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Nutrients and Sensory Qualities of Moi Moi Developed from Flours of Broad Bean (*Vicia faba*) Seeds Grown in South Eastern Nigeria as Affected by Different Processing Treatments

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ABSTRACT

Background: Broad bean is a lesser-known and underutilized legume with excellent source of protein. This nutritious but underutilized bean is difficult to cook, requiring lots of energy to prepare and is on its way to extinction. This study assessed the impacts of different processing techniques which includes soaking, sprouting, cooking as well as combined effect of soaking and cooking on the nutritional and sensory qualities of moi moi made from processed broad bean flour.

Methods: Broad bean seeds were processed into flours using standard procedures. Conventional methods were used to assess the nutritional properties of processed and unprocessed flours. Sensory investigation was performed on moi moi produced from broad bean flour versus moi-moi developed from cowpea. Antinutrient and functional characteristics were also analyzed and thus, varied significantly across processing treatments.

Result: The results demonstrated that the combination of soaking prior to cooking approach significantly reduced the antinutrients while increasing the flour's protein, fibre and ash levels. Minerals and vitamins contents increased significantly across all processing treatments, with sample SPBBF having the highest values, except for vitamin C. The sensory qualities of the moi-moi prepared from soaked/cooked broad bean showed the highest values in terms of aroma (7.10), taste (6.50) and overall acceptance (7.12) whereas the sprouted broad bean Moi-moi had the lowest values in terms of appearance (7.02), aroma (5.90), taste (5.90)and overall acceptability (5.83) when compared to the control (7.50) which is moi-moi made from cowpea. The study's findings revealed that effective processing techniques improved the nutrient profile of the flours such as proteins, ash and fibre contents with an enhanced sensory profile of the moi-moi produced from the flours. Soaking broad beans before cooking increased the nutritional value of the flour and sensory characteristics of the moi-moi.

Key words: Antinutrients, Broad beans, Functional, Minerals, Moi moi, Processing techniques, Sensory, Vitamins.

INTRODUCTION

Broad bean, botanically known as *Vicia faba* L. and more popularly known as Faba bean, Horse bean, Windsor bean, *etc*, is an underutilized leguminous plant in the *Fabaceae* family. Broad bean is also known as Azomiri and *Asaja* in South Eastern Nigeria. According to FAO (2009), broad beans are the world's sixth most produced legume. They are high in protein, energy and fibre, making them suitable for human and animal consumption. Broad bean protein content ranges from 24%-35% of seed dry matters, making it reasonably high in lysine, an important amino acid in humans (Khazae *et al*., 2020; Nwokenkwo *et al.,* 2020). It also contains essential mineral micronutrients such as potassium, phosphorus, sulphur, calciumand iron (Robinson *et al.,* 2019). Broad bean seeds are excellent source of protein and are underutilized (Iwe and Odimegwu, 2019; Olawuni *et al*., 2024). As a result of the high protein contents, this could make its flour excellent for moi-moi manufacture, but its limitations include its antinutrients, the difficult-to-cook phenomenon and underutilization of seeds due to lack of information. Broad

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beans are cooked with seasonings and served as a main course with pre-gelatinized shredded cassava, known as *Ighu*, in South Eastern Nigeria. The most popular commercial moi-moi meal in Nigeria nowadays are made from cowpea. However, there is little information available on broad bean flour being utilized in moi moi production. Broad bean flour has not yet been fully developed for commercial use, confining the seed to its whole cooked form, which is time and energy consuming. Soaking, dehulling, boiling, sproutingand other processing procedures improve legume nutritional and functional qualities as substantial amounts of antinutrients are removed during the pre-processing treatments (Owuamanam *et al.,* 2014).

Nevertheless, moi moi is a gel prepared by boiling cowpea paste with oil, spicesand other ingredients and it has been made from a variety of raw materials, including cowpea/African yam bean and cowpea/water yam (Nwosu *et al.,* 2014). These moi moi products were investigated in order to create nutritious and acceptable products derived from locally accessible underutilized legumes other than cowpea.

The study's goal was to assess the impact of processing techniques on some nutritional properties of flour made from Broad bean seed and then assess the acceptability of moi-moi samples made with the resulting flours in comparison to the commercial Cowpea moi-moi product.

MATERIALS AND METHODS

Source of broad beans

The mature broad bean seeds were grown and harvested from a farm in Orsu Local government Area, Imo State, Nigeria. The equipment and chemicals were obtained from the Food Science and Technology Department, Federal University of Technology Owerri. Fig 1 depicts the fresh matured broad bean plant, dry pods of mature broad bean and broad bean seeds.

Place and period of research

The research was carried out in the Department of Food Science and Technology Laboratory, Federal University of Technology, Owerri, Imo state Nigeria within a period of 9 months.

Duration

The work was started on September, 2023 and completed on May, 2024.

Processing of broad bean seeds

The method described by Odimegwu *et al*. (2020) and Olawuni *et al.* (2023), was adopted for this process. The broad bean seeds were divided into five groups and treated differently. The first portion was dehulled, milled and sieved into flour. The second portion was soaked in water before processing into flour. The third portion was sprouted before processing into flour. The fourth portion was cooked in water, drainedand dried in the oven before processing into flour. The fifth portion was soaked in water, cooked for a few minutes, drainedand dried in the oven before processing into flour. The five groups were labelled RBBF, SKBBF, SPBBF, CKBBF and SCBBF correspondingly.

Processing of broad bean using soaking method

A 300 g of broad bean seeds were washed, drained off water and soaked for 6 hours with the water intermittently changed every hour, after which it was dehulled and washed with potable water. The seeds were drained, dried in a gas oven (LG LSGL6337F Smart Slide-In Gas Range) at 60°C for 6 hours, milled into flour, sieved (212 µm sieve), packaged in airtight containers and stored at ambient temperature for further analysis.

Processing of broad bean using cooking method

Three hundred grams of broad bean seeds were weighed, rinsedand drained. The broad beans were cooked in water for 30 minutes at 100°C, drained, dehulled and allowed to cool for 30 minutes before being dried in an oven (LG LSGL6337F Smart Slide-In Gas Range) at 50-60°C for 6 hours, milled in an attrition milland sieved using a mesh of 212 µm. The flour was stored in airtight containers for later examination.

Processing of broad beans using a combined processing (soaking and cooking) method

Three hundred grammes of broad bean seeds were weighed, washed and drained afterwards. The broad bean seeds were water-soaked for 2 hours, drained and cooked for 10 minutes at 100°C. The cooked broad beans were rinsed, dehulledand cooled for 30 minutes. The seeds were dried at 50-60°C for 6 hours in an oven (LG LSGL6337F Smart Slide-In Gas Range), milledand sieved with a 212-ìm sieves. The resultant flour was stored in an airtight container for subsequent investigation.

Processing of broad bean by sprouting

Standard analytical method of Obiozaba (1990) was used for sprouting broad bean seeds, which was slightly modified.

Proximate composition of broad bean flour

The methods described by AOAC (2010) was used for the determination of the nutrient contents of the broad bean flour. The moisture, protein, ash, crude fibre, fat and carbohydrate contents of the samples were determined using standard analytical procedures.

Determination of phytates

The AOAC (2010) procedure was used in order to determine the phytate content.

$$\% \text{ Phytate} = \frac{100}{Wt} \times \frac{au}{as} \times cx \frac{Vt}{Va} \quad \text{....(1)}$$

Determination of oxalate

The oxalate content was analysed using Nwosu *et al.* (2014) methodology. The oxalate contents was determined as follows:

$$\text{Percentage oxalate} = \frac{100 \times 0.0025 \times \text{Total titre volume}}{\text{Weight of sample}} \quad ....(2)$$

Saponins determination

Samples' saponin content was determined by applying the technique outlined by AOAC (2010). The percentage of saponin was calculated as follows:

$$\% \text{ Saponin} = \frac{(\text{crucible + saponins}) - \text{Mass of crucible}}{\text{Mass of sample}} \times 100\% \quad ....(3)$$

Determination of tannin

According to Nwosu *et al.* (2014), the tannin concentration was ascertained using the Folin Denis calorimetric method. The tannin content was determined by using the following expressions:

$$\% \text{ Tanin} = \frac{100 \times au \times c \times V\,t \times D}{W \times as \times Va} \quad ....(4)$$

Determination of the functional properties of Broad bean flour

Swelling Index of flour samples

The samples' swelling indices were calculated by as modified by Odimegwu *et al.* (2020) methodology.

$$\text{Swelling index} = \frac{\text{Vol of sample before swelling}}{\text{Vol of sample after swelling}} \quad ....(5)$$

Foaming capacity/stability of flour samples

The AOAC (2010) method was utilized to examine the flour samples' foaming capacity and stability. Foam capacity was expressed as percentage increase in volume as follows:

$$\text{Foam capacity} = \frac{\text{Volume after whipping - Volume before whipping}}{\text{Volume before whipping}} \times 100 \quad ....(6)$$

$$\text{Foam stability} = \frac{\text{Foam volume after time}}{\text{Initial volume}} \times 100 \quad ....(7)$$

Determination of bulk density

The Onwuka (2005) approach was used for this determination. It is calculated as follows:

$$\text{Bulk density (g/ml)} = \frac{\text{Weight of sample (g)}}{\text{Volume of sample (ml)}} \quad ....(8)$$

Water/oil absorption capacities

The capacity of the samples to absorb water and/or oil was determined using the AOAC (2010) technique.

Gelling and boiling points of flour samples

This was calculated using the Nwosu *et al*. (2014) approach.

Mineral analysis of the flour samples

The mineral contents (Potassium, Calcium and Iron) of the flour samples were carried out by the methods of AOAC (2010) while the zinc contents of the samples was determined by using atomic absorption spectrophotometer with absorbance measured at wavelengths of 360 nm, 510 nm and 470 nm respectively.

Determination of vitamin (Thiamin, riboflavin, niacin and ascorbic acid)

The Thiamin Riboflavin and Niacin were determined by using spectrophotometric method. The absorbance was measured at wavelengths of 360 nm, 510 nm and 470 nm respectively. The Barakat titrimetric method as outlined by (AOAC, 2010) was used to determine Vitamin C.

Moi-moi preparation

Moi-moi samples were prepared from broad bean flour and the control was made from cowpea flour. The Moi-moi samples were prepared by using the method of Akajiaku *et al.* (2014) with slight modifications. Two hundred grams (200g) of broad bean and cowpea flour were separately mixed in a bowl with 552 ml of warm water, 2 cubes of maggi, 25 g of red pepper, 20 g of onion, 100 ml of vegetable oil, 2 g of crayfish, 100 g of egg, 0.5 g of mixed spices, 5.5 g of salt and mixed thoroughly. The slurry were wrapped with aluminum foil and allowed to cook for 30 minutes.The moi-moi samples were cooled and evaluated for sensory properties.

Sensory evaluation

The sensory attributes of the moi-moi samples were evaluated using Iwe (2002) approach. Students from Federal University of Technology, Owerri comprising fifteen panelists were used. A 9-points hedonic scale was used to determine the appearance, taste, aroma, textureand overall acceptability.

Experimental designs and statistical analysis

A randomized complete block design was used while all the data generated in triplicate determinations were analyzed using IBM SPSS software version 20.0 (SPSS Inc.). The mean comparison was carried out using a one-way ANOVA while the sample means were separated using the Fisher's least significant difference at $P<0.05$.

RESULTS AND DISCUSSION

The proximate and anti-nutritional composition of the processed broad bean flour samples

Table 1 represents the results of the proximate and anti-nutrient contents of the flour samples.

Ash content

The proximate content revealed that the ash content in the flour samples ranged from 1.71-2.48% and were significantly different ($P<0.05$) from one another with theexception of Sample SKBBF and SPBBF. Sample CBBF had the highest ash content and this is in accordance with the view of Nwokenkwo *et al.* (2020) who stated that cooking and soaking operation reduced the antinutrients in

soybean, thereby releasing their mineral contents which further increased the ash content in the flour sample.

Fiber content

The fiber content of the flour samples were significantly ($P<0.05$) different with the exception of Samples RBBF and SKBBF. The fiber content of the samples ranged from 2.34 to 6.37%, with sample RBBF having the highest fiber content of (6.37%) and Sample SCBBF had the least fiber content (2.34%). The least fiber content in sample SCBBF could be attributed to the processing techniques applied to the raw broad bean, which may have resulted to the hydrolysis of high molecular weight fiber compounds into soluble polymer. This view is in agreement with the findings of Nithya *et al*. (2007) on green peas. However, Samples CKBBF and SCBBF having involved in the application of heat by the cooking operation resulted in the breakdown of more fibrous compounds into soluble forms than Sample SKBBF and SPBBF.

Moisture, carbohydrate and protein content

The moisture content of the broad bean flour ranged from 10.35% to 12.30% while the carbohydrates ranged from 51.51% to 55.91%. However, the protein values of the samples were generally high as proteins are high in leguminous plants, because proteins are major storage compounds for legumes. The protein content analyzed were significantly different, as the samples show varying protein content due to the application of different processing technique with values ranging from 24.58 to 26.71%. This is higher than the approved standard protein content of 16% of foods for infant formula, thereby enabling the use of broad bean in the fortification of foods low in protein (Codex, 2007). The results obtained here are lower than

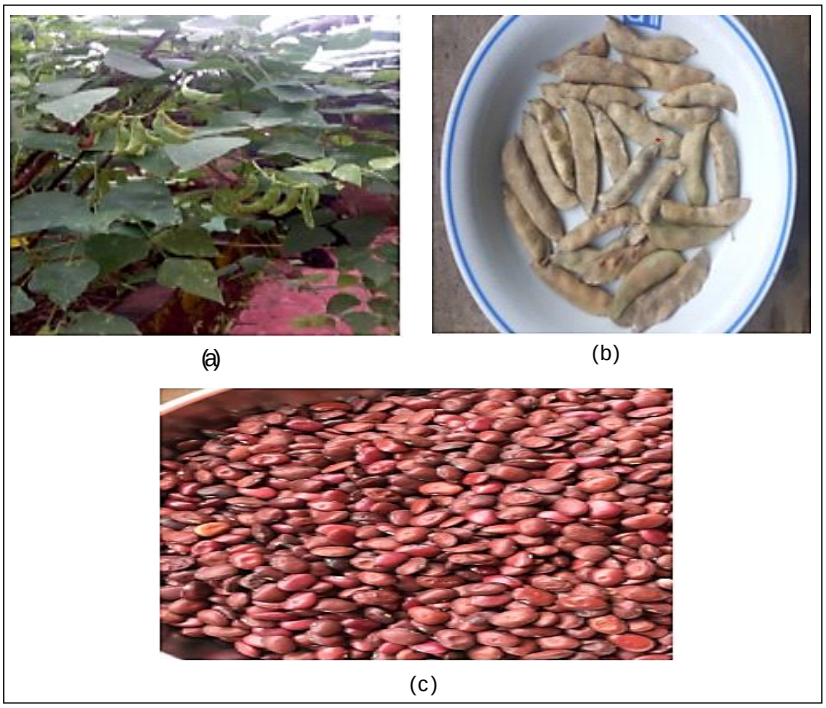

Fig 1: (a) Fresh matured broad bean pods, (b) Dry pods of mature broad bean and (c) Broad beans seeds.

Table 1: The proximate composition and anti-nutrient contents of the broad bean flour samples.

Sample	Moisture (%)	Ash (%)	Protein (%)	Fibre (%)	Fat (%)	Carbohydrate (%)	Phytate (%)	Oxalate (%)	Tanin (%)
RBBF	$10.35^{b}\pm0.03$	$1.71^{a}\pm0.03$	$24.58^{a}\pm0.3$	$6.37^{a}\pm0.13$	$4.97^{a}\pm0.12$	$51.51^{a}\pm0.001$	$0.78^{a}\pm0.02$	$6.90^{c}\pm0.01$	$1.50^{a}\pm0.01$
SKBBF	$10.63^{a}\pm0.31$	$1.98^{b}\pm0.37$	$25.23^{ab}\pm0.1$	$5.78^{a}\pm0.031$	$3.25^{a}\pm0.01$	$52.43^{b}\pm0.001$	$0.63^{b}\pm0.02$	$5.13^{a}\pm0.43$	$0.91^{b}\pm0.03$
SPBBF	$10.94^{b}\pm0.19$	$2.03^{c}\pm0.52$	$25.71^{b}\pm0.3$	$4.95^{b}\pm0.043$	$2.97^{b}\pm0.16$	$53.27^{b}\pm0.032$	$0.55^{a}\pm0.01$	$4.78^{a}\pm0.02$	$0.71^{b}\pm0.02$
CKBBF	$11.31^{b}\pm0.08$	$2.48^{d}\pm0.16$	$26.34^{c}\pm0.35$	$3.97^{c}\pm0.13$	$1.97^{c}\pm0.03$	$53.41^{c}\pm0.030$	$0.43^{b}\pm0.03$	$3.52^{b}\pm0.00$	$0.63^{c}\pm0.06$
SCBBF	$12.30^{c}\pm0.06$	$2.48^{d}\pm0.16$	$26.71^{c}\pm0.7$	$2.34^{d}\pm0.23$	$2.23^{b}\pm0.17$	$55.91^{d}\pm0.013$	$0.30^{c}\pm0.01$	$3.38^{b}\pm0.01$	$0.52^{c}\pm0.02$
LSD	0.21	0.32	0.52	0.37	0.17	0.01	0.032	0.0021	0.005

that reported by Odimegwu *et al*. (2020). The flour sample produced from combined effects of soaking and cooking technique had the highest protein content, as protease inhibitors and anti-nutrients that bind proteins present in broad bean were readily released by the technique. However, Samples RBBF, SKBBF and SPBBF exhibited no significant ($p>0.05$) difference as the soaking and sprouting techniques caused low changes in the protein content when compared to Sample CKBBF and SCBBF which involved the use of heat for the processing.

Fat content

The fat content of the flour samples ranged from 1.97 to 4.97% with same CKBBF having the highest fat content (4.97%). The fat contents of the flour samples were significantly different from each other with the exception of Samples RBBF, SKBBF, SPBBF and SCBBF which are not significantly different from each other. The reduced fat content of the flour sample processed from cooked Broad bean may be attributed to the breakdown of fat molecules by the application of heat in the cooking process. This could be as a result of differences in temperature and cooking time. The fat content of the analyzed samples were however lower than most legumes and cereal crops obtained in a study by Nithya *et al*. (2007) which would however cause an increase in the shelf stability of the samples, as there would be low effect of spoilage by rancidity.

Phytate content

The application of the processing techniques resulted in a decrease in the phytate content, which is why the phytate content analyses were considerably different. This is in line with findings published by Luo *et al*. (2010a), which show that phytates, which bind up zinc, iron, magnesium and calcium to prevent the body from utilizing them, are primarily concentrated in the cotyledon of legumes. When the hulls of broad beans are removed during processing, the hull to cotyledon mass ratio decreases, which lowers the phytate percentage in the processed broad bean (Thamaraiselvi *et al*., 2024). At 0.78%, Sample RBBF had the greatest phytate concentration, while Sample SCBBF had the lowest, at 0.30%. Comparable to earlier research on legumes by Chinma *et al*. (2022) observed a comparable decline in phytate concentrations on pigeon pea as processing treatment (germination) advanced. According to Wang *et al*. (2008), the processing methods may have activated endogenous phytase, which decreased the amount of phosphorus stored as phytic acid and, as a result, decreased the samples' phytate concentration. However, the type of legume seed under study affects the amount of reduction in phytates. Due to the heat-stable nature of phytates in broad beans, a published article by Duhan *et al.* (2002) suggested that cooking may raise the phytate value. According to Vijayakumari *et al.* (2007), the phytate level of soybeans was decreased considerably by the combined processing procedure of soaking and cooking; this was nevertheless noticeable in Sample SCBBF.

Oxalate content

There was a notable significant difference in the oxalate content generated by oxalic acid in the form of soluble (potassium and sodium) or insoluble (calcium, magnesium and iron) salts, rendering them inaccessible. The oxalate contents were decreased to varying concentrations by the different processing methods. Sample SCBBF had the lowest oxalate concentration (3.38%) while Sample RBBF had the highest (6.70%). By breaking the bonds that oxalic acids have with calcium, magnesium, iron, potassiumand sodium ions, respectively, the processing methods used decreased the amount of oxalate in the samples (Chinma *et al.,* 2022). This study's oxalate concentration was less than that of soybean flour as reported by Shiriki *et al.* (2015).

Tannin content

Table 2 showed the results of the tannin content. All samples were significantly different in tannin contents, except sample SKBBF and SPBBF, CKBBF and SCBBF, respectively. The tannin concentration was high, ranging from 1.50 to 0.52%. Broad beans have large amounts of tannin in their testa and it is regarded as one of the main anti-nutrients. They are responsible for binding of proteins, carbohydrates and iron, which makes it unavailable for the body to absorb. With a tannin level of 1.50%, Sample RBBF had the greatest tannin content, while Sample SCBBF had the lowest, at 0.52%. According to Osman (2007) and Chukwu *et al*., (2024), the tannin content of the samples

Table 2: Mean functional properties of the processed broad bean flour samples.

Sample	Bulk density (g/cm^3)	Swelling power	Foam capacity	Foam stability	Gelatinization temperature (^oC)	Boiling temp. (^oC)	Water absorption capacity	Oil absorption capacity
RBBF	$0.74^{c}\pm0.01$	$1.41^{a}\pm0.03$	$6.5^{a}\pm0.3$	$4.7^{a}\pm0.17$	$80.3^{ab}\pm1.57$	$94.0^{a}\pm1.20$	$0.97^{c}\pm0.74$	$1.13^{a}\pm0.02$
SKBBF	$0.71^{c}\pm0.01$	$1.53^{a}\pm0.01$	$6.9^{a}\pm0.03$	$5.1^{a}\pm0.32$	$83.5^{a}\pm0.17$	$91.3^{ab}\pm1.7$	$1.28^{ab}\pm0.03$	$1.28^{ab}\pm0.11$
SPBBF	$0.65^{b}\pm0.01$	$1.65^{b}\pm0.01$	$7.3^{b}\pm0.02$	$5.5^{b}\pm1.37$	$79.7^{b}\pm0.03$	$85.2^{b}\pm1.31$	$1.27^{b}\pm0.11$	$1.34^{b}\pm0.02$
CKBBF	$0.61^{ab}\pm0.03$	$1.85^{b}\pm0.04$	$15.4^{c}\pm0.3$	$12.7^{c}\pm0.87$	$69.2^{bc}\pm1.31$	$83.1^{ab}\pm0.70$	$2.55^{a}\pm0.02$	$1.94^{b}\pm0.21$
SCBBF	$0.53^{a}\pm0.02$	$1.72^{c}\pm0.05$	$13.5^{c}\pm0.12$	$10.5^{c}\pm0.97$	$66.7^{c}\pm1.71$	$79.1^{c}\pm0.97$	$1.93^{b}\pm0.12$	$2.05^{c}\pm0.01$
LSD	0.071	0.021	1.71	1.21	1.97	2.11	0.031	0.037

was lowered by the processing methods. This could be as a result of the breakdown caused by soaking and sprouting or elimination of anti-nutrients using high temperatures, which releases bound nutrients and increases their availability for the body use.

Saponin

The saponin contents ranges from 3.52% to 2.48% in which samples SKBBF, SPBBF, CKBBF and SCBBF differed significantly among each other. Reduced saponin content might be due to different processing procedures with SCBBF having the lowest saponin level. The loss of nutrients as a result of heating at high temperatures and the hydrolysis of large molecular weight soluble polymers could be the cause of this (Nithya *et al*., 2007). Soaking and cooking eliminated heat-sensitive/heat-stable antinutrients from kidney beans, which is consistent with our findings that both methods significantly decreased the saponin content of the beans (Osman, 2007).

Functional properties of the processed broad bean samples

Bulk density

The bulk densities of all the samples (Table 2) showed significant differences except for sample RBBF and SKBBF; SPBBF and SCBBF, which were not influenced by the different processing techniques. The bulk densities varied from 0.735% to 0.53% while Sample SCBBF had the lowest value (0.53%). Heat treatment converted several high molecular fibre components that give food bulk into soluble forms (Fasoyiro *et al*., 2010). Given that high fibre contributes to the bulk of food samples, these results correlated with the findings of the protein, fat and crude fibre analyses shown in Table 1. Sample RBBF, on the other hand, had the highest bulk density (0.735%), which is consistent with the findings of Ogbo *et al*. (2017). This is because the sample had no processing, which allowed the high molecular compound to stay intact and contribute bulk to the flour sample. The bulk density as measured in Sample SKBBF was not significantly different ($p>0.05$) from Sample RBBF, suggesting that the soaking technique had little effect on the bulk density. Particle size and density have an impact on flour's bulk density, which in turn influences packaging requirements.

Swelling power

The samples' water absorption index during heating was shown by the swelling power, which varied significantly except for Samples RBBF and SKBBF; SPBBF and CKBBF, which did not. The samples' swelling power differs when heat and water are applied and this may be due to the variations in the sample composition brought about by the various processing methods (Ndife and Abbo, 2009). Sample CKBBF had the highest swelling power (1.85- 1.4), which is consistent with the findings of Duhan *et al.* (2002). This may be because Sample CKBBF contains more soluble components, like proteins and carbohydrates, which absorbed water upon heating and increased in size. On the other hand, Sample RBBF (1.41) showed the opposite pattern, with less soluble components due to no processing.

Foam capacity/foam stability

The samples responded differently to the air-water contact, their foam stability varied greatly, with Sample CKBBF having the highest foam capacity (13.5). The soluble proteins in the sample have the ability to absorb air at the air-water interface and lower the water's surface tension, which is known as the foam capacity. Since proteins are what absorb the air-water interface and cause overhead foam, this could be the result of having more protein as observed in our study and less denatured protein as reported by Ndife and Abbo, (2009). However, sample RBBF showed the opposite pattern, with a lower protein concentration than the other samples. Nonetheless, the results of this study's foam capacity was higher than that found in the flour of *Mucuna pruriens* seeds by Ezegbe *et al.* (2022). This suggests that broad beans could be utilized in recipes for cakes, "akara" salad dressings, *etc*. Thus, the samples exhibiting high foam capacity also exhibited high foam stability. Sample CKBBF and Sample RBBF have strong and low foam stability, respectively, within the range of 12.7 to 4.7.

Gelatinization temperature

The temperature at which the samples gelled upon heating because they contained soluble starch granules is known as the gelatinization temperature. The study's gelatinization temperature varied significantly due to the various amounts of soluble particles produced by the different processing methods, which led to the formation of gel. The samples' gelatinization temperatures varied from 83.5 to 66.7°C, with sample SKBBF having the highest gelatinization temperature while sample SCBBF, the lowest. The cooking process may have broken down high molecular carbohydrates into soluble components like starch, which solidified upon cooling, resulting in the lowest gelatinization temperature in sample SCBBF; nevertheless, reheating produced gels at lower temperatures. According to Fasoyiro *et al.* (2010), it may have taken a higher temperature and energy for the broad bean flour to initiate rapid water ingression and swelling of starch granules in samples RBBF and SKBBF due to the processing techniques' inability to produce soluble compounds.

Water absorption capacity

The water absorption capacity is a measure of the degree of granular integrity, which establishes the strength of the associative forces between the starch granules; thus, a reflection of the protein and carbohydrate content of the blends (Acobs, 1999). With the exception of samples SPBBF and SCBBF, which showed an increase in water absorption capacity, there were significant differences

(P<0.05) in the water absorption capacities of the samples. Water absorption capacity varied from 2.55 and 0.97, with Sample RBBF being the lowest while sample CKBBF being the highest; thus, aligns with the findings of Ijarotimi *et al.* (2012). This could be because polysaccharides are broken down into compounds that absorb or take up water molecules and more polar amino acids are present.

Oil absorption capacity

According to Usman *et al*. (2016), the physical entrapment of oil is responsible for the oil absorption capacity and flavour retention and improved food mouthfeel. Samples RBBF, SPBBF and SCBBF showed significant differences from each other, except for Samples SPBBF and CKBBF, indicating an increase in the samples' oil absorption capacity. Sample SCBBF had the highest oil absorption capacity, which may account for its high mouthfeel and taste. Sample RBBF, on the other hand, had the reverse effect, since Sample CPF moi moi was made using cowpea flour, which served as the control sample. The oil absorption capacity ranged from 2.05 to 1.13. From a flavour perspective, the food sample enhanced by oil is demonstrated by the maximum oil absorption ability.

Mineral content of broad beans flour processed using different techniques

The results of the mineral contents (iron, zinc, calcium and potassium) of broad beans processed using various methods were assessed and presented in Table 3. Sample RBBF had a potassium concentration of 16.32 mg/100 g, while sample SPBBF had a potassium content of 46.23 mg/100 g. With the exception of samples RBBF and CKBBF, the potassium level of the samples varied significantly ($p \leq 0.05$). Osmotic pressure is sustained in part by potassium which additionally, aids in maintaining the body's proper acid-base balance (Hadiza, 2021).

The calcium contents of the flour samples varied from 7.86 mg/100 g for the SCBBF sample to 26.10 mg/100 g for the SPBBF sample. All samples had significantly differing calcium contents with the exception of the RBBF and CKBBF samples. The sample with the highest iron content was the flour made from sprouted broad beans. There were significant difference in the iron contents of the samples. High iron concentrations in food samples aid in the production of haemoglobin, which promotes red blood cell renewal while the formation and growth of bones depend on the mineral calcium (Ofoedu *et al.,* 2021).

All samples has low levels of zinc, with sample SPBBF having the highest level. However, all samples differed considerably in terms of zinc concentration. Significant differences were seen in the values Zinc is crucial to good health to maintain body system due to its ability to form a co-factor in a number of important enzyme systems.

Vitamin content of broad beans flour processed using different techniques

Table 3 shows the vitamin composition (vitamin B1, B2, B6 and vitamin C) of broad beans flour processed using

Table 3: Minerals and vitamins content of broad beans flour processed using different techniques.

Samples	Potassium (mg/100 g)	Calcium (mg/100 g)	Iron (mg/100 g)	Zinc (mg/100 g)	B_1 (mg/100 g)	B_2 (mg/100 g)	B_6 (mg/100 g)	Vitamin C (mg/100 g)
RBBF	16.32^{c}+0.25	8.36^{c}+0.15	3.64^{b}+0.20	2.86^{b}+0.25	6.86^{b}+0.25	8.56^{b}+0.25	6.18^{b}+0.25	0.860^{a}+0.25
SKBBF	23.26^{b}+0.05	16.20^{b}+0.00	3.40^{c}+0.10	2.56^{c}+0.50	4.26^{c}+0.05	6.86^{c}+0.05	4.86^{c}+0.05	0.726^{c}+0.05
SPBBF	46.23^{a}+0.51	26.10^{a}+0.02	8.20^{a}+0.20	9.48^{a}+0.25	8.16^{a} +0.51	9.26^{a}+0.51	7.26^{a}+0.51	0.82^{b}+0.51
CKBBF	23.23^{c}+0.02	8.92^{c}+0.01	3.05^{d}+0.21	2.48^{d}+0.35	3.86^{d}+0.02	4.86^{d}+0.02	4.12^{c}+0.02	0.68^{e}+0.02
SCBBF	18.23^{d}+0.10	7.86^{e}+0.02	2.95^{e}+0.10	2.10^{e}+0.45	2.60^{e}+0.10	3.84^{e}+0.10	3.26^{e}+0.10	0.78^{d}+0.10
LSD	0.3465	0.6545	0.2505	0.2875	0.3245	0.3465	0.3678	1.86

different techniques. The Vitamin B1 contents of the sample ranged from 2.60 mg/100 g for sample CKBBF to 8.16 mg/100 g for the Sample SPBBF. However, vitamin B1 content of the samples were significantly different among the samples with vitamin B2 ranging from 3.84 mg/100 g for sample CKBBF to 9.26 mg/100 g for the sample SPBBF. Sprouted broad bean flour had the highest vitamin B2 whereas the vitamin B6 for sample SPBBF ranged from 3.26 mg/100 g to 7.26 mg/100 g. Vitamin B_6 content of the samples differ significantly among each other and were high; thus, help in prevention of soreness and burning of the lips, mouth, tongue, photophobia, burning sensations and eye itching (Olusanya, 2018; Makwana *et al*., 2021 and Mohanapriya *et al*., 2024).

The vitamin C content of the samples were low and differ significantly among the samples ($P<0.05$). Vitamin C contents of the samples ranged from 0.68 mg/100 g for sample CKBBF to 0.860 mg/100 g for sample RBBF.

Sensory evaluation of Moi Moi samples produced from the processed Broad bean flours

Appearance

From the results obtained in Table 4, it was observed that there were significant differences between the control sample CPF with a mean score of 7.50 and the other samples in terms of appearance of the samples of moi moi produced. This could be due to no effect of processing technique on the color of the flour of the moi moi. However, Sample SPBBF rated the lowest score (7.02) and was moderately liked. Sample CPF was liked very much than other samples due to the difference in raw material as panelists preferred the moi moi developed from cowpea flour than the broad beans moi moi in terms of appearance.

Aroma

The aroma score of Sample CPF (7.3) was moderately liked and shows significant difference from Sample SKBBF (6.3) which was liked slightly. Sample CPF, SPBBF, CKBBF and SCBBF were not significantly different ($p>0.05$) from each other but the least aroma score (5.90) which was slightly liked was observed in Sample SPBBF. The least score observed in Sample SPBBF may be attributed to the difference in raw material when compared to Sample CPF. However, on the application of the processing techniques, the aroma score of the broad bean moi moi samples increased with Sample SCBBF having the highest score (7.10) amongst the broad bean moi moi samples. This observed results is in correlation with a report by Russel *et al*. (2006) and this could be as a result of high water and oil absorption capacity of the sample, as it retains more flavor than other samples.

Texture

The texture of Sample CPF ranked highest with a mean score of 7.8 and was significantly different from Samples SKBBF, CKBBF and SCBBF respectively. The moi moi samples developed from sample CKBBF had the least mean score (5.40), which indicates that the samples were neither liked nor disliked. This however could be due to the earlier cooking operation performed on the sample at high temperature, as the sample gelatinized easily on cooking, due to starch hydrolysis, making the sample to produce soluble gels which solidifies on cooling and on further cooking produced more concentrated gels (Luo *et al.,* 2010a).

Taste

From the Table 4, the taste score were significantly different with the exception of Samples SKBBF, SPBBF, CKBBF and SCBBF which were not significantly different from one another. Sample CPF had the highest score (7.50) which indicates that the moi moi samples was liked very much. The moi moi sample produced from flour of soaked broad bean had the least taste score of 5.30 by the panelists and it was significantly different from other Samples. The low taste score may be attributed to its low water and oil

Table 4: Mean sensory scores of the moi moi samples produced from different processed broad bean flours.

Sample	Appearance	Aroma	Texture	Taste	Mouth feel	Overall acceptability
CPF	$7.50^{b}\pm0.37$	$7.30^{ab}\pm1.05$	$7.80^{a}\pm2.01$	$7.50^{a}\pm2.37$	$6.90^{a}\pm1.71$	$7.62^{b}\pm1.77$
SKBBF	$7.1^{a}\pm1.47$	$6.30^{c}\pm1.78$	$6.90^{c}\pm1.79$	$5.30^{b}\pm1.97$	$6.31^{a}\pm1.91$	$6.41^{a}\pm2.13$
SPBBF	$7.02^{a}\pm0.34$	$5.90^{b}\pm1.73$	$7.30^{a}\pm1.87$	$5.90^{b}\pm1.30$	$6.20^{c}\pm1.76$	$5.83^{a}\pm2.67$
CKBBF	$7.13^{a}\pm1.27$	$6.90^{b}\pm1.31$	$5.40^{b}\pm1.71$	$6.00^{c}\pm2.35$	$5.12^{b}\pm2.13$	$7.00^{c}\pm1.04$
SCBBF	$7.05^{a}\pm0.78$	$7.10^{a}\pm1.61$	$5.90^{b}\pm2.31$	$6.50^{c}\pm1.30$	$5.73^{b}\pm2.13$	$7.12^{b}\pm2.19$
LSD	1.71	1.75	2.37	1.12	2.03	2.19

Note: The “a,b,c,….” mean having different superscripts along the same columns are significantly different ($P\leq0.05$).

Keys: Sample CPF = Raw Cowpea flour (control).

Sample SKBBF = Broad bean flour developed from soaking process.

Sample SPBBF = Broad bean flour developed from sprouting process

Sample CKBBF = Broad bean flour developed from cooking process.

Sample SCBBF = Broad bean flour produced from combined processing technique of soaking and cooking.

absorption capacities as it entrapped lower flavors. In accordance with a report by Nwosu *et al*. (2014), there exist a relationship between the water absorption capacity and flavor intake of food samples, as foods having high water absorption capacity tends to entrap more flavor compounds.

Mouthfeel

The mouthfeel score of Sample CPF (6.90) was moderately liked and was significantly different from Sample SPBBF, CKBBF and SCBBF and was not significantly different from Sample SKBBF. The highest mean score (6.90) of mouth feel in Sample CPF may be due to its different raw material from the broad bean. Sample CKBBF (5.12) which is neither liked nor disked had the least score for mouthfeel. The poor preference in mouthfeel could however be due to the overcooking cooking.

Overall acceptability

The control sample (CPF) had the highest overall acceptance (7.62), as it was liked moderately and Sample SPBBF had the lowest acceptability score (5.83) which was liked slightly. However, all the moi moi samples were acceptable, as their overall acceptance score were above 5.0 and they were significantly different from one another, with the exception of Sample CPF and SCBBF and SKBBF and SPBBF, which were not significantly different from each other.

CONCLUSION AND RECOMMENDATIONS

The various processing techniques in this study reduced anti-nutrients significantly. The various samples showed that the anti-nutritional content in the processed samples were lower than the range for Nigerian Industrial Standard (NIS) and hence are suitable for human consumption. Proximate composition carried out also showed that broad bean is rich in nutrients, especially proteins and should be incorporated into protein deficient foods to help alleviate malnutrition and enhance food security. However, the mineral and vitamin contents of the samples were improved by all the processing techniques evaluated. The sensory analysis elaborated on the moi moi developed from broad bean showed that it can be used as a substitute for moi moi production and still present same organoleptic attributes of other moi moi sources. The processing of the broad bean by combining soaking and cooking resulted in an increase in the nutritional contents of the processed flour, as it contains higher amount of protein, ash and carbohydrate contents. Sprouting was the most effective method in improving the mineral and vitamin contents. The sensoryproperties of the moi moi samples also increased on the application of the combined processing technique. The consumption of broad bean should be encouraged as it is rich in protein and could be incorporated into a protein deficient diet. Micronutrients, antioxidant properties, *in vitro*-protein digestibility and microbial study of the moi moi samples should be studied.

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