean high in protein, Acha rich in calories and pawpaw rich in vitamin A and C, fibre and mineral would provide reasonable level of enrichment. The application of extrusion cooking would improve the preservation of these vital nutrients. Furthermore, extrusion cooking principles have been widely applied for the retention of nutrients, and against nutritional factors [14].

Extrusion cooking is a very versatile, high temperature processing method widely used in the food processing industry because of the extruder high production capacity and efficiency. Extrusion cooking technology incorporates mechanical shear, high pressure, and inter-particulate frictional heat to quickly convert raw materials into cooked goods [15]. It has also been demonstrated to increase the nutritional quality of foods such as snacks [16]. This research work seeks to combine Acha, Jackbean and Pawpaw pomace in various proportion to produce snack which will enhance nutritiously the ever increasing snack market. It will also stimulate the cultivation, utilization as well as provide direction for future research work of lesser known crops such as Acha and Jackbean.

2. MATERIALS AND METHODS

2.1 Materials Sample Collection

Acha grains was obtained from Jos central market, Jos, Plateau State, Jack bean was obtained from Bodija market, Ibadan, Oyo state, Pawpaw fruit was purchased at National Horticultural Research Institute, other ingredients such as sugar, salt, vegetable oil, was purchased from Bodija market, Oyo state.

2.2 Methods

2.2.1 Production of acha flour

Acha flour was produced as shown in Fig. 1. The grain was manually cleaned by handpicking of the chaff and the dust and stones were removed by washing in tap water and dried, the washed and de-stoned grains were dried at 50°C for 4hrs in a hot air cabinet Dryer (Genlab oven) and milled into fine powder using a disc mill. The flour was sieved to pass through 0.3mm screen size mesh (Laboratory test sieve, endecotts Ltd, London England) and packed in a tight polyethylene bag [17].

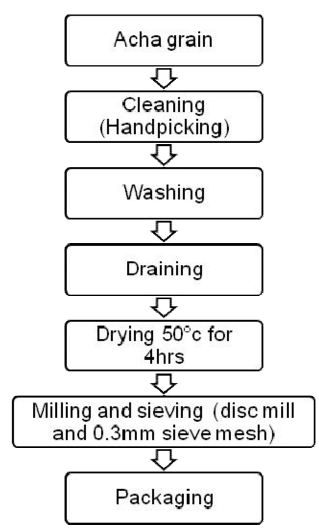

Fig. 1. Flow diagram for the production of Acha flour

Source: Ayo and Andrew, 2016

2.2.2 Production of Jack bean flour

The method used was as shown in Fig. 2. The seeds were sorted and soaked in water for 24hours at room temperature to loosen the coat and prepare it for germination. The beans were drained and the wash water discarded, the soaked jack bean was spread on a tray at room temperature and water sprinkled daily for until they germinated. The sprouts were dried in an oven (Genlab oven) at 55°C for 6hrs and the remaining hull removed. The dehulled dried beans were milled into flour with hammer mill [18].

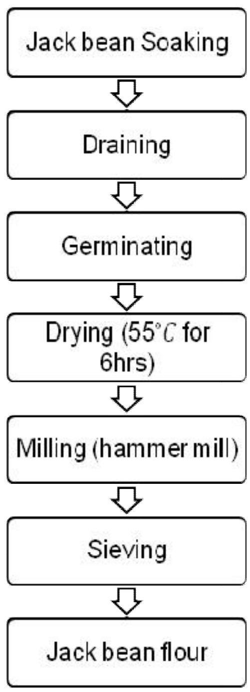

Fig. 2. Preparation of Jack flour
Source: Chaturvedi et al. 2015

2.2.3 Production of pawpaw pomace flour

Pawpaw fruits were sorted and washed to remove dirt and other adhering materials and weighed as shown in Fig. 3. The fruits was peeled and sliced with a sharp knife then blended and squeezed to extract the juice, the chaff was then blanched for 4 minutes, dried at 70°c in a hot air cabinet Dryer for 7hours and milled into fine powder using a hammer mill, The flour was sieved to pass through 0.3mm screen size mesh (Laboratory test sieve, endecotts Ltd, London England) and packed in a tight polyethylene bag [19].

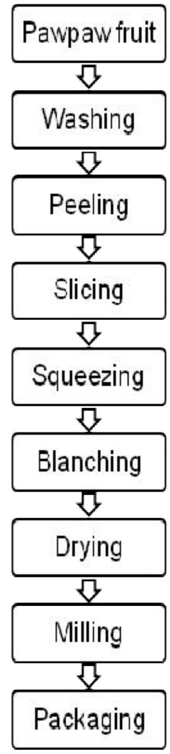

Fig. 3. Flow diagram for the production of pawpaw flour
Source: Odom et al, 2013

2.2.4 Preparation of flour blend

Composite blends of Acha flour was mixed with Jack bean flour and pawpaw flour in different ratios (Table 1). The flour were thoroughly mixed to obtain homogenous blends. Samples were stored in air-tight HDPE film at room temperature until ready to use.

2.2.5 Production of extruded snacks

Extrusion cooking was done in a single-screw extruder (American Extrusion International 498 Prairie hill road south Beloitril 61080 AE 50: model number: AEI-FDR-HOP), equipped with a variable speed DC drive unit and strain gauge type torque meter. The extruder was fed manually through a screw operated conical hopper using a plastic bowl. The hopper which was mounted vertically above the end of the extruder is equipped with a screw rotated at variable speed. The experimental design for the extrusion runs were carried out at a screw speed of 280rpm, extrusion temperature was maintained at 101°C. After the extrusion cooking. The extrudates were oven dried at 150°c for 5 minutes to obtain dried extrudates and cooled [20].

2.3 Analysis of Raw Material and Product

Chemical, physical and sensory analyses were performed on the products as described below.

2.3.1 Proximate composition

The quality of the extruded snacks was assessed in terms of proximate composition, the moisture (925.09B), protein (979.09), fat (920.39C), ash (923.03), crude fibre (962.09E) contents were determined using the AOAC (2005) method [21]. The amount of carbohydrate available was calculated using the following formula: Carbohydrate = 100 - (% moisture + % protein + % fat + % ash + % crude fibre) using the method of FAO [22].

2.3.1.1 Moisture content

A clean crucible was dried in an oven (Genlab oven) at 105 °C for 1 hours and placed in desiccators to cool, and the weight of crucible (W1) was determined. About 3grams of samples was weighed in dry crucible (W2) and dried at 105°c for 3hours after cooling to room temperature, and was weighed (W3) again. At the end the moisture content was determined from the equation: Moisture content in percent

$$(\%) = \frac{W2 - W3}{W2 - W1} \times 100$$

Where;

W1= Weight of the drying crucible,
W2= Mass of the drying crucible and the sample before drying,
W3 = Mass of the drying crucible and the sample after drying.

2.3.1.2 Crude protein content

The dried ground sample (0.6g) was weighed into an already dried kjeldahl flask. A few drops of water was added to the sample to moisten it, using a burette, 3ml of concentrated H_2SO_4 acid was added into the flask followed by the addition of 0.5g of $CuSO_4$. The content of the flask was then digested in a fume cupboard with occasional stirring until a clear solution was obtained. The flask was allowed to cool and a small quantity of distilled H_2O added. The digest was then transferred into 100ml volumetric flask and the initial volume recorded. The mixture was shaken thoroughly to obtain a homogenous solution.

The mixture was now ready for distillation. The distillation apparatus was steamed for 30 minutes as to get rid of traces of alkali left in the flask. With the aid of a pipette, 10ml of the digest was added to the micro distillation apparatus using a funnel. 10ml of 50% NaOH solution was put in the funnel with measuring cylinder, with stopper glass rod in place. A water condenser set was connected with a 100ml conical flask used as a receiver which contained 10ml of 4% boric acid and two (2) drops of mixed indicator (bromocressol green/methyl red). The drop end of the condenser was immersed well into the boric acid. The stopper glass rod was gradually removed to allow the NaOH solution to thoroughly mix with the sample digest solution. The funnel was filled with distilled H_2O and the steam generator was closed at the top and steam passed into the distillation set. NH_3 was liberated and was distilled into 10ml 4% boric acid for 15 minutes. 50ml of the distillate of blue/green colour was collected and the drip end of the condenser was washed with distilled water into the 100ml conical flask containing the distillate. The distillate was then titrated against 0.1N hydrochloric acid till it changed to pink colour.

A reagent blank was run as a control and the protein content was then calculated by multiplying Nitrogen obtained with the factor of 6.25, expressed on dry basis. The experiment was carried out in triplicates. The formula for % crude protein is given below: % Protein = $\%N_2$ × 6.25.

$$\%N_2 = \left[\frac{100}{W} \times \frac{N \times 14}{1000} \times \frac{V_t}{V_a}\right] T - B$$

Where;

W = Weight of sample
N = Normality of titrant
V_t - Total digest volume
V_a = Volume of digest analyzed
T = Sample titre value
B = Blank titre value

2.3.1.3 Crude fat

Empty extraction flasks were cleaned and dried at 92 °C for at least an hour and then kept in the desiccator for at least half an hour. The mass of cooled flasks were weighed (Wj). About 5 g of the sample was weighed (W2) in to each of the thimbles lined with fat free cotton at their upper and bottom. The thimbles with their sample content were placed in to the Soxhlet extraction chamber.

A 40 ml of petroleum ether was added in to each flask used for the extraction. The extraction process was done for about 6 hours, the thimble was removed with care, and the petroleum ether was recovered for reuse. When the flask was free of ether it was removed and dried at 92°C for 1 hour in an oven. The flask was cooled in a desiccator and weighed. The masses of each flask together with its fat contents were weighed immediately after it is taken out of the desiccator (W3).

The crude fat content was calculated from the equation: Weight of fat W-W3-W,

$$\%Fat = \frac{W}{W2} \times 100$$

Where:

W = weight of fat
W_3 = weight of fat + flask after extraction and drying
W_j = weight of empty extraction flask
W_2 = weight of the sample

2.3.1.4 Crude fibre

2.0 g of defatted sample was weighed in each of 600 ml beaker. A 200 ml of 1.25% sulfuric acid solution was added to each beaker and allowed to boil on hot plate for 30 min by rotating and stirring periodically. During boiling the level was kept constant by addition of hot distilled water. After 30 min, 20 ml of 28% potassium hydroxide solution was added in to each beaker and again allowed to boil for another 30 min. The level was still kept constant by addition of hot distilled water. The solution in each beaker was then filtered through crucibles containing sand by placing each of them on Buchner funnel fitted with rubber stopper. During filtration the sample was washed with hot distilled water. The final residue was washed with 1% sulphuric acid solution, hot distilled water, 1% sodium hydroxide solution and finally with acetone. Each of the crucibles with their contents was dried for 2 hour at 130°C and cooled in desiccators and weighed (W1). Then again they were ashed for 30 min at 550°C in furnace and were cooled in desiccators. Finally the mass of each crucible was weighed (AVS). The crude fiber was calculated from the equation: Total Crude fiber = (W1-W2/W3) X 100.

Where:

W1 = Crucible weight after drying
W2 = Crucible weight after ashing
W3 = Sample dry weigh

2.3.1.5 Total ash

Clean porcelain crucible, dried at 120 C in an oven was ignited at about 550 C in a muffle furnace for 3 hours was cooled in desiccators and weighed (M1). Then about 2.0 g samples were weighed into a previously dried and weighed (M2) porcelain crucible. These samples were dried at 120°C for 1 hour and carbonized by oven until the contents turn black. The crucible with the contents were placed in a Muffle furnace set at 550°C for 1hour to ignite until ashing was complete. After this period the crucible with its content was removed and cooled in desiccators. The crucible with the residue was weighed (M3). The weights of the ash were expressed as a percentage of the initial weight of the samples. The total ash was expressed as percentages on dry matter basis as follows Total Ash (%) = (M3-M1/M2-M1) X 100/1

Where;

M1 = Mass of dried dish
M2 = Mass of dish and sample before ashing
M3 = Mass of dish and sample after ashing

2.3.1.6 Total carbohydrates

Total carbohydrates (CHO) was determined by difference that was by subtracting the sum of the percentages of moisture (M), crude protein (P), lipid (L), Fiber (F) and ash content (A) from I00 following the method of [22]. Carbohydrate = 100 - (% moisture + % protein + % fat + % ash + % crude fibre).

2.3.2 Anti nutritional analysis

2.3.2.1 Tannin determination

The Folin-Denis (2012) spectrophotometric method was used. The method was described by [23]. A measured weight of each sample (1.0g) was dispersed in 10ml distilled water and agitated. This was left to stand for 30min at room temperature, being shaken every 5min. At the end of the 30mins, it was centrifuge and the extract gotten. 2.5ml of the supernatant (extract) was dispersed into a 50ml volumetric flask. Similarly 2.5ml of standard tannic acid solution was dispersed into a separate 50ml flask. A 1.0ml folin-denis reagent was measured into each flask, followed by 2.5ml of saturated Na2C03 solution. The mixture was diluted to mark in the flask (50ml) and incubated for 90min at room temperature. The absorbances were measured at 250nm in an electronic spectrophotometer. Readings were taken with the reagent blank at zero. The tannin content was given as follows;

$$\%\ \text{Tannin} = \frac{Au\ \times C}{AsW} \times \frac{100}{Va} \times Vf\ \times D$$

Where;

Au = Absorbance of test sample
As = Absorbance of standard tannin solution
C = Concentration of standard tannin solution
W = weight of sample used
Vf = total volume of extract
Va = Volume of extract analysed
D = Dilution factor (if any)

2.3.2.2 Determination of phytate

The method described by Nwosu [24] was used. Thephytic acid in the samples was precipitated with excess $FeCl_3$ after extraction of 1g of each sample with 100ml 0.5N HCl. The precipitate was converted to sodium phytate using 2ml of 2% NaOH before digestion with an acid mixture containing equal portions (1ml) of cone. H_2SO_4 and 65% $HClO_4$. The liberated phosphorus was measured colorimetrically at 520nm after colour development with molybdate solution. The percentage phytate was thus calculated:

$$\%\ \text{Phytate} = \frac{100}{Va} \times \frac{au}{W} \times \frac{C}{as} \times Vt$$

Where;

W = weight of sample used
au - absorbance of test sample
as = absorbance of standard phytate solution
C = Concentration of standard phytate solution
Vt = Total volume of extract
Va - Volume of extract analyzed

2.3.2.3 Determination of saponins

The method described by Sutharsingh et al. [25] was used. 20 g of powdered sample was treated with 100 ml of 20% aqueous solution of ethanol, heated over a hot water bath for 4 hours at about 55°C with continuous stirring. The mixture was filtered and the residue re-extracted. The combined extracts were reduced to 40 ml over a water bath at about 90°C and the concentrate was transferred into a separating funnel and 20 ml of diethylether was added and shaken vigorously. The aqueous layer was recovered while the ether layer was discarded. The purification process was repeated and 60 ml of n-butanol was added to the combined extracts and washed twice with 10 ml of 5% aqueous NaCl. The remaining solution was heated in a water bath, dried in an oven to a constant weight and the saponin content was calculated as g $l00g^{-1}$

2.3.3 Functional properties

2.3.3.1 Bulk density

This was determined using the method described by Onwuka [26]. About 2.5 g of flour sample was filled in a 10 ml graduated cylinder and its bottom tapped on the laboratory bench until there was no decrease in volume of the sample. The volume was recorded.

$$\text{Bulk density } = \frac{\text{Weight of sample (g)}}{\text{Volume of sample (ml)}}$$

2.3.3.2 Water and oil absorption capacities

The water and oil absorption capacities were carried out according to the method described by Odedeji and Adeleke [27]. 15 ml distilled water or oil was mixed with 1g of the flour sample in a weighed 25ml centrifuge tube and stirred for 2minutes, then centrifuged (Benchtop centrifuge, model 1C241R, UK) at 4000rpm for 20 min and finally the water and oil absorption capacities of the flour were expressed as grams of water or oil absorbed by 1g of the flour sample.

Water/Oil absorption capacity = V1-V2
Weight of sample

Where;

V1= Initial volume of water used
V2= Volume of water after centrifuging

Table 1. Flour blends prepared from Acha flour, Jackbean flour and Pawpaw flour

Samples	Acha Flour %	Jack bean Flour %	Pawpaw Flour %
AA	100	0	0
AJP	70	20	10
APJ	70	10	20
AJN	70	30	0
ANP	70	0	30

2.3.4 Determination of some physical properties of the extrudates

2.3.4.1 Bulk density

The bulk density was determined by measuring the actual dimension of the extrudates [28]. The diameter of the extrudates were measured using a digital vernier caliper, while the length was measured with the aid of a metric ruler. The weights per unit length of the extrudates were determined by weighing measured lengths. The bulk density (Pb) was then calculated using the following formula.

$$\text{Pb} = \frac{4 \times M}{\pi d^2 L}$$

Where;

Pb = Bulk density (g/cm3)
d = Diameter of the extrudate (mm)
L = Length per gram of the extrudate (mm/g)
M= Mass of the extrudate (g)

2.3.4.2 Apparent density

Apparent density was determined according to the method of [29]. The extrudates were manually ground using a ceramic pestle and mortar. A 5ml gradated cylinder was tarred using a digital balance and gently filled with the milled extrudate. The bottom of the cylinder was repeatedly tapped gently until there was no further reduction of sample volume and was weighed. The apparent density (Ps) of the extruded sample was calculated as mass per unit volume (g/cm^3);

$$\text{Ps} = \frac{Mass\ (g/cm^3)}{Volume}$$

2.3.4.3 Porosity

The porosity of the extrudates was determined from the bulk and apparent volumes [29]. Porosity was calculated using the equation;

$$\text{Porosity} = \text{Bulk volume} - \text{Apparent volume}$$

Where;

Bulk volume = 1/Pb
Apparent volume = 1/Ps

2.3.4.4 Lateral expansion

The ratio of the diameter of the extrudates and that of the die was used to express the expansion of the extrudate [30]. The size and length of the extrudates were selected at random. The diameter of the extrudates was measured at 10 different positions along the length of each of the five samples using a digital vernier caliper. Lateral expansion (LE) was calculated using the Mean of the measured diameters as follows:

$$\text{LE} = \frac{\text{Diameter of product} - \text{Diameter of die hole x100}}{\text{Diameter of die hole}}$$

2.3.5 Sensory evaluation of extruded snack

The Acha-jackbean-pawpaw snack was compared to 100% whole Acha (control) and assessed by a thirty-member taste panel. The panelists were selected randomly based on their familiarity with the product. Panelists had to commit to participation throughout the evaluation period. The products were evaluated for colour, texture, flavour, aroma and overall acceptability. A nine-point Hedonic scale from [31] 9 (like extremely) to 1 (dislike extremely) was used. The scores were statistically analysed using analysis of variance. The products were coded AAA = 100:0:0% whole Acha flour, AJP - 70:20:10% Acha, Jack bean and pawpaw flour, APJ = 70:10:20% Acha, Jack bean and pawpaw flour, AJN = 70:30:0% Acha, jack bean and pawpaw flour and APN = 70:0:30% Acha, Jackbean and pawpaw flour and were placed in white plastic plates. The panelists rinsed their mouths with bottled water after tasting each sample.

2.3.6 Mineral determination

2.3.6.1 Calcium content determination

This was determined by using the AOAC (official method 975.11) [21]. The ash of each sample obtained was digested by adding 5ml of 2ML of HCL to the ash in the crucible and heat to dryness on a heating mantle. 5ml of 2M HCL was added again, heat to boil, and filtered through a filter paper to into a 100ml volumetric flask. The filtrate was made up to mark with distilled water stopper and made ready reading of concentration of calcium on the digital flame photometer using the filter corresponding to the mineral element. The concentration of the element was calculated using the formula:

$$\%\text{Ca} = \text{Meter reading (MR) x slope x dilution factor}$$

2.3.6.2 Determination of magnessium

This was determined by using AOAC official method (975.23) [21]. The digest of sample obtained in calcium determination was washed into 100ml volumetric flask with deionised or distilled water and made up to mark. This diluents was aspirated into the atomic absorption spectrophotometer (AAS) through the suction tube. Each of the trace elements was read at their respective wavelengths hollow cathode lamps using appropriate fuel and oxidant combination. The meter reading for each element was used to calculate for the concentration of each element using the fomula:

$$\text{Ppm} = \frac{\text{Meter Reading x Slope x Gradients x Dilution factor}}{1000}$$

2.3.6.3 Determination of potassium

Potassium was determined by a procedure described by Omah [32] using a flame photometer. Potassium standard was prepared. The standard solution was used to calibrate the instrument read out. The meter reading was at 100% E (emission) to aspire the top concentration of the standards. The %E of all the intermediate standard curves were plotted on linear graph paper with these readings. The sample solution was aspired on the instrument and the readings (% E) were recorded. The concentration of the element in the sample solution was read from the standard curve. Calculation:

$$\%\ \text{Potassium} = \frac{\text{DF x I00xPpm}}{Million\ 1}$$

2.3.7 Statistical analysis

The scores were determined and subjected to one way analysis of variance (ANOVA) using the statistical package for social statistical (SPSS version) means were separated using the Duncan (1955) multiple range test.

3. RESULTS AND DISCUSSION

3.1 Chemical Composition Of The Extruded Products

The proximate composition of the extruded snacks from Acha, Jackbean fortified with pawpaw (AJP, API, and ANP), Acha and jackbean (AJN) and the control sample Acha (AAA) are presented in Table 2

3.1.1 Crude protein

There were significant (P < 0.05) differences in all the measured parameters. The protein contents which ranged from 6.98 to 10.92% were significantly (P > 0.05) different from each other. The lowest value was expectedly observed in control sample which was mainly acha flour, as reported by [6] that acha contains about 7% crude protein, the reduction in protein content may be probably due to the increase in calorific content. However, acha blend with 30% pawpaw fortification (ANP) extrudate had significantly higher protein content than the other samples this may be due to the flour mixture [33]. So these might be the possible reason for the relatively higher value of protein contents of ANP extrudates in this study. Also, Acha blend with jackbean with 0% pawpaw and 10% pawpaw also has a higher protein (9.00%) than acha blend with jackbean and pawpaw 20% sample (8.68%). This could probably due to the fact that jackbean has higher protein content than pawpaw, it was also observed in this study that protein content of the extrudates reduces as jackbean percentage by quantity is reducing.

3.1.2 Moisture content

The moisture content of all samples ranges from 2.66%-3.88% and they were significantly (P < 0.05) different. The control sample (AAA) has the highest range while acha-jackbean with 10% pawpaw (AJP) has the lowest. The low moisture content of the snacks is important because, it will help in extending the shelf life if adequately protected, by inhibiting the development of contaminating micro-organisms, whose growth and activities are favoured by presence of moisture [30]. Low moisture content will give the product a long shelf

3.1.3 Fat

The fat content ranged from 3.00 to 4.41% in the extrudate. This increase could be attributed to the vegetable fat added to the formulation, the sample with the lowest value observed in the Acha-jackbean sample (AJN) and Acha-jackbean with 10% pawpaw (AJP), they were significantly (P < 0.05) different among the other samples. The fat content increased as jackbean flour was reduced into the recipes, the highest value was observed in Acha with 30%pawpaw ratio, this may be due to addition of pawpaw as described by Ramesh et al. [34] that pawpaw pomace has 4.73% fat content which is higher than that of jackbean 2.3%-3.9% as reported by [7]

3.1.4 Fibre

The crude fibre contents of the extruded snacks ranged from 1.81 to 3.60%, sample AJP was found to be the highest due to different formulation of pawpaw and jackbean. Also noticeable was a slight increase in the fibre with increasing addition of pawpaw in the blends, as reported that pawpaw pomace has 29.58% fibre and 4.9-8.0% in jackbean [7,34]. Sample AJN and AJP are significantly different from other sample at (P <0.05). Fibre is important for the removal of waste from the body thereby preventing constipation and many health disorders. The snacks have a great potential for application as Super Cereal Plus for young children aged 6 months – 2 years, because of the fibre source in their formulation that could be modified to generate a near perfect recipe for production of Super Cereal Plus.

3.1.5 Ash

The percentage ash content of the samples was within the range of 1.59% and 2.89% and they were significantly different from other at (P < 0.05). The ash content of the sample decreases with addition of germinated Jackbean flour. The percentage ash of the sample gives an idea about the inorganic content of the samples from where the mineral content could be obtained. Samples with high percentages of ash contents are expected to have high concentrations of various mineral elements, which are expected to speed up metabolic processes and improve growth and development as reported by [35].

3.1.6 Carbohydrate

The total carbohydrate content ranged between 83.76% for (AJP) extrudate to 79.40% for (ANP) extrudate, this may be due to the increased amount of jackbean and pawpaw in both extrudate, as it was reported that jackbean has 45.2% - 56.9% of carbohydrate and 9.81% for that of pawpaw as described by USDA [7]. Jackbean seed flour and pawpaw can be considered as a potential source of carbohydrate when used to enrich the content of conventional source like cereals [35].

3.2 Mineral Analysis of the Extruded Snacks

The Mineral analysis of the extruded snacks from Acha, Jackbean" fortified with pawpaw (AJ, APJ, and ANP), Acha and jackbean (AJN) and the control sample Acha (AAA) are presented in Table 3. The calcium, magnesium and potassium content obtained for extruded snacks ranged between 576.25 – 435.50mg/100g, 233.25 – 208.25mg/100g and 203.75 – 148.75 mg/l00g respectively, Significant (P < 0.05) differences were observed among the samples. The mineral contents of the extruded snacks increased as the level of incorporation of pawpaw and jackbean flour increased. Extrusion cooking had been found to improve the absorption of minerals by reducing antinutritional factors (such as hydrolysis of phytate that form complexes with metals and protein thereby inhibiting its absorption), but does not significantly (P > 0.05) affect mineral composition of jack bean seeds [36].

3.3 Anti-Nutritional Analysis of the Extruded Snacks

The antinutritional analysis of the extruded snacks from Acha, Jackbean fortified with pawpaw (AJP, APJ, and ANP), Acha and Jackbean (AJN) and the control sample Acha (AAA) are presented in Table 4. The phytate level ranges from 0.66mg/g to 0.25mg/g in the extruded samples. 100%acha (AAA) has the lowest phytate level and high in 70%Acha and 30% pawpaw (ANP) and 70% acha, 10% pawpaw and 20% jackbean (AJP). All samples show no significant difference in phytate content. Tannin content of ANP and AJP shows no significant difference while sampls AAA, AJN and APJ are significantly different (P < *0.05*). Samples AJN and AJP shows no significant difference in their saponin content and AAA and ANP shows no significant difference in their saponin content but sample APJ is significantly different (*P < 0.05*). Extrusion cooking further reduced the level of phytate in the extrudates. The values obtained in this study were lower than 2.5% phytic acid reported for acha flour [14]. It would be expected that lowering of this compound should enhance the content of some minerals in the extrudates as phytic acid has been implicated in making these minerals unavailable.

The Tanin level ranges from 0.18mg/g to 0.36mg/g in the extruded samples. (AAA) has the lowest tanin level and high in (ANP) and 70% (AJP). The highest tannin and phytate level obtained in this study were in ANP, this may be due to the fortification with pawpaw.

Saponin level ranges from 0.35mg/g to 0.73mg/g and there are significantly differences between the samples.

3.4 Functional Analysis of the Flour Samples

The functional analysis of the extruded snacks from Acha, Jackbean fortified with pawpaw (AJP, APJ, and ANP), Acha and jackbean (AJN) and the control sample Acha (AAA) are presented in Table 5. Bulk density ranged from 0.84 g/cm for Acha, jackbean and pawpaw with ratio 70%, 20% and 10% respectively to 0.92 g/cm3 for acha flour (AAA). As more pawpaw and jackbean bean powder were incorporated, the bulk density decreases the result show that there was no significant difference among the samples (*P <* 0.05). Bulk density is significant in package design, storage and transport of foodstuff [15].

Water absorption capacity ranged from 3.55% to 0.88%. There were significant differences among the blended samples. The water absorption capacities increased with an increase level of incorporation of jackbean flour and pawpaw flour when compared with Acha flour, which had the lowest water absorption capacity. Water absorption capacity is important in bulking and consistency of product as well as in baking applications [37].

Oil Absorption Capacity (OAC) ranged between 2.33% - 1.33%. OAC increases with incorporation of jackbean flour and pawpaw flour, OAC has been reported to be important for the development of new food products and have influence on their storage stability, particularly for flavour binding and on the development of rancidity [38]. High protein contents in flours and the nature of the proteins also contribute significantly to the oil retaining properties of food materials [39]. Therefore, the high OAC of the flours could be attributed to the high protein contents in the jackbean flour used.

3.5 Physical Properties of the Flour Samples

The physical analysis of the extruded snacks from Acha, Jackbean fortified with pawpaw (AJP, APJ, and ANP), Acha and jackbean (AJN) and the control sample Acha (AAA) are presented in Table 6.

Table 2. Proximate composition of extruded snacks made from Acha, Jack bean and Pawpaw flour blends

Sample Ratio	Moisture (%)	Protein (%)	Fat (%)	Crude fiber (%)	Ash (%)	Carbohydrate (%)
(AAA) 100:0:0	3.88 ± 0.06^{e}	6.98 ± 0.05^{a}	3.59 ± 0.01^{C}	2.20 ± 0.03^{C}	2.89 ± 0.01^{e}	82.65 ± 0.02^{C}
(AJN) 70:30:0	3.54 ± 0.01^{d}	9.00 ± 0.04^{C}	3.00 ± 0.02^{a}	1.81 ± 0.02^{a}	2.55 ± 0.01^{d}	81.89 ± 0.05^{b}
(AJP) 70:20:10	2.66 ± 0.03^{a}	9.00 ± 0.04^{C}	3.00 ± 0.01^{a}	3.58 ± 0.02^{d}	1.59 ± 0.01^{a}	83.76 ± 0.03^{d}
(APJ) 70:10:20	3.43 ± 0.00^{C}	8.68 ± 0.13^{b}	3.11 ± 0.02^{b}	3.60 ± 0.01^{d}	2.20 ± 0.01^{C}	82.55 ± 0.12^{C}
(ANP) 70:0:30	3.16 ± 0.01^{b}	10.92 ± 0.05^{d}	4.41 ± 0.02^{d}	2.00 ± 0.1^{b}	2.10 ± 0.01^{b}	79.40 ± 0.03^{a}

Samples with different superscript within the same column were significantly (P < 0.05) different. Samples = Acha flour: Jackbean flour: Pawpaw pomace flour. (AAA = 100%Acha, AJP = 70%acha, 20%jackbean, 10%pawpaw, APJ = 70%Acha, 20%pawpaw, 10%jackbean, ANP = 70%Acha, No jackbean, 30%pawpaw, AJN = 70%Acha, 30%jackbean, No pawpaw)

Table 3. Mineral analysis of extruded snacks made from acha, jack bean and pawpaw flour blends

Sample	Potassium	Calcium	Magnesium
(AAA) 100:0:0	160.50±6.36^{a}	435.50±10.60^{a}	208.25±2.47^{a}
(AJN) 70:30:0	193.75±1.76^{bc}	465.00±7.07^{a}	233.00±2.82^{c}
(AJP) 70:20:10	148.75±01.76^{a}	465.50±17.67^{a}	215.75±2.47^{b}
(APJ) 70:10:20	188.75±8.83^{b}	485.50±0.60^{a}	216.00±4.24^{b}
(ANP) 70:0:30	203.00±1.76^{c}	576.25±37.12^{b}	229.25±1.06^{c}

Samples with different superscript within the same column were significantly (P < 0.05) different. Samples = Acha flour; Jackbean flour: Pawpaw pomace flour. (AAA = 100%Acha, AJP = 70%acha, 20%jackbean, 10%pawpaw, APJ = 70%Acha, 20%pawpaw, 10%jackbean, ANP = 70%Acha, No jackbean, 30%pawpaw, AJN= 70%Acha, 30%jackbean, No pawpaw)

Table 4. Antinutritional analysis of extruded snacks made from Acha, Jackbean and Pawpaw flour blends

Samples	Phytate (mg/g)	Tannin (mg/g)	Saponin (mg/g)
(AAA) 100:0:0	0.18±0.03^{a}	0.25±0.05^{a}	0.73±0.05^{c}
(AJN) 70:30:0	0.28±0.03^{bc}	0.56±0.03^{c}	0.56±0.03^{b}
(AJP) 70:20:10	0.33±0.03^{cd}	0.66±0.03^{d}	0.62±0.03^{b}
(APJ) 70:10:20	0.23±0.03^{ab}	0.36±0.03^{b}	0.35±0.05^{a}
(ANP) 70:0:30	0.37±0.03^{d}	0.63±0.03^{d}	0.73±0.03^{c}

Samples with different superscript within the same column were significantly (P < 0.05) different. Samples = Acha flour: Jackbean flour: Pawpaw pomace flour. (AAA = 100%Acha, AJP = 70%Acha, 20%Jackbean, 10%Pawpaw, APJ = 70%Acha, 20%Pawpaw, 10%jackbean, ANP = 70%Acha, No jackbean, 30%Pawpaw, AJN = 70%Acha, 30%Jackbean, No pawpaw)

Table 5. Functional properties of Acha, Jack bean and Pawpaw flour blends

Samples	Bulk density	Water absorption	Oil absorption
(AAA) 100:0:0	0.92±0.07^{a}	0.88±0.13^{a}	1.76±0.25^{ab}
(AJN) 70:30:0	0.85±0.04^{a}	1.26±0.25^{a}	1.33±0.76^{a}
(AJP) 70:20:10	0.84±0.01^{a}	2.30±0.20^{b}	2.33±0.28^{b}
(APJ) 70:10:20	0.85±0.06^{a}	3.10±0.17^{c}	1.50±0.05^{ab}
(ANP) 70:0:30	0.85±0.02^{a}	3.50±0.50^{c}	1.60±0.17^{ab}

Samples with different superscript within the same column were significantly (P < 0.05) different. Samples = Acha flour: Jackbean flour: Pawpaw pomace flour. (AAA = 100% Acha, AJP = 70%acha, 20%jackbean, 10%pawpaw, APJ = 70%Acha, 20%pawpaw, 10%jackbean, ANP = 70%Acha, No jackbean, 30%pawpaw, AJN = 70%Acha, 30%jackbean, No pawpaw)

Table 6. Physical properties of Acha, Jackbean and Pawpaw flour blends

Samples (g/cm^3)	Bulk density (g/cm^3)	Apparent density Expansion	Lateral	Porosity
(AAA) 100:0:0	0.38±0.15[a]	0.61±0.03[c]	94.47±5.57[b]	0.58±0.10[ab]
(AJN) 70:30:0	0.27±0.05[a]	0.62±0.02[c]	76.61±2.15[a]	0.47±0.02[a]
(AJP) 70:20:0	0.28±0.04[a]	0.36±0.00[a]	132.76±1.40[d]	0.81±0.02[c]
(APJ) 70:10:0	0.25±0.47[a]	0.39±0.00[b]	141.00±10.32[d]	0.79±0.03[c]
(AMP) 70:0:30	0.23±0.90[a]	0.48±0.00[b]	111.00±11.90[c]	0.61±0.10[b]

Samples with different superscript within the same column were significantly (P < 0.05) different. Samples = Acha flour: Jackbean flour: Pawpaw pomace flour. (AAA = 100%Acha, AJP = 70%acha, 20%jackbean, 10%pawpaw, APJ = 70%Acha, 20%pawpaw, 10%jackbean, ANP = 70%Acha, No jackbean, 30%pawpaw, AJN = 70%Acha, 30%jackbean, No pawpaw)

3.5.1 Bulk density

The bulk density of the snack samples ranged from 0.23 - 0.38 g/cm3 with sample (AAA) being the maximum, while sample (ANP) was the least. There was no significant difference among the samples. Addition of jackbean flour increased the bulk density of the extruded snack samples. Bulk density has been linked with the expansion ratio in describing the degree of puffing in the extrudates [40]. Therefore, it is expected that, under similar conditions, as expansion index increases the bulk density would automatically decrease. High bulk density is important with regards to packaging. High bulk density is associated with low expansion index because more compact material is obtained after milling a less expanded product [29].

3.5.2 Apparent density

The apparent density of the snacks ranged from 0.39 to 0.62 g/cm3. Apparent density reflects the snack's density, including all the pores within them [41].

3.5.3 Lateral expansion

Lateral expansion of the extrudates ranged from 79-130%.With sample (AAA) being the least, while sample (AJP) was the highest. There was no significant difference among AAA, AJN, ANP samples but significantly different to other sample. Expansion was less pronounced in Acha flour. Since starch is the main component responsible for dough development inside the extruder barrel, as well as consequent expansion at the die exit [30].

The apparent density was found to increase with increasing addition of jack bean and pawpaw in the formulations, they were significantly different from other at ($P < 0.05$).

3.5.4 Porosity

The porosity of the extruded snacks which ranged from 0.47% to 0.81% increased with increase in jackbean and pawpaw addition, but decreased with increase in Acha. Porosity indicates the volume fraction of void space or air space inside a material [42]. Porosity created during extrusion has been used to describe the expansion properties of extruded products [28; 43]. It helps in modelling, design of heat and mass transfer processes, and serves as an important parameter in predicting diffusional properties of cellular foods [40].

3.6 Sensory Properties of the Extrudates

The sensory properties of the extruded snacks from Acha, Jackbean fortified with pawpaw (AJP, APJ, and ANP), Acha and jackbean (AJN) and the control sample Acha (AAA) are presented in Table 7. Pawpaw addition was found to increase the ratings of all the sensory attributes (colour, taste, mouth feel, aroma, crispiness and over acceptability) analysed. The extruded snack without jackbean and with 30% pawpaw inclusion (ANP) was the most acceptable followed by 10% addition (AJP) and 20% pawpaw addition (APJ). The lower sensory mean score/acceptability of the extrudates was the control sample (AAA), this may be due to the brown colour and probably because people are not used to this type of product.

Table 7. Sensory scores of extruded snacks made from Acha, Jack bean and Pawpaw flour blends

Sample Ratio	Colour	Taste	Flavour	Crispiness	Mouth feel	Overall acceptability
(AAA) 100:0:0	6.88±1.26^{ab}	6.56±1.19^{a}	6.40±1.47^{a}	6.36±1.57^{a}	6.24±1.45^{a}	6.88±1.36^{a}
(AJP) 70:20:10	7.52±1.04^{b}	7.24±1.33^{a}	7.52±1.12^{b}	7.48±1.19^{b}	7.48±1.19^{b}	7.52±1.26^{ab}
(APJ) 70:10:20	7.08±1.25^{ab}	7.28±1.45^{a}	6.92±1.35^{ab}	7.36±1.18^{b}	7.28±0.97^{b}	7.44±1.08^{ab}
(AJN) 70:30:0	6.25±1.53^{a}	6.80±1.53^{a}	6.76±1.36^{b}	6.80±1.89^{ab}	6.72±1.51	6.96±1.54^{a}
(ANP) 70:0:30	7.56±1.53^{b}	7.32±1.37^{a}	7.36±1.22^{b}	7.52±1.00^{b}	7.48±1.19^{b}	7.80±1.00^{b}

Values are mean ± SD of 30 panelists. Samples with different superscript within the same column were significantly (P < 0.05) different. Samples = Acha flour: Jackbean flour: Pawpaw pomace flour. (AAA = 100%Acha, AJP = 70%acha, 20%jackbean, 10%pawpaw, APJ = 70%Acha, 20%pawpaw, 10%jackbean, ANP = 70%Acha, No jackbean, 30%pawpaw, AJN = 70%Acha, 30%jackbean, No pawpaw)

There was no significant difference ($P > 0.05$) between the control sample (AAA) and the other samples except in ANP with 30% pawpaw while significant ($P < 0.05$) differences were observed between the ANP and all the other samples in all the sensory attributes. The high sensory ratings indicated that the extruded snacks were of good quality and were acceptable by the panelists.

4. CONCLUSION AND RECOMENDATION

4.1 Conclusion

Acceptable product of adequate nutritional and organoleptic quality were successfully produced by Extrusion cooking processes from Acha, Jackbean and Pawpaw pomace composite flour along with other ingredients. These composite flour and their products were good sources of protein (6.98 to 10.92%), carbohydrate (79.40 – 83.76%) and some micronutrients such as minerals (potassium 148.75 – 203.75mg/100g, Calcium 435.50 – 576.25mg/100g and Magnesium 208.25 – 233.00mg/100g) which could be used for different food production. Most of the proximate constituents increased with increasing addition of jackbean flour as well as pawpaw pomace flour, whereas the crude fibre content increased with increasing addition of pawpaw in the blends. Extrusion cooking of the blends brought about significant ($P < 0.05$) increase in protein digestibility and improvement on other nutrients such as minerals. The nutrient composition of the snacks especially the protein and fat content renders the snacks a valuable nutrient resource. The snacks could help to reduce protein energy malnutrition prevalent in developing countries and add variety to the predominantly carbohydrate-based snack foods in the market.

4.2 Recommendation

Ready to eat protein enriched extruded product can be developed from locally available ingredients and as the project is feasible it can be implemented.

Also, the use of extrusion cooking should be encouraged in the production of cereal-legume based snacks because it improves protein quality, reduces anti-nutrients and enhances acceptability of product.

For further study, it is recommended that the extruded product be analysed for vitamins to ascertain the stability of vitamins in extruded products and anti-nutritional factors (protease inhibitors, lectins, saponins and tannins) of Jackbean be analysed to ascertain its poisonous content.

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DISCLAIMER

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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