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Research Article

Effect of Processing Methods on Physical Properties of Gum Extracts from Selected Legume Seeds

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Abstract

The use of legume seed flours as emulsifiers and flavouring agents in traditional soups is a function of the high level of their gum contents. The method of processing of legumes generally affects the physical behavior when applied to subsequent food processing. Generally, legume seed flours are obtained after some level of heat treatments (boiling and roasting) for a period of 10 min. Extraction of gums from tropical legume seeds has not been a common practice. This work was therefore designed to determine the effect of various processing methods on the physical properties of gum extracts of selected legume seeds. The various seed gums were extracted from de-coated *Afziela africana* "akparata", *Mucuna. sloanei* "ukpo", *Brychestegia eurycoma* "achi" and *Detarium microcarpum* "ofor" seeds after being processed as follows: boiling at 100 ℃ for 10, 20, 30 min; roasting at 130 ℃ for 10, 20, 30 min and soaking at ambient temperature for 8, 16, 24 h. Flours from each of the raw seeds served as control. The flours were de-fatted using petroleum ether and gums extracted using propan-2-ol. The functional properties of the seed gums were determined. *D. microcarpum* seed gums had the highest swelling indexes for all the processing methods adopted. Generally, gums from roasted seeds had the highest bulk density (0.60 g/ml), water absorption capacity (5.25 g/ml), oil absorption capacity (4.64 g/ml), gelation temperature (74.56 ℃), wettability (26.44 s) and swelling index (5.30) though lowest foaming capacity (15.43%), foaming stability (15.32%) and emulsion capacity (25.77%). The result showed that the legume seed gums could be useful raw material in food industry such as: bakery and dairy industries, especially in the use of non-wheat flour in baking, the gum could be a substitute for gluten in wheat. The results from this research will also help to reduce cost of importation of commercially available food gums and hydrocolloids.

Keywords

Afziela africana, *Mucuna sloanei*, *Brychestegia eurycoma*, *Detarium microcarpum*, Processing, Physical Properties

1. Introduction

Legumes are important sources of affordable alternative protein to poor resource people in many tropical especial-ly in Africa and Asia where they are predominantly con-sumed [16]. In the developing countries, research atten-

tion is being paid to better utilization of legumes in addressing protein malnutrition and food security issues. *Afzelia africana* "Akparata", *Mucuna sloanei* "Ukpo", *Brachystegia eurycoma* "Achi" and *Detarium microcarpum* "Ofor" are legumes commonly used as soup thickeners in the South-Eastern part of Nigeria and they belong to the same family *leguminosae* as well as the same sub-family *caesalpiniacea* [8]. Flours from these seeds are used as thickeners, emulsifiers and flavouring agents in traditional soups (for eating gari, pounded yam or cocoyam and cassava fufu), as a result of their inherent gum contents essential in thickening and gel formation. The gums are extracted from the seeds and serve as natural hydrocolloids, when crushed to flour and in powdered form they have the ability to swell in water and thus are able to influence the flow and consistency of the liquid.

Food gums are diverse group of long chain polymers characterized by their property of forming viscous dispersions and/or gels in water. The presence of large number of hydroxyl groups increases their affinity for binding water molecules, and so belongs to the group of hydrophilic compounds. According to [12], food gum produces dispersion, which is intermediate between a true solution and a suspension, and exhibits the properties of a colloid. Considering these two properties, they are appropriately regarded as hydrophilic colloids or hydrocolloids. Hydrocolloids have a wide array of functional properties in foods including; thickening, gelling, emulsifying, stabilization and coating. The primary reason behind the use of hydrocolloids in foods is their ability to modify the rheology of food systems [18]. This includes two basic properties of food systems that is, flow behavior (viscosity) and mechanical solid property (texture) which in turns affect its sensory properties.

The world hydrocolloid market which is valued at about USD 4.4 billion per annum, with a total volume of about 260,000 tonnes in the year 2000. This reflects a remarkable demand for hydrocolloids which has influenced the price and availability [32]. Sequel to the increase in the hydrocolloid market demand, it is therefore imperative to exploit some new raw materials as potential and alternative sources of food hydrocolloids and seed gums [11]. Studies on the extraction of the hydrocolloids from seeds such as: *Mucuna sloanei* and *Irivingia gabonensis* and their visco-elastic properties have been reported [26]. The gums from the cotyledon of these legumes have not found much use in food systems unlike the tapioca starch which is used in numerous industrial and food applications, as thickening and gelling agents [8]. The method of processing of food commodities generally affects their functional behavior [26]. This work is aimed at the determining the effect of processing methods on the physical property of gum extracts from selected legume seeds.

2. Materials and Method

2.1. Material Collection

Mucuna sloanei "ukpo", *Detarium microcarpium* "ofor", *Brachysteia eurycoma* "Achi)" *Afzelia africana* "akparata", seeds were obtained from "Ekeikpa" (a local market) in Ihitte/ Uboma, Imo state, Nigeria. Petroleum ether, distilled water and propane-2-ol were purchased from a scientific laboratory in Owerri, Imo state, Nigeria and were of analytical grade. Other reagents and equipment/facilities were obtained from the department of Food Science and Technology of University of Agriculture and Environmental Sciences.
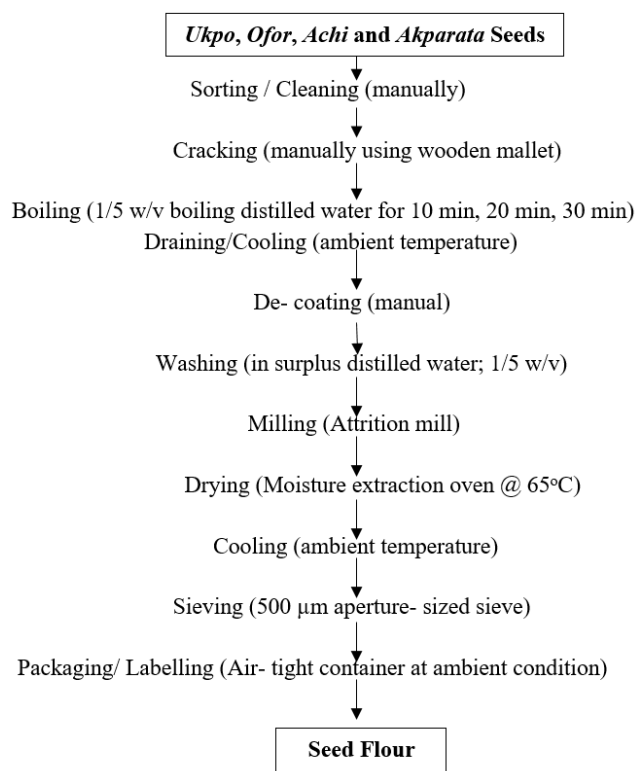
2.2. Processing of Seed Flour

The seeds of 'Ukpo', 'Achi', 'Akparata' and 'Ofor' were cleaned to remove dirt. The whole and healthy seeds were weighed separately and manually cracked with the use of a wooden hammer (Mallet). They were divided into four equal portions each; the first three portions were subjected to boiling, roasting and soaking respectively while the fourth portion was processed raw.

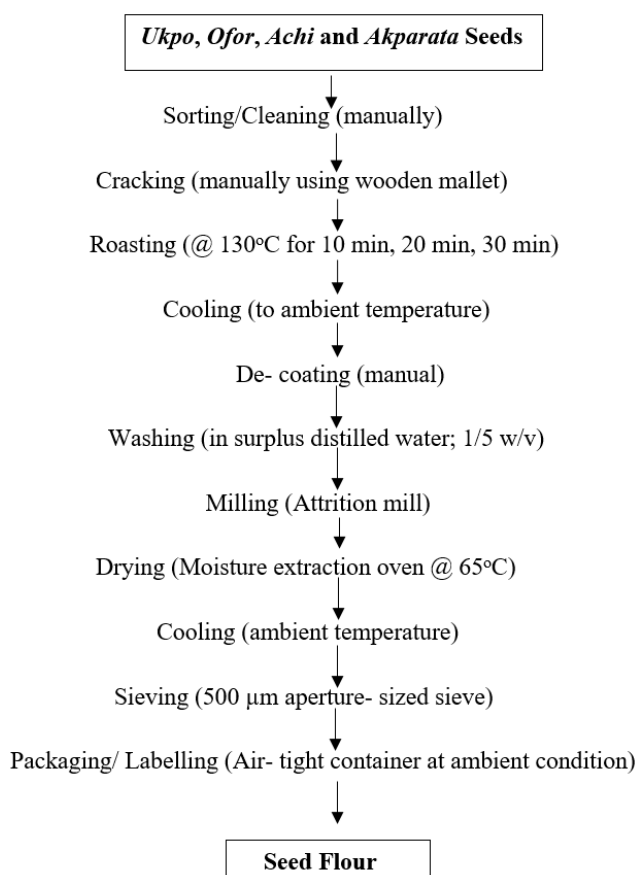#### 2.2.1. Processing of Flour from Boiled Seeds

The first portion of the cracked seeds was divided into three equal portions and placed in boiling distilled water in the ratio of 1/5 (w/v) for durations of 10 min, 20 min and 30 min. They were drained and allowed to cool to ambient temperature. They were de-decoated to obtain the seeds endosperms by scraping the seed coats with a stainless-steel knife and washed in surplus water (1/5 w/v) and milled using an attrition mill. The flours were dried in a moisture extraction oven (DHG- 9053 Model) at 65 ℃ to a constant weight, cooled to ambient temperature and sieved through a 500 μm mesh-sized sieve to generate fine flour. They were packaged in airtight containers and stored at ambient conditions for further analysis and application. The production flow chart is as shown in Figure 1.

2.2.2. Processing of Flour from Roasted Seeds

The second portion of the cracked seeds were divided into three equal portions, and toasted in a pre- heated locally fabricated oven at 130 ℃ for 10 min, 20 min and 30 min, allowed to cool to ambient temperature. They were de-coated to obtain the seeds endosperms by scraping the seed coats with a stainless-steel knife and washed in surplus water (1/10 w/v) and milled using an attrition mill. The flour was dried in a moisture extraction oven (DHG- 9053 Model) at 65 ℃ to a constant weight, cooled to ambient temperature and sieved through a 500 μm mesh-sized sieve to generate fine flour. They were packaged in airtight containers and stored at ambient conditions for further analysis and application. The production steps are as shown in Figure 2.
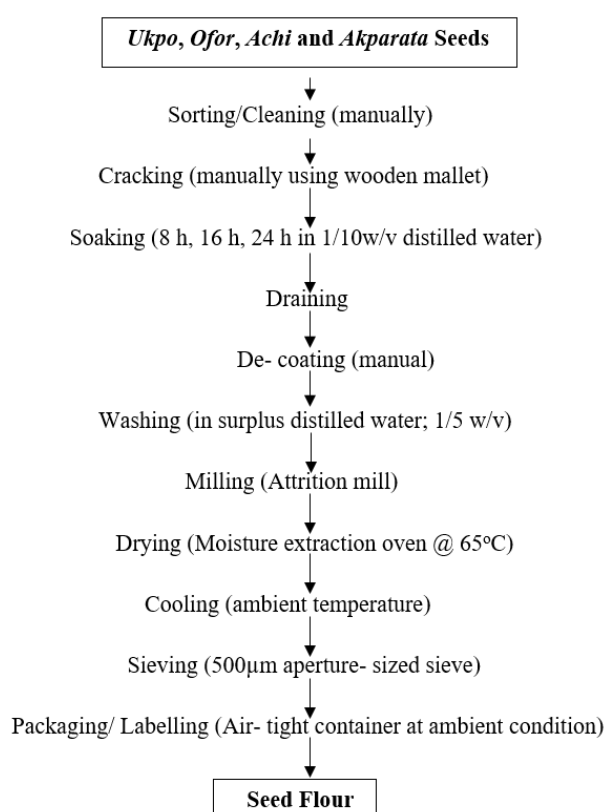
Ukpo, Ofor, Achi and ***Akparata*** **Seeds**

Sorting / Cleaning (manually)

Cracking (manually using wooden mallet)

Boiling (1/5 w/v boiling distilled water for 10 min, 20 min, 30 min)
Draining/Cooling (ambient temperature)

De- coating (manual)

Washing (in surplus distilled water; 1/5 w/v)

Milling (Attrition mill)

Drying (Moisture extraction oven @ 65ºC)

Cooling (ambient temperature)

Sieving (500 µm aperture- sized sieve)

Packaging/ Labelling (Air- tight container at ambient condition)

Seed Flour

Figure 1. Flow Chart for the Preparation of Flour from Boiled Seeds (Ukpo, Ofor, Achi and Akparata).

Ukpo, Ofor, Achi and ***Akparata*** **Seeds**

Sorting/Cleaning (manually)

Cracking (manually using wooden mallet)

Roasting (@ 130ºC for 10 min, 20 min, 30 min)

Cooling (to ambient temperature)

De- coating (manual)

Washing (in surplus distilled water; 1/5 w/v)

Milling (Attrition mill)

Drying (Moisture extraction oven @ 65ºC)

Cooling (ambient temperature)

Sieving (500 µm aperture- sized sieve)

Packaging/ Labelling (Air- tight container at ambient condition)

Seed Flour

Figure 2. Flow Chart for the Preparation of Flour from Roasted Seeds (Ukpo, Ofor, Achi and Akparata).

2.2.3. Processing of Flour from Soaked Seeds

The third portion of the cracked seeds were soaked in distilled water in the ratio of 1/10(w/v) at ambient temperature for 8 h, 16 h and 24 h. The soaking liquors were drained at the elapse of each soaking time, de-coated to obtain the seeds endosperms by scraping the seed coats with a stainless-steel knife and washed in surplus water (1/5 w/v) and milled using an attrition mill. The flour was dried in a moisture extraction oven (DHG- 9053 Model) at 65 ℃ to a constant weight, cooled to ambient temperature and sieved through a 500 µm mesh-sized sieved to generate fine flour. They were packaged in airtight containers and stored at ambient conditions for further analysis and application. The processing steps are as shown in Figure 3.
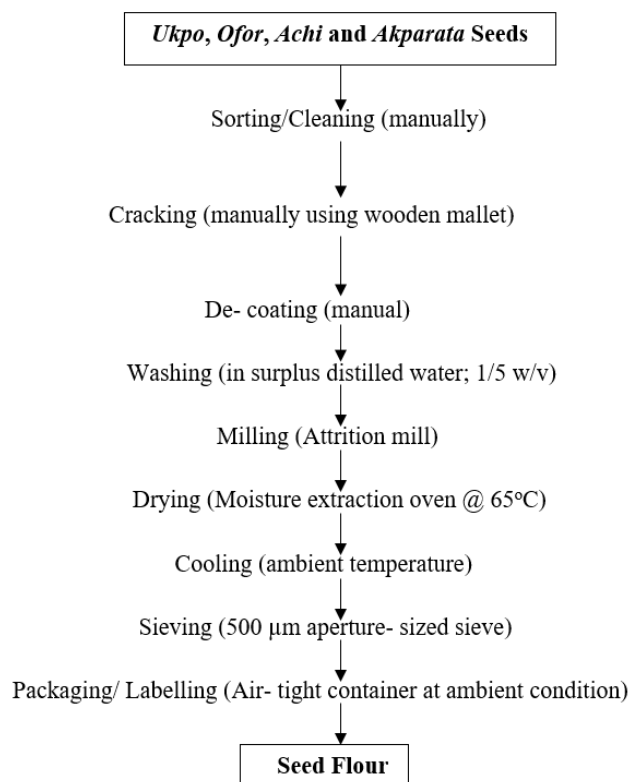
Ukpo, Ofor, Achi and ***Akparata*** **Seeds**

Sorting/Cleaning (manually)

Cracking (manually using wooden mallet)

Soaking (8 h, 16 h, 24 h in 1/10w/v distilled water)

Draining

De- coating (manual)

Washing (in surplus distilled water; 1/5 w/v)

Milling (Attrition mill)

Drying (Moisture extraction oven @ 65ºC)

Cooling (ambient temperature)

Sieving (500µm aperture- sized sieve)

Packaging/ Labelling (Air- tight container at ambient condition)

Seed Flour

Figure 3. Flow Chart for the Preparation of Flour from Soaked Seeds Sample (Ukpo, Ofor, Achi and Akparata).

2.2.4. Processing of Flour from Raw Seeds

The fourth portion of the cracked seeds was de-coated raw to obtain the seeds endosperms by scraping the seed coats with a stainless-steel knife and washed in surplus water (1/5 w/v) and milled using an attrition mill. The flour was dried in a moisture extraction oven (DHG- 9053 Model) at 65 ℃ to a constant weight, cooled to ambient temperature and sieved through a 500 µm mesh-sized sieved to generate fine flour. They were packaged in airtight containers and stored at ambient conditions for further analysis and application. The

processing steps are as shown in Figure 4.

Figure 4. Flow Chart for the Preparation of Flour from Raw Seeds Sample (Ukpo, Ofor, Achi and Akparata).

2.3. De-fatting of Seed Flours

Cold (bulk) extraction method of [1] was used for the de-fatting of the flours. The full-fat flour (200 g) was wrapped in a white cotton fabric and soaked in 400 ml of Petroleum ether in an enclosed transparent glass jar and allow for a period of 72 hours. The wrapped flour was removed and rinsed in fresh Petroleum ether and manually squeezed to express out the entrapped solvent. The de-fatted flour was spread on a stainless tray for 4 hours to allow the trapped solvent to volatilize. The flour was sieved through a 500 μm mesh sized sieve, packaged in air-tight container and stored at ambient condition for further analysis and applications.

2.4. Seed Gum Extraction

The method of [20] was adopted for gum extraction from the de-fatted seed flours. Five (5) g of the flour samples were dispersed in 400 ml distilled water and hydrated continuously by means of a magnetic stirrer (FBI 15001, Fischer Scientific, UK) for 6 h. Four hundred (400) ml of Propane -2-ol was gradually (drop by drop) added to the hydrated flour solution. The precipitated gums that spool out of the solution were gently separated from the mother liquor with the use of perforated spoon. The clear liquor was decanted, while the trapped solvent was removed by filtering under suction in a Buchner funnel. The precipitates were dried in a moisture extraction oven (DHG-9053 Model) at 60 ℃ till a flaky-dried gum (Figure 5) could be easily scrapped off the drying tray. The resultant gums were cooled in desiccators to ambient temperature pulverized using the dry section of an electric blender and stored at ambient temperature in a sealed container.

2.5. Determination of Physical Properties of Gum Extracts

Physical properties (foaming capacity/stability, bulk density, water absorption capacity, oil absorption capacity, gelation temperature, wettability and swelling index) were determined on the extracted seed gums.

2.5.1. Foam Capacity/ Stability Determination

The method of [27] was used. Two gram (2 g) of gum sample was blended with 100 ml distilled water in a warring blender (the suspension was whipped at 1000 rpm for 5 minutes). The mixture was poured into a 250 ml measuring cylinder and the volume was recorded after 30 seconds. Foam capacity was expressed as percent increase in volume using the formula (equation 1) below:

$$Foaming\ Capacity\ (\%) = \frac{(Volume\ after\ whipping - Volume\ before\ whipping)}{Volume\ before\ Whipping} x\ 100 \tag{1}$$

The foam stability was determined by recording the foam volume after 15, 30, 60 and 120 seconds after whipping. Foam stability was calculated using equation 2.

$$Foaming\ Stability\ (\%) = \frac{Foam\ Volume\ after\ time\ (t)}{Initial\ Foam\ Volume} x\ 100 \tag{2}$$

2.5.2. Emulsification Capacity Determination

The Method of [27] was adopted. Emulsification capacity was estimated by blending 2 g of gum sample with 25 ml distilled water at room temperature for 30 seconds in a warring blender at 1600 rpm. After complete dispersion, 25 ml of vegetable oil (groundnut Oil) was added and the blending was continued for another 30 seconds, then it was put into a cen-

trifuge tube and centrifuged at 1600 rpm for 5 minutes. The volume of oil separated from the sample after centrifuging was

read directly from the tube. Emulsion capacity is expressed as the amount of oil emulsified and held per gram of sample.

$$\text{Emulsion Capacity (\%)} = \frac{\textit{Height of emulsion layer in the tube}}{\textit{Height of the total fluid in the tube}} \times \frac{100}{1} \tag{3}$$

2.5.3. Bulk Density Determination

This was done according to [24]. Ten (10 ml) capacity graduated measuring cylinder was filled with the gum sample and the initial volume was recorded. The cylinder was tapped continuously to displace air and vacuum until the volume becomes constant. The final volume was noted after it was leveled, and bulk density of the samples was calculated as shown in equation 4.

$$\text{Bulk density (g/ml)} = \frac{\textit{weight of sample}}{\textit{volume of sample after tapping}} \tag{4}$$

2.5.4. Water Absorption Capacity Determination

The method as was described by [27] was adopted. A gram (1 g) of each gum samples were weighed separately and the weight of the samples in a clean dry centrifuge tube was also taken. The sample and 10 ml distilled water were mixed thoroughly for 30 seconds, then the sample was allowed to stand for 30 minutes at room temperature and then centrifuged at 5000 rpm for 30 minutes, then the volume of free water (supernatant) was read directly from the graduated centrifuge tube. Density of water was assumed to be 1.0 g/ml. The water absorption was expressed as the amount of water retained by 1 g of gum (g/ml).

$$\text{Water absorption capacity (g/ml)} = \frac{\textit{weight of water absorped} \times \textit{density of water}}{\textit{weight of sample}} \tag{5}$$

2.5.5. Oil Absorption Capacity Determination

The method as described by [27] was adopted. A gram (1 g) of each gum samples were weighed separately and the weight of the samples in a clean dry centrifuge tube was also taken. Oil was mixed with the sample to make up to 10 ml dispersion. The sample and oil were mixed thoroughly for 30

seconds; the sample was allowed to stand for 30 minutes at room temperature and then centrifuged at 5000 rpm for 30 minutes. The volume of free oil was read directly from the graduated centrifuge tube. Density of oil was assumed to be 0.38 g/ml. The Oil Absorption was expressed as the amount of oil bound by 1 g of gum (g/ml) estimated with equation 6.

$$\text{Oil absorption capacity (g/ml)} = \frac{\textit{weight of oil absorped} \times \textit{density of oil}}{\textit{weight of sample}} \tag{6}$$

2.5.6. Gelatinization Temperature Determination

The method described by [27] was used. Ten percent (10%) suspension of the gum sample was prepared in a test tube. The formed aqueous suspension was heated in a boiling water bath with continuous stirring. The temperature after 30 seconds after gelatinization was visually noticed was recorded as the gelatinization temperature.

2.5.7. Wettability Determination

The method of [24] was adopted. One gram of the gum sample was weighed into a clean, dry test tube and was covered. The tube was clamped in-vertically on a retort stand 15 cm over 200 cm^3 distilled water container in 250 cm^3 beaker at room temperature. Gently the paper covering the tube was removed and the sample was allowed to fall under gravity into the beaker. The wetting time was recorded as the time (seconds) required for all the powder to be wetted and penetrate the surface of the still water.

2.5.8. Swelling Index Determination

The procedure described by [9] was used to determine the

swelling indexes of the gum samples. One gram the gum sample was mixed with 10 ml of distilled water in a centrifuge tube and heated at 80 ℃ for 30 min under continuous agitation. After heating, the suspension was centrifuged at 1500 rpm for 15 min. The supernatant was decanted and the weight of the paste taken. The swelling index was calculated as follows:

$$\text{Swelling Index} = \frac{H2}{H1} \tag{7}$$

Where: H$_2$ = final height
H$_1$ = initial height

2.6. Statistical Analysis

The data obtained were subjected to statistical analysis such as simple description mean and standard deviation, Analysis of variance (ANOVA), using General Linear Model (GLM) procedure. A comparison test (LSD) was used to separate the means where significant differences existed.

***Figure 5**. Samples of Flaky Gum Extract.*

3. Results and Discussions

3.1. Foaming Capacity of Seed Gums

Table 1 show that the gums' foaming capabilities under various processing techniques varied significantly (p < 0.05) among the legume varieties. Gums from roasted seeds showed the lowest foaming capabilities (15.43%), while those from boiled seeds had the highest (17.19%) on average. *A. africana* gum exhibited the lowest foaming capacities among the gums that were removed from the cooked and soaked seeds, whereas *B. eurycoma* gums had the highest foaming capacities. Their respective results fell between 15.43% and 18.97% and 15.85% and 18.90%. However, *M. sloanei* gum exhibited the highest foaming capacity (17.04%) among the gums made from roasted seeds, whereas *D. microcarpum* gum had the lowest (14.70%). According to [22], foaming capacity is influenced by factors such as: processing methods, temperature and nature of protein present which in turns affect the surface tension of the protein molecules in the food material. Reduction in the foaming capacities of the gum extracts from roasted seeds could be attributed to the nature and level of heat treatment involved which probably denatured the protein molecules responsible for foam formation [21]. The average foaming capacity of the gums from raw seeds as shown in Table 2 was 16.44% and that of guar gum was 20.41%. Generally, increase in processing time significantly (p≤ 0.05) affected the foaming capacities of the gum extracts. Soaking increased this value to 17.04% (24 h), while boiling and roasting reduced the value to 16.27 % and 13.38% after 30 min processing time, respectively. From Figure 7, the average foaming capacities of gum extracted from legume cultivars, slightly reduced from 16.71% to 16.70% with increase in pre-treatment levels. According to [19], the foaming capacity of food material is related to the rate of reduction in the surface tension of air-water interface resulting from protein molecules absorption.

3.2. Foaming Stability of Seed Gums

For all the processing methods adopted in this research (Table 1), the foaming stability of the gum extracted was as follows: 15.42% to 16.33%, 14.67% to 15.82% and 15.39% to 16.19%% for boiled, roasted and soaked seeds respectively. Flour from *D. microcarpum* seeds generally had the lowest, while *A. africana* had the highest value. According [14], foaming stability is affected by so many factors which include: temperature, pH and processing methods. For all the cultivars, gums from boiled seeds had the highest foaming stability, while those from roasted seeds had the lowest. The same trend was followed in Table 2 where roasting operation resulted to reduction (11.37%) in the foaming stability of the gum extracts after 30 min, while boiling (30 min) and soaking (24 h) slightly increased the foaming stability from 12.39% (raw) to 13.24% and 12.98%, respectively. According to [29], the minor decrease in the gums' ability to foam from the boiled and roasted seeds may be related to protein de-naturation brought on by heat processing (boiling and roasting). Food emulsions including ice cream, yoghurt, and salad creams could be stabilized by using gums with higher foam stability.

3.3. Emulsion Capacity of Seed Gum

As shown in Table 1 and Figure 5, gums from boiled seeds had the highest (28.99%), while those from roasted seeds had the lowest (25.77%) emulsion capacities. Moreover, increase in boiling time significantly (p ≤ 0.05) increased the emulsion capacities of the seed gums from 26.84% to 27.36%, while increase in roasting time as shown in Table 2, significantly (p < 0.05) reduced the emulsion capacities of the seed gums from 26.84% to 21.66%. Gums from *A. africana* seeds had the lowest emulsion capacities, whereas gums from *D. microcarpum* seed had the highest emulsion capacities, with the exception of the gums from the roasted legume cultivars, where *M. sloanei* had the highest concentration (32.99%). The emulsion capacity of the gum that legume seeds contain determines their ability to thicken soup, and according to [25], boiling and other processing techniques increased the emulsion capacity of *Mucuna flagellips* flour. Gums with high emulsion capacities will be suitable in the preparation of food emulsions such as ice- cream and yoghurt where they will serve as emulsifying agents. According to [7], processing such as heat treatments can lead to a level of repulsion existing between the lipids and water which are the major components of an emulsion.

3.4. Bulk Density of Seed Gums

The bulk density of the seed gums was as follows: 0.48 g/ml to 0.57 g/ml (boiled), 0.54 g/ml to 0.74 g/ml (roasted) and 0.51 g/ml to 0.69 g/ml (soaked). *M. sloanei* gums had the lowest bulk density for all processing methods while *B. eurycoma* had the highest bulk densities (Table 1). Generally, gums from roasted seeds had the highest (0.60 g/ml) bulk

densities while those from boiled seeds had the lowest (0.52 g/ml). Increase in bulk density increases the rate of starch dispersion during reconstitution. As shown in Table 2, the bulk density of gums from raw seeds was 0.54 g /ml. For gums extracted from seed roasted for 30 minutes, this value rose to 0.72 g/ml. All of the gum extracts from the various legume seeds had average bulk densities that were greater than the guar gum's (0.48 g/ml). According to [6], bulk density increases with increase in particle size and low bulk density may be caused by the texture, density and loose structure of the starch polymers. It is therefore an important functional property in the prediction of packaging requirement, handling and wet- processing in the food industry [4]. Researchers have shown that low bulk density is desirable in granular material because it results to lower dietary bulk and reduces paste thickness during reconstitution.

3.5. Water Absorption Capacity of Seed Gums

Table 1 showed that the water absorption capacities of the gums extracted from the legume seeds under study significantly (p ≤ 0.05) varied from each other. For all the processing methods, *A. africana* seed gums had the highest water absorption capacity. Moreover, on the average, gums from roasted seeds had the highest (5.25 g/ml) water absorption capacity, while those from boiled samples had the lowest (4.70 g/ml). The high-water absorption capacity of the gums from the roasted seeds could be associated with increase in the level of moisture lost from the seeds during the roasting process. From this research, gums from the roasted seeds with high water absorption capacities could be better applied in soup and sauce thickening where high water absorption capacities is of high importance [7]. Increase water absorption capacity is desirable in bakery products because the starch molecules need to imbibe moisture in dough formation. According to [13], water absorption capacity of granular food materials is affected by the presence of hydrophobic amino acids in the sample and as an index of starch gelation measures the level of water that the starch is able to absorb [28]. Table 2 showed that average water absorption capacity of gum extracted from raw seeds was 4.90 g/ml. Boiling and soaking treatments significantly (p ≤ 0.05) reduced the water absorption capacities of the extracted gums to 3.76 g/ml and 4.58 g/ml after 30 min and 24 h respectively, while roasting (30 min) significantly (p ≤ 0.05) increased it to 5.33 g/ml with increase in processing time. These results were in agreement with the findings of [29] on the effect of processing methods on the functional properties of *Deterium microcarpum* seed flours.

Although there were no significant differences (p > 0.05), the average water absorption capacity of seed gums decreased from 5.04 g/ml to 4.90 g/ml as pre-treatment levels increased. Guar gum had a higher water absorption capacity (5.89 g/ml) than the extracted gums from this study. Water absorption capacity is directly proportional to the level of starch molecules and gel-forming capacity of the macromol-

ecules. Water absorption capacity of flour and gum is important in the determination of their utilization in aqueous food formulations such as dough and related products because flour with high water absorption capacity will reduce firming of bread by providing initial softness and smoothness of the dough before and after baking. The variation in the water absorption capacities of the gum extracted from the different legume seeds could be as a result of variations in the physico- chemical nature of the different legume seeds [30].

3.6. Oil Absorption Capacity of Seed Gums

The oil absorption capabilities of seed gums differed considerably (p < 0.05) from one another (Table 1). Generally, the oil absorption capacity of the gums from roasted seeds was the highest (4.64 g/ml), while that of boiled seeds was the lowest (4.12 g/ml). Among the legume cultivars, gums from *M. sloanei* showed the lowest oil absorption capacity, while those from *A. africana* had the highest for all of the processing methods tested. The results are as follows: (3.25-5.13) g/ml for boiled seeds, (3.26-6.53) g/ml for roasted seeds, and (2.99-6.17) g/ml for soaking seeds. Oil absorption capacity of granular particles is usually a measure of the ability of their components such as protein and starch to physically bind fat through capillary attraction [10]. According to [3], this property is of great importance where emulsification is required and is usually affected by particle size, shape, pH, and ionic strength [31]. From Table 2, the oil absorption capacities of the extracted gums increased significantly (p ≤ 0.05) with increase in the roasting (4.42-4.63) g/ml and soaking (3.98-4.01) g/ml time, but reduced significantly (p ≤ 0.05) with increase in boiling (3.99-3.26) g/ml time. The oil absorption capacities of both the gums from the different raw and processed seeds were all lower than that of the guar gum (5.75 g/ml). The increase in the oil absorption capacities of gum extracts from roasted seeds could be attributed to the fact 22 that heat processing facilitates the oil absorption capacities of food particles. Oil absorption capacity of granular substances is an indication of the level of hydrophobic proteins which determines the level of binding of lipids. Researches have shown that high oil absorption capacity aids in flavour retention and increases sensory attributes such as mouth-feel, gum extracts from roasted seeds will be preferred for use in food formulations such as baked and pasta products where such sensory attributes are required [21].

3.7. Gelation Temperature of Seed Gums

Table 1 showed that no particular trend was followed on gelation temperatures of the gum extracted from the different cultivars under different processing methods and levels of pre- treatments. There was no significant (p > 0.05) difference between the gelation temperatures of the gum from boiled *B. eurycoma* (73.09 ℃) and boiled *A. africana* (72.18 ℃) seeds. Gums from roasted seeds had the highest

average gelation temperature (74.56 ℃), while those from boiled seeds had the lowest (70.08 ℃). These also reflected in Table 2 where the average gelation temperature of the gums from raw seeds (68.47 ℃) increased with increase in roasting and soaking time to 77.72 ℃ (30 min) and 70.18 ℃ (24 h) respectively while those from boiled seeds slightly reduced with increase (30 min) in boiling time (67.47 ℃). There were no significant (p > 0.05) differences observed in the gelation temperatures of guar gum (76.27 ℃) and those from roasted (20 and 30) min seeds. Also, increasing the soaking duration had no significant (p > 0.05) effect on the gelation temperatures of the generated gums. Gelation temperature is the temperature at which starch molecules absorb moisture and swell to create a viscous mass known as gel. According to [22], gelation temperature of starch is a function of the degree of starches contained in the food, and different types of starchy materials experience this at different temperature levels due to changes in their chemistry [15].

3.8. Wettability of Seed Gums

The wettability of the gums from the various cultivars under different processing procedures differed slightly; gums from roasted seeds (Table 1) had the highest (26.44 s), while those from boiled seeds had the lowest (22.54 s). The wettability of gums from seeds decreased slightly from 23.43 s (raw) to 22.09 s with increasing boiling time (30 min). However, increasing roasting time significantly (p ≤ 0.05) increased the wettability of the gum extracts, while no significant (p > 0.05) difference was observed in the wettability of the gums as soaking time increased (Table 2). This is because according to [17], there is an increased tendency of fibrous materials to absorb moisture as was observed in the water absorption capacities previously discussed. The wettability of guar gum (21.27 s) was lower than that of the gums from the different legume cultivars under study. With respect to levels of pre-treatments, as shown in Table 2, the wettabilities of gums from all the cultivars under examination had no significant (p > 0.05) differences as the pre-treatment levels increased. Wettability is a function on the nature and level of polysaccharides present in the sample and it has a correlation with water absorption capacity and swelling power [23].

3.9. Swelling Index of Seed Gums

The swelling indexes of the gums from different legume cultivars under different processing methods significantly (p ≤ 0.05) differed from each other. As shown in Table 1 and Figure 6, gums from roasted seeds had the highest average swelling index (5.30), while those from soaked seeds had the lowest (4.05). Comparing the gums from the different legume seeds, *A. africana* gums had the lowest swelling index, while *D. microcarpum* gums had the highest and they are as

follows: (5.78) boiled, (6.09) roasted and (5.64) soaked. The average swelling index for the gum extracted from raw seeds was 4.09 and this significantly (p ≤ 0.05) increased with increase in roasting time and reduced with increase in boiling and soaking time (Table 2). Roasting increased the swelling index to 5.59, while boiling and soaking reduced the swelling indexes of extracted gums to 3.75 and 3.23 after 30 min and 24 h processing, respectively. Results showed that the swelling indexes of both raw and processed seeds were all lower than that of guar gum (6.22). Lower swelling index observed in the gum extracts from raw seeds could be associated with the level of inertness of starch in the raw seeds. From the results, there is an indication that gums from the roasted seeds (high swelling index) would be better applied to bakery products in order to improve the baking performance of the dough [5]. The average swelling indexes of the gums from the different legume seeds reduced slightly from 4.60 to 4.57 with increase in pre-treatment levels. According to [22], the swelling indexes of granular materials are determined by the capacity of some intermolecular hydrogen bonds to loosen during processing, such as heating, allowing for increased water absorption and granule expansion. The swelling power of most starch granules is quite low at cold temperatures and increases with heating. This is because, as the temperature rises, intermolecular hydrogen connections break and networks loosen, enabling more moisture to enter and granules to expand. Thus, there is a linear relationship between wettability, water absorption capacity and swelling index. Amylose in starch tend to retard and resist the swelling power of starch and the level of binding forces holding the granules is been shown on the swelling power of such starch [7]. The higher the binding forces, the lower the swelling. Moreover, in as much as this property is peculiar to starch, it is also being affected by the interaction of the starch with other components such as protein and fat [2]. The formation of potein- amylose complex according to [30] lowers the swelling index of starch.

4. Conclusion

Data from water absorption capacity (5.25 g/ml) and oil absorption capacity (4.53 g/ml) of gums from roasted seeds are indications that they might find application in baked products. The swelling index (6.09) of *D. microcarpum* seed gum was very close to that of guar gum (6.22) and is an indication that it could compete favorably with guar gum in foods where increase in volume is required. Results from this research showed that food gums for industrial purposes is achievable from legume seeds used in this research.

Table 1. *Effect of Processing Methods on Functional Properties of Gums from Selected Legume Seeds.*

Processing methods	FC (%)	FS (%)	EC (%)	BD (g/ml)	WAC (g/ml)	OAC (g/ml)	GT(℃)	Wet (s)	SI
Boiling									
A. Africana	15.43[d]	16.33[a]	20.31[d]	0.53[b]	5.78[a]	5.13[a]	72.18[a]	24.30[a]	2.97[d]
M. sloanei	17.08[c]	16.10[c]	33.08[b]	0.48[d]	4.11[d]	3.25[d]	65.78[c]	22.63[c]	5.49[b]
D.microcarp	17.28[b]	15.42[d]	33.62[a]	0.49[c]	4.17[c]	4.10[b]	69.26[b]	20.29[d]	5.78[a]
B. eurycoma	18.97[a]	16.15[b]	28.97[c]	0.57[a]	4.74[b]	4.01[c]	73.09[a]	22.93[b]	3.29[c]
Mean	*17.19*	*16.00*	*28.99*	*0.52*	*4.70*	*4.12*	*70.08*	*22.54*	*4.38*
Roasting									
A. Africana	14.92[c]	15.82[a]	20.22[d]	0.55[c]	7.14[a]	6.53[a]	76.52[b]	26.02[c]	3.90[d]
M. sloanei	17.04[a]	15.74[b]	32.99[a]	0.54[c]	4.19[c]	3.26[d]	66.79[d]	24.99[d]	5.53[c]
D.microcarp	14.70[d]	14.67[d]	25.59[b]	0.59[b]	4.84[b]	4.33[c]	81.29[a]	28.15[a]	6.09[a]
B. eurycoma	15.04[b]	15.07[c]	24.27[c]	0.74[a]	4.84[b]	4.44[b]	73.63[c]	26.61[b]	5.66[b]
Mean	*15.43*	*15.32*	*25.77*	*0.60*	*5.25*	*4.64*	*74.56*	*26.44*	*5.30*
Soaking									
A. Africana	15.85[d]	16.19[a]	20.41[d]	0.50[d]	6.56[a]	6.17[a]	73.12[a]	26.02[a]	3.31[d]
M. sloanei	17.99[b]	15.96[c]	29.69[b]	0.51[c]	5.02[b]	2.99[d]	71.73[a]	26.95[a]	3.92[b]
D.microcarp	17.31[c]	15.39[d]	32.27[a]	0.54[b]	4.13[d]	4.02[c]	69.79[b]	20.27[b]	5.64[a]
B. *eurycoma*	18.90[a]	16.16[b]	28.60[c]	0.69[a]	4.15[c]	4.08[b]	70.35[b]	21.39[b]	3.35[c]
Mean	*17.51*	*15.92*	*27.99*	*0.55*	*4.96*	*4.32*	*71.50*	*23.66*	*4.05*
Guar gum	20.41	29.24	36.79	0.48	5.89	5.75	76.27	21.27	6.22

Means on the same column with different superscript are significantly (p ≤ 0.05) different from each other
Key: FC - Foaming Capacity, FS - Foaming Stability, EC - Emulsion Capacity, BD - Bulk Density, WAC - Water Absorption Capacity, OAC - Oil Absorption Capacity, GT - Gelation Temperature, Wet - Wettability, SI - Swelling Index

Table 2. *Functional Properties of Gums from Selected Legume Seeds as affected by Processing Time.*

Processing Time (min.)	FC (%)	FS (%)	EC (%)	BD (g/ml)	WAC (g/ml)	OAC (g/ml)	GT (℃)	Wet (s)	SI
0 (Raw)	16.44[b]	12.39[e]	26.84[e]	0.54[ab]	4.90[b]	3.87[c]	68.47[bc]	23.43[a]	4.09[b]
Boiling									
10	16.43[bc]	12.41[d]	28.87[d]	0.55[a]	4.63[c]	3.99[b]	69.47[b]	23.41[a]	3.97[c]
20	16.42[c]	12.73[c]	27.11[c]	0.53[b]	4.32[b]	3.76[d]	68.72[bc]	22.49[b]	3.89[d]
30 *Roasting*	16.27[d]	13.24[b]	27.36[b]	0.50[c]	3.76[e]	3.26[e]	67.47[c]	22.09[c]	3.75[e]
10	13.46[c]	11.96[e]	21.81[c]	0.61[c]	5.03[d]	4.42[d]	73.91[b]	28.10[c]	5.26[d]
20	13.42[d]	11.67[d]	21.76[d]	0.68[b]	5.12[c]	4.54[c]	76.43[a]	28.89[b]	5.32[c]
30	13.38[e]	11.37[e]	21.66[e]	0.72[a]	5.33[b]	4.63[b]	77.72[a]	30.55[a]	5.59[b]
Soaking (h)									
8	16.81[d]	12.44[d]	25.44[d]	0.55[bc]	4.77[c]	3.98[c]	71.43[b]	25.36[a]	3.39[c]
16	16.87[c]	12.59[c]	25.38[e]	0.56[b]	4.68[d]	3.97[d]	71.14[b]	25.47[a]	3.35[d]
24	17.04[b]	12.98[b]	25.51[c]	0.62[a]	4.58[b]	4.01[b]	70.18[b]	25.44[a]	3.23[e]

Processing Time (min.)	FC (%)	FS (%)	EC (%)	BD (g/ml)	WAC (g/ml)	OAC (g/ml)	GT (℃)	Wet (s)	SI
Guar gum	20.41[a]	29.24[a]	36.79[a]	0.48[d]	5.89[a]	5.75[a]	76.27[a]	21.27[b]	6.22[a]

Means on the same column with different superscript are significantly (p ≤ 0.05) different from each other
Key: FC - Foaming Capacity, FS - Foaming Stability, EC - Emulsion Capacity, BD - Bulk Density, WAC - Water Absorption Capacity, OAC - Oil Absorption Capacity, GT - Gelation Temperature, Wet - Wettability, SI - Swelling Index

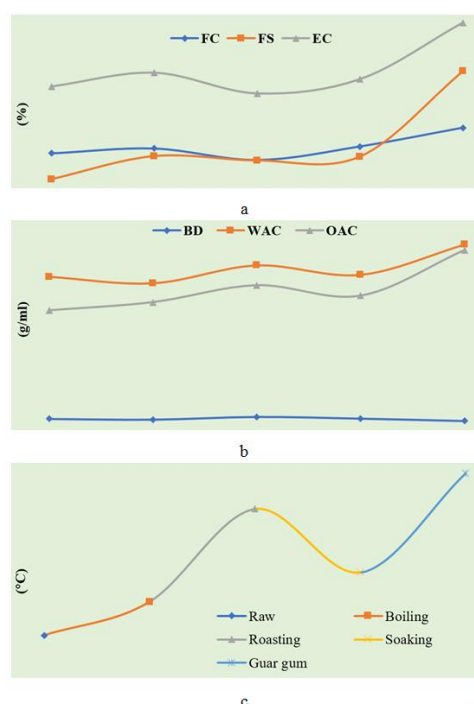***Figure 6.*** *(a-c). Functional Properties of Legume Seed Gums as affected by Processing Methods.*

Figure 7. *(a-c). Functional Properties of Seed Gums as Affected by Pre-treatment Levels.*

Abbreviations

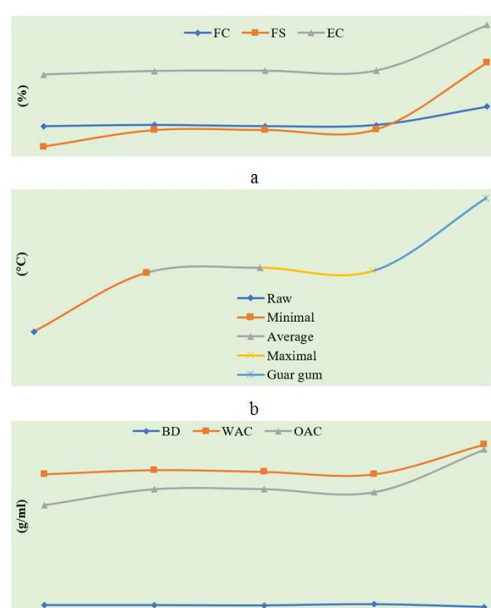|	
FC	Foaming Capacity
FS	Foaming Stability
EC	Emulsion Capacity
BD	Bulk Density
WAC	Water Absorption Capacity
OAC	Oil Absorption Capacity
GT	Gelation Temperature
Wet	Wettability
SI	Swelling Index

Conflicts of Interest

The authors declare no conflicts of interest.

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