International Scholars Journals

African Journal of Food Science Research ISSN 2375-0723 Vol. 7 (2), pp. 001-012, February, 2019. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Physical properties of *Tylosemia esculentum* and the effect of roasting on the functional properties of its flour

V. A. Jideani*, J. Van Wyk and M. H. Cruywagen

Department of Food Technology, Cape Peninsula University of Technology, P.O. Box 652, Cape Town 8000, South Africa.

Accepted 26 November, 2018

The physical properties of two varieties of Morama beans and the effect of roasting on the functional properties of their flours were studied. Majority (65, 92.5, 79%) of the seeds has medium dimensions (17.0 - 19.99, 14.0 - 19.99, 12.0 - 14.99 mm) of length, width and thickness respectively. The size of the Morama bean (MB) follows a normal distribution, being much heavier than most other oil seeds and legumes with 1000-seed weight of 2.2 - 2.3 kg. Significantly higher angle of repose was observed for the cement surface (9.76^{o}). MB sphericity (85.7-86.8%) and aspect ratio (91.9 - 92.5%) indicates that the bean will roll rather than slide. Morama flour (MF) is rich in protein (31.7 - 33.1%), fat (36.4 - 39.0%) and ash (2.9%). Roasting significantly increased the protein and ash. Roasting increased the water absorption capacity of MF significantly ($P < 0.05$) (211% increase). Roasting significantly increased the oil absorption capacity (112% increases) . Emulsifying activity ranged from 37.90 - 38.20% respectively for light- and dark-brown Morama flour. Emulsion stability ranged from 70.62% (light brown) to 72.18% (dark brown). The colour of unroasted MF is light yellow (L = 82.71, Hue angle = 88.05, Chroma = 26.21), turning darker and less saturated on roasting.

Key words: Morama bean, physical properties, functional properties, lightness, hue, chroma.

INTRODUCTION

Tylosemia esculentum is a woody prostrate trailing plant which produces an oil seed legume called Morama beans, is endemic to the Southern parts of Africa where it grows in the grasslands and bushveld (Coetzer and Ross, 1977), with large populations in Botswana (around the central Kgalagadi) and Namibia, smaller populations in the provinces of Limpopo, North-west and Gauteng of South Africa (National Research Council, 2006). The plant thrives in poor quality soil and harsh climatic con-ditions and has creeping stems which are up to 6 meters long, protecting it from the destructive windstorms of the Kalahari Desert (Hartley, 1997). Morama beans grow in a large, flat woody pod in groups of approximately six beans per pod. The beans are chestnut to dark brown in colour, normally spherical and weigh 2- 3 g each. Each bean has a hard inedible outer shell with an edible two lobed seed inside. The inner flesh is cream coloured (National Research Council, 2006) . *T. esculentum* has a long history as a food resource. It is believed that mora-ma beans, and other edible parts of this plant, may have been in our diet as long as food was in existence, and even today it is an important component for some living in the southern parts of Africa which include the Herero, Tswana, Khoi san and other Bantu speaking people (National Research Council, 2006).

The composition of the Morama bean is similar to that of peanuts and soybeans. It has a protein content of 29.6 - 41.8% and an oil content of 32.1 - 45.3% (Monagham and Hallovan, 1995). In addition to its high protein and oil content, Morama beans also contain minerals and vitamins which include potassium, phosphorus, thiamin, riboflavin and nicotinic acid. Morama bean is a source of clear golden yellow oil, which has a nutty odour with an agreeable taste similar to almond oil. The taste of the Morama bean is soapy with a slimy texture due to its high

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*Corresponding author. E-mail: JideaniV@cput.ac.za.

Abbreviation: MB; Morama bean, **MF;** Morama flour, **WAC;** Water absorption capacity, **OAC;** Oil absorption capacity.

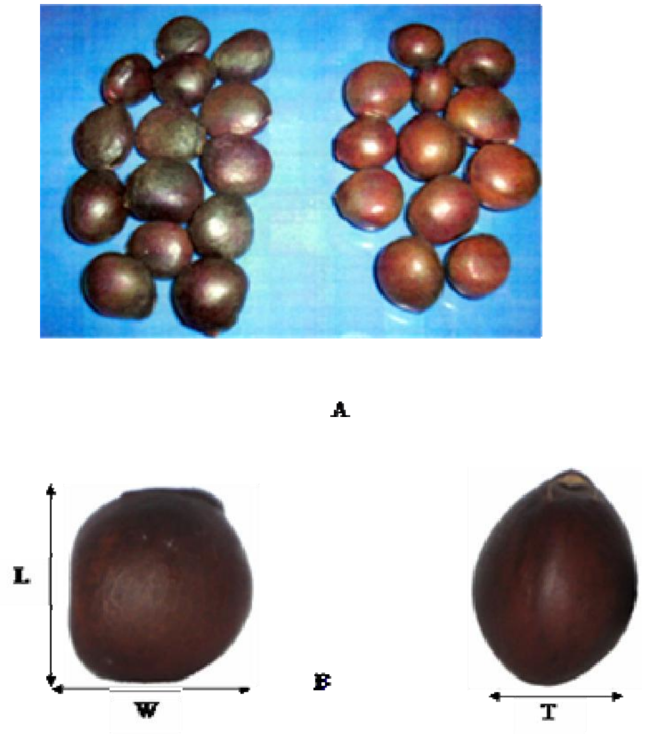

Figure 1. (A) Morama seed varieties, left- dark brown; right- light brown. (B) Characteristic dimensions of Morama bean: length (L), width (W) and thickness (T).

water activity (Hartley, 1997). The bean is not eaten raw but rather roasted and eaten as a snack or boiled and consumed as a vegetable (Mmonatau, 2005). When roasted Morama beans resemble the taste of roasted cashew nuts or chestnuts (Mmonatau, 2005). It has been reported that Morama beans contain trypsin inhibitors; these are however destroyed by heat which would usually be applied during the cooking or roasting processes (Mmonatau, 2005).

Malnutrition is an increasing global issue. The Morama bean is widely believed to potentially play a significant role in solving the world's malnutrition problems due to its high content of unsaturated fatty acids, proteins and other nutrients. Despite the high nutritional value of the Morama bean, the only food application is roasting the dry beans and consuming it as a snack. The acceptability of legume flours in foods depends on their nutritional value and functional properties (Ahenkora et al., 1999). Some of these properties useful in food product development are water and oil absorption, emulsification, foam capacity and gelation (Wu et al., 2009). Besides, physical properties of foodstuffs are important in the design, handling, storage and drying systems, as well as daily operation of the foodstuff. Unfortunately, information about the physical and functional properties of Morama bean is lacking. To tap into the high nutritional content of the Morama bean our objective was to assess the physical properties of Morama bean, functional properties of the flour and effect of roasting with a view to obtain an indication of what possible products the flour can be applied to.

MATERIALS AND METHODS

Source of Morama beans

The Morama beans were purchased from Ghanzi, Botswana. The beans were kept at a temperature of 5°C and removed 1 h before the physical properties of the beans were measured. The beans were sorted into two varieties based on colour: light- and dark-brown seeds (Figure 1A) . All tests were conducted separately on the seeds and flours from these two groups.

Physical properties of Morama beans

Linear dimensions

The method stated of Mpotokwane et al. (2008) was adopted to measure the linear dimensions of the beans. Hundred (100) seeds were selected from each variety by obtaining a hand full of beans from a random location in a bowl containing the beans. The length (L), width (W) and thickness (T) as illustrated in Figure 1B of each selected bean were measured to an accuracy of 0.001 mm using a Vernier caliper. From the results obtained in these measurements, the geometric diameter, sphericity, volume, surface area and aspect ratio were determined.

Geometric diameter, sphericity, volume, surface area and aspect ratio

The equations of Mohsenin (1986) were used to determine the geometric diameter (D_g) and sphericity ( ) of the bean.

$$D_g = (LWT)^{1/3} \tag{1}$$

$$\varphi = \frac{(LWT)^{1/2}}{L} \tag{2}$$

Where; L = bean length, W = bean width and T = bean thickness in mm as shown in Figure 1B. The bean volume (V) and surface area (S) were determined using equations adopted from Jain and Bal (1997).

$$V = \frac{\pi B^2 L^2}{6(2L - B)} \tag{3}$$

$$S = \frac{\pi B^2 L^2}{2L - B} \tag{4}$$

Where; $B = (WT)^{0.5}$; L = length of the seeds; W = width of the seeds; T = thickness of the seeds in mm as shown in Figure 1B.

One thousand bean weight

The method reported by Mpotokwane et al. (2008) was adopted to determine one thousand bean weights. The mass of one thousand seeds of each variety were obtained using an electronic balance weighing to an accuracy of 0.0001 g. This was done in triplicate.

Bulk – and true density

The method of Asoegwu et al. (2006) reported by Mpotokwane et al. (2008) was used to determine the bulk density of the beans. A 500 ml cylinder was filled to the 500 ml mark with beans and weighed on an electronic balance. The bulk density was calculated as the ratio of bulk weight and volume of the cylinder (g/ml).

The true density was calculated using the liquid displacement method of Asoegwu et al. (2006). All weights were measured using a top loading balance. A 500 ml beaker was filled to the 350 ml mark with water. Approximately 100 g of beans were immersed in the water. The mass of the water displaced is the balance reading with the seed submerged minus the mass of the beaker with water. The seed volume was estimated by dividing the mass of displaced water (g) by the density of water (g/cm^3). Seed density was determined by dividing the seed mass by the measured seed volume. This was repeated thrice for each group of beans.

Seed porosity: Seed porosity is a property of grain which depends on its bulk- and kernel densities. Seed porosity (P) was determined using the equation stated by Mpotokwane et al. (2008):

$$-\frac{p_b}{p_t} \times 100$$

Where p_b = bulk density (kg/m^3) and p_t = seed density (kg/m^3).

Angle of repose

The method stated by Mpotokwane et al. (2008) was adopted for determination of the repose angle. A topless and bottomless cylinder, with a height of 17 cm and a diameter of 10.5 cm was used. The cylinder was filled to the top with beans. The cylinder was then slowly raised until the beans formed a natural heap. The angle of repose was calculated from the diameter and height of the heap formed on cement -, glass- and wooden- surface. The angle of repose determined in replicates was determined using the formula $\tan^{-1}(2H/L)$ where H = height of heap and L = length of the heap.

Preparation of Morama bean flours

Roasting of Morama beans

The method reported by Mmonatau (2005) was used for roasting Morama beans (light and brown). The beans were roasted for 15 min at 160°C using Defy 731 Multifunction thermofan oven.

Cracking of Morama beans

The unroasted and roasted Morama beans from the light and brown varieties were separately cracked using a hammer. The edible part of the beans was separated from the shell by hand picking.

Preparation of unroasted and roasted Morama bean flour

Unroasted Morama bean flour was prepared following the method reported by Chau and Cheung (1998) with modifications. The dehulled unroasted beans were blanched at 100°C for 30 min followed by soaking in distilled water at 25 ± 3°C for 3 h. The soaked beans were washed, drained and dried at 50°C for 72 h. The dried beans was milled into flour using a Hallde blender and sieved to a mesh size of 500 micron. The unroasted flour was packaged in polyethylene bags, sealed and stored at 5°C until required.

Roasted beans were milled into flour using a Hallde (Sweden) blender at high speed and sieved to a mesh size of 500 micron. The roasted flour was packaged in polyethylene bags, sealed and stored at 5°C until required.

Proximate composition of Morama bean flours

The AOAC (1990) method was used to determine the moisture, fat, protein and ash content of the unroasted and roasted Morama flours. The energy content of the flours was estimated using the Atwater factor as reported by Marero et al. (1988).

Energy content = [(4 × protein) + (4 × carbohydrate) + (9 × fat)] × 4.2 where protein, carbohydrate and fat are contents of the sample expressed in g/100 g sample, 4, 4 and 9 are kilocalories from protein, carbohydrate and fat respectively, 4.2 is a factor for converting from calories to joules. The determination was carried out in triplicate.

Functional properties of Morama bean flour

Water absorption capacity

The method described by Mc Walters et al. (2002) was adopted to measure the true-and apparent water absorption capacities of unroasted and roasted Morama bean flours. Each flour, (2 g) [M_0] was suspended in 20 ml of distilled water and agitated in a mechanical shaker for 1 hour. The slurry was then centrifuged at 31304 × g for 1 h and the sediments dried on Whatman filter paper ($M_1 + H_2O$) for 1 h. The proportion of water absorbed was calculated as apparent water absorption capacity using the formula reported by Mc Walters et al. (2002).

$$WA_a = \frac{(M_1 + H_2O) - M_0}{M_0} \times 100 \qquad (5)$$

Protein solubility

Protein solubility of the Morama bean flours were determined using Mc Walters et al. (2002) method. The filtrated obtained from the sample while measuring water absorption capacity was used to determine protein solubility. The Invritrogen Quibit Fluorometer was used to measure the amount of soluble proteins present in the filtrate. Protein solubility was reported as percentage soluble proteins. The measurement was done in triplicate.

Fat absorption capacity

A method adopted by Sogi and Chandi (2007) was used to determine the fat absorption capacity of Morama bean flours. Flour (0.5 g) was mixed with 10 ml canola oil and centrifuged at 750 x g for 15 min. The supernatant was then drained off for 30 min using cheese cloth and the weight gain reported as oil absorption capacity in triplicates.

pH

Morama bean flour (0.6 g) was dissolved in 20 ml distilled water to obtain a 3% suspension. The pH of the suspension was measured using a pH meter.

Least gelation concentration

The least gelation concentration was determined using the method adopted by Sathe and Salunke (1981). A test tube containing suspensions of 2, 4, 6, 8; 10, 12, 14, 16, 18 and 20% weight per volume material in 5ml distilled water was heated in boiling water for 1 h. This was followed by cooling in ice and further cooling for 2 h at 4°C. The least gelation concentration stated was the tube with the lowest concentration suspension of which the content did not fall down or slip when the test tube was inverted at pH 7. This was done in triplicates.

Emulsion capacity and stability

The method reported by Naczk et al. (1985) with modifications was used to determine the emulsion capacity and stability of the Morama flours. Flour (3.5 g) was mixed using a mechanical mixer for 1 min. Canola oil (25 ml) was added and the mixture was mixed again for 1 min. Another 25 ml of canola oil was then added and the mixture was mixed for 3 min. The emulsion was divided evenly into two centrifuge tubes and centrifuged at 1100 x g for 5 min. The emulsifying activity was calculated by dividing the volume of the emulsified layer by the volume of the emulsion before.

The emulsion stability was determined using samples prepared for measurement of emulsifying activity. These samples were heated for 15 min at 85°C, cooled, divided evenly into two 50ml centrifuge tubes and centrifuged at 1100 × g for 5 min. The emulsion stability was expressed as the percentage of emulsifying activity remaining after heating at pH 7.

Colour measurement

The colour of the different varieties of unroasted and roasted Morama bean flour was measured using the Hunter lab instrument in daylight colour mode (D65) and 10° Standard Observer. The flour samples (30 g) were place in the sample holder and the surface color was measured at three different positions (Senthil et al., 2002). The colour readings were displayed as L* a* b* values where L* represents lightness/ darkness dimension, positive and negative a* value indicates redness and greenness respectively and b* indicates yellowness for positive and blueness for negative values. The colour measurement was repeated four times. The colour values were converted to hue $\left[\tan^{-1}\left(b^* / a^*\right)\right]$ and chroma $\sqrt{{a^*}^2 + {b^*}^2}$.

Data analysis

Analysis of variance (ANOVA) and one sample t-test was used to determine mean differences in treatment. Duncan's multiple range tests was used to separate means where differences existed (SPSS, 2007).

RESULTS

Physical properties of Morama beans

Linear dimensions of Morama beans

The length, width and thickness of Morama bean (MB) are detailed in Table 1. The Morama varieties did not differ significantly ($p > 0.05$) in their linear dimensions. Morama seeds have a mean length of 18.6 mm and a range of 12.0 - 23.2 mm. The width of Morama seeds ranged from 12.0 - 27 mm with a mean of 17.0 mm and the thickness ranged from 9.80 - 19.20 mm with a mean of 13.1 mm.

Table 1 details the L/W, L/T and L/D_g ratio for Morama bean (MB) . The varieties did not differ significantly in the ratios. L/T exhibited the highest value in both varieties. The L/D_g and L/W ratios were very similar.

Figure 1 shows the frequency distribution for the length, width and thickness of Morama bean. Majority (65%) of the seeds has medium length of 17.0 - 19.99 mm. In terms of width, 92.5% of the seeds have a medium width of 14.0 - 19.99. With respect to thickness 79% of the seeds have a medium size of 12.0 - 14.99 mm.

Geometric properties of Morama beans

The geometric properties of Morama beans are presented in Table 2. The Morama bean varieties did not differ significantly ($p > 0.05$) in geometric properties. The geo-

Table 1. Effect of variety on linear dimensions of Morama beans*.

Variety	Dimension	Mean (mm)	Range (mm)	L/W	L/T	L/D_a
Light	Length	18.6 ± 1.5	12.0 - 22.8	1.11 ± 0.16	1.42 ± 0.16	1.19 ± 0.09
	Width	17.1 ± 2.0	12.0 - 27.0			
	Thickness	13.2 ± 1.1	10.0 - 15.7			
Dark	Length	18.6 ± 1.8	15.5 – 23.2	1.10 ± 0.12	1.45 ± 0.18	1.20 ± 0.08
	Width	17.0 ± 1.5	13.6 - 20.8			
	Thickness	12.9 ± 1.4	9.8 - 19.2			
Total	Length	18.6 ± 1.6	12.0 – 23.2	1.10 ± 0.14	1.44 ± 0.17	1.20 ± 0.08
	Width	17.0 ± 1.8	12.0 – 27.0			
	Thickness	13.1 ± 1.3	9.8 – 19.2			

*Values are mean ± standard deviation.

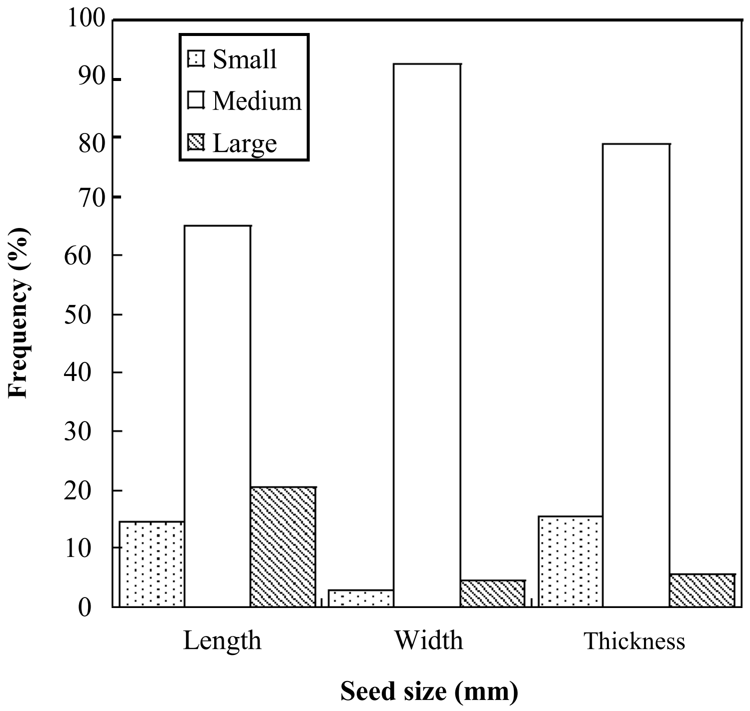

Figure 2. Morama bean seed dimension distribution of at Morama bean. Length (small <17 mm; medium 17.00-19.99 mm, large >20 mm); Width (small <14 mm, medium 14.00-19.99 mm, large >20 mm); Thickness (small <12, medium 12.00-14.99 mm, large >15).

Table 2. Geometric properties of Morama beans*.

Variety	Geometric diameter (mm)	Seed volume (mm^3)	Surface area (mm^2)	Sphericity (%)	Aspect ratio (%)
Dark	15.5 ± 0.93	1143 ± 210	10752 ± 2293	83.7 ± 5.7	91.9 ± 9.8
Light	15.7 ± 0.96	1183 ± 222	11219 ± 2360	84.4 ± 6.8	92.5 ± 14.5
Total	15.6 ± 0.95	1163 ± 217	10986 ± 2333	84.1 ± 6.2	92.2 ± 12.3

*Values are mean ± standard deviation.

Table 3. Effect of variety on gravimetric properties of Morama beans*.

Variety	1000-seed weight (kg)	Bulk density (kg/cm^3)	True density (kg/cm^3)	Repose angle (°)	Porosity (%)
Dark	2.3 ± 0.1	652 ± 21	996 ± 6	9.2 ± 0.5	34.6 ± 2.0
Light	2.2 ± 0.2	668 ± 21	1000 ± 1	9.4 ± 0.5	32.6 ± 2.0

*Values are mean ± standard deviation.

metric diameter of the beans was 15.84 and 15.65 mm respectively for the dark and light variety.

The mean volume of the beans was 1143 and 1182 mm^3 respectively for the dark and light variety. The mean volume and surface area did not differ significantly among the varieties. The mean sphericity of the dark brown variety was 85.7% and that of the light brown variety was 86.8%. The sphericity of the light variety of Morama beans was higher than the dark brown beans.

The mean aspect ratio of the dark brown bean was 91.9% and that of the light brown beans was 92.5%. There were no significant differences between the aspect ratio of the different varieties of Morama beans.

Gravimetric properties of Morama beans

The effect of variety on gravimetic properties of the Morama beans are reported in Table 3. There were no significant differences in gravimetric properties between the varieties. The dark brown beans had a mean 1000 seed weight of 2.3 kg and the light brown beans a mean of 2.2 kg.

The mean bulk densities of the beans were 668 and 652 kg/cm^3 respectively for the light and dark brown Morama beans. The mean true densities of the beans were 999 and 996 kg/cm^3 respectively for the light brown and dark brown beans.

The porosity for the dark and light brown beans was 34.6 and 32.6% respectively. The porosity of the dark brown beans was higher than that of the light brown bean, though not significant.

Frictional properties

The effects of variety and surface on angle of repose are detailed in Table 4. The mean angle of repose for the dark brown beans on a glass-, cement- and wood-surfaces were 8.74, 9.55 and 9.27° respectively and that of light brown beans on glass-, cement- and wood-surfaces were 9.15, 9.97 and 9.05° respectively. The effect of variety and surfaces on angle of repose differed significantly ($p < 0.05$). The light brown Morama was significantly higher in angle of repose than the dark brown Morama. Significantly higher angle of repose was observed for the cement surface (9.76°). The glass and wood surfaces did not differ significantly in their effect on angle of repose.

Table 4. Effect of variety and surface on repose angle of Morama bean*.

Material	Repose angle (°)		Total
	Dark brown	Light brown	
Glass	8.74 ± 0.43	9.15 ± 0.12	8.95 ± 0.37^a
Cement	9.55 ± 0.21	9.97 ± 0.29	9.76 ± 0.33^b
Wood	9.27 ± 0.24	9.05 ± 0.12	9.16 ± 0.21^a
Total	9.19 ± 0.45^a	9.39 ± 0.47^b	

*Values are mean ± standard deviation. Different superscripts in each row or column indicate significant difference ($p < 0.05$).

Comparison of Morama bean physical properties with other seeds

Table 5 details the comparison of mean properties of the Morama bean with that of Bambara groundnut, Chickpea, Jack bean, Egyptian peanut and African bread fruit. One sample t-test with 95% confidence interval on the linear dimensions indicates that Morama bean is significantly ($p < 0.05$) longer than bambara, chickpea, and African bread fruit; but shorter than Jack bean and the Egyptian peanut. In terms of width Morama bean is significantly wider than all the other seeds. MB is thicker than the other seeds except for Egyptian peanut. MB has a higher aspect ratio than Bambara groundnut, chickpea, jackbean and breadfruit. Sphericity of MB is higher than chickpea, jackbean and African breadfruit, but the equal to Bambara groundnut. Porosity of Morama is the same as that of jackbean but higher than Bambara.

Effect of variety and roasting on the nutritional composition of Morama bean flour. The nutritional composition of unroasted and roasted Morama flour is detailed in Table 6. The moisture content ranged from 6.4% for dark brown variety to 6.9% for the light brown variety. The fat content ranged from 36.4% (light brown) to 39.0% in dark brown.

Protein content ranged from 31.7% in light brown variety to 33.2% in dark brown variety. The ash content ranged from 2.9% in dark brown Morama to 2.9% in light brown Morama. The varieties differed significantly ($P < 0.05$) in moisture and protein content.

The multivariate tests indicated that variety did not have significant ($p = 0.133$ with partial eta squared = 0.643) contribution to the multivariate model. However, the high partial eta squared indicated that variety had sig-

Table 5. Comparison of Morama bean physical properties with other seeds.

Property	Morama bean	Bambara groundnut[a]	Chickpea[b]	Jackbean[c]	Egyptian peanut[d]	African breadfruit
L (mm)	18.6	11.48	10.2	18.66	35.86	11.91
W (mm)	17.0	9.66	7.74	13.14	14.96	5.69
T (mm)	13.1	9.17	7.66	10.22	16.34	4.64
True density (kg/m^3)	998	1003	-	1190	20.54	979
Bulk density (kg/m^3)	660	775	-	778	-	614
Porosity	33.56	22.7	-	32.6	-	-
Aspect ratio (%)	92.5	84.6	75.6	70.6	-	47.8
Sphericity (%)	84.1	85.8	82.9	72.7	-	57.1
Geometric mean diameter (mm)	15.9	9.81	8.46	13.56	-	6.80

[a] Mpotokwane et al. (2008); [b] Tabatabaeefar et al. (2003); [c] Eke et al. (2007); [d] Alfaro et al. (2004); [e] Omobuwajo et al. (1999).

Table 6. Effect of variety and roasting on the nutritional properties of the Morama flour[1].

	Composition	Morama variety		Type of flour[2]	
		Dark brown	Light brown	Unroasted	Roasted
Proximate (g/100 g dry basis)	Moisture	6.4 ± 0.5^a	6.9 ± 0.1^b	6.5 ± 0.5	6.8 ± 0.3
	F-ratio	7.61		1.86	
	p-value	0.0222		0.2062	
	Partial eta squared	0.4580		0.1710	
	Fat	39.0 ± 4.1	36.4 ± 6.0	35.2 ± 6.2	40.3 ± 1.6
	F-ratio	1.01		3.88	
	p-value	0.3407		0.0804	
	Partial eta squared	0.1011		0.3012	
	Protein	33.2 ± 1.3^a	31.7 ± 1.1^b	31.6 ± 0.8^a	33.3 ± 1.3^b
	F-ratio	11.25		16.49	
	p-value	0.0085		0.0028	
	Partial eta squared	0.5555		0.6469	
	Ash	2.9 ± 0.5	2.9 ± 0.3	2.6 ± 0.2^a	3.2 ± 0.2^b
	F-ratio	0.01		30.19	
	p-value	0.9193		0.0004	
	Partial eta squared	0.0012		0.7704	
	Carbohydrate	18.5 ± 4.3	22.0 ± 7.1	24.2 ± 6.2^a	16.4 ± 1.3^b
	F-ratio	2.06		10.13	
	p-value	0.1846		0.0111	
	Partial eta squared	0.1866		0.5296	
	Energy (kJ/100 g)	2343 ± 89	2279 ± 124	2265 ± 139	2358 ± 34
	F-ratio	1.258		2.609	
	p-value	0.2911		0.1407	
	Partial eta squared	0.1226		0.2248	

[1] Values are mean ± standard deviation. In each column different superscripts in each row indicate significant difference ($p < 0.05$).

[2] Combined effect of unroasted (dark and light) and roasted (dark and light).

nificant effect on some of the nutritional composition of Morama flour.

On the contrary, the effect of roasting on the nutritional composition of Morama flour was significant ($p = 0.001$, partial eta squared = 0.936). The between-subjects effects showed that roasting significantly increased the protein ($p = 0.003$) and ash ($p = 0.000$), while the effect on carbohydrate ($p = 0.011$) was a decrease.

Effect of variety and roasting on the functional properties of bean flour

The multivariate tests showed that both varieties ($p = 0.041$ with partial eta squared = 0.912) and roasting ($p = 0.000$, partial eta squared = 0.999) contributed significantly to the multivariate model (Table not shown).

Water and oil absorption capacity

The effect of variety and roasting on the water absorption capacity (WAC) and oil absorption capacity (OAC) of Morama flour is stated in Table 7. WAC of unroasted Morama flour ranged from 10.8% (light brown) to 11.8% (dark brown). Varieties differed significantly ($p < 0.05$) in water absorption capacity (WAC). Dark brown Morama had significantly higher WAC when compared with light variety. Roasting increased the WAC of Morama flour significantly ($p < 0.05$) in both varieties, a 5.5% for unroasted flour to 17.1% for roasted flour (211% increases).

Oil absorption capacity (OAC) of unroasted Morama ranged from 27.3% (dark brown) to 27.6% (light brown). There was no significant difference in OAC between the dark and the light brown Morama flour. However, significant difference ($p < 0.05$) existed between the unroasted and roasted flours. For each variety roasting significantly increased the OAC resulting in 112% increase.

Emulsifying activity and stability

The effects of variety and roasting on the emulsion activity and stability of Morama flour are detailed in Table 7. Emulsifying activity ranged from 37.9 for light brown to 38.2% for dark brown Morama. Emulsion stability ranged from 70.6% (light brown) to 72.2% (dark brown). The two varieties did not differ significantly in emulsifying activity and stability. The unroasted and roasted flours differed significantly ($p < 0.05$) in emulsifying activity, but no difference was observed for emulsion stability.

pH, protein solubility and least gelation concentration

The effect of variety and roasting on the pH and protein solubility of Morama flour is detailed in Table 7. The pH of the unroasted flour from the two varieties ranged from 6.54 (light brown) to 6.68 (dark brown). Although the P value for pH indicate significant difference ($p < 0.05$), between the varieties and the flours, the very low partial eta squared value for variety (0.4127) and flour type (0.3878) suggests that the differences in pH was by chance. The pH of roasted Morama flour negatively correlated with WAC ($R = -0.855$, $P = 0.030$), OAC ($R = -0.836$, $p = 0.038$), emulsifying activity ($R = -0.814$, $P = 0.049$) and emulsion stability ($R = -0.945$, $p = 0.004$). The protein solubility ranged from 83.3% (light brown) to 86.8% (dark brown). The varieties differed significantly ($p < 0.05$) in protein solubility. Roasting significantly increased the protein solubility in both varieties. Protein solubility of unroasted Morama flour positively correlated with WAC ($R = 0.951$, $p = 0.003$), OAC ($R = 0.948$, $p = 0.004$) and EA ($R = 0.838$, $p = 0.037$). Protein solubility of roasted Morama flour negatively correlated with protein content ($R = -0.843$, $p = 0.035$). The least gelation concentration for both varieties of Morama flour was 4%.

Effect of variety and roasting on the colour of Morama flour

The multivariate tests showed that both variety ($P = 0.038$ with partial eta squared = 0.520) and roasting ($P = 0.000$, partial eta squared = 0.995) contributed significantly to the multivariate model (Table not shown). The effect of variety and roasting on the lightness, hue angle and chroma of Morama flour is shown in Table 8. Lightness (L) of Morama flour ranged from 82.4 for the dark brown to 83 for the light brown variety. The hue angle for the dark variety was 88.1^{o} and 88^{o} for the light variety. The chroma values were 25.6 for the dark variety and 26.80 for the light variety. Although the multivariate tests (Table 8) indicated that the effect of variety on the lightness and hue of Morama colour is significant, the partial eta squared values (< 0.5) suggests that the difference may be by chance. However, significant difference exists between the varieties in chroma. The lightness of 82.7, hue angle of 88.1 and chroma of 26.2 suggest that the colour of unroasted Morama flour is light yellow.

DISCUSSION

Linear dimensions and geometric properties of Morama beans

The similarity of L/D_g and L/W ratios (Table 1) indicates that thickness of the seeds is closely related to its length.

Baryeh (2002) reported similar results for millet and Co kuner and Karababa (2007) for coriander seeds and Ogunjimi et al. (2002) for locust bean seed. The following general expression can be used to describe the relationship among the dimensions of Morama seed

$$L = 1.10W = 1.44T \qquad (6)$$

The size of the Morama bean follows a normal distribution

Table 7. Effect of variety and roasting on the functional properties of Morama flour[1].

Functional property (%)	Morama variety		Nature of flour[2]	
	Dark brown	Light brown	Unroasted	Roasted
WAC	11.8 ± 6.3^a	10.8 ± 6.4^b	5.5 ± 0.7^a	17.1 ± 0.6^b
F-ratio	42.40		5136.47	
p-value	0.0001		0.0000	
Partial eta squared	0.8249		0.9983	
OAC	27.3 ± 9.1	27.6 ± 10.5	18.5 ± 0.7^a	36.4 ± 1.1^b
F-ratio	0.35		1030.66	
p-value	0.5700		0.0000	
Partial eta squared	0.0372		0.9913	
Emulsifying activity	38.2 ± 1.8	37.9 ± 2.2	36.2 ± 0.6^a	39.8 ± 0.3^b
F-ratio	1.23		180.32	
p-value	0.2963		0.0000	
Partial eta squared	0.1202		0.9525	
Emulsion stability	72.2 ± 0.8	70.6 ± 2.2	70.6 ± 2.2	72.2 ± 0.8
F-ratio	3.16		3.00	
p-value	0.1090		0.1171	
Partial eta squared	0.2601		0.2502	
Protein solubility	86.8 ± 2.6^a	83.3 ± 2.0^b	83.5 ± 2.1^a	86.6 ± 2.8^b
F-ratio	14.44		11.42	
p-value	0.0042		0.0081	
Partial eta squared	0.6160		0.5593	
pH	6.7 ± 0.1^a	6.5 ± 0.1^b	6.7 ± 0.1^a	6.6 ± 0.2^b
F-ratio	6.32		5.7	
p-value	0.0330		0.0407	
Partial eta squared	0.4127		0.3878	

[1] Values are mean ± standard deviation. In each column different superscripts in each row indicate significant difference ($P < 0.05$).

[2] Combined effect of unroasted (dark and light) and roasted (dark and light).

(Figure 1).

The geometric mean diameter values were lower than the length and width, but higher than the thickness of Morama bean. On the contrary Coşkuner and Karababa (2007) reported that the geometric mean diameter of coriander seeds were lower than the length, and higher than its width and thickness.

A sphericity higher than 70% gives an indication of how close the shape of the Morama beans are to that of a sphere (Eke et al., 2007). Such a higher sphericity enables the beans to roll rather than slide which is a property required in the design of hoppers, chutes and other storage facilities (Mpotokwane et al., 2008) . A similar trend had been reported for the Bambara groundnut (Mpotokwane et al., 2008) and Jackbean (Eke et al., 2007).

The high aspect ratio indicates that Morama bean is more oblong in shape (Mpotokwane et al., 2008). The values of aspect ratio which are higher than 70% indicated that the beans are likely to roll rather than slide. The sphericity and aspect ratio of the Morama beans are similar to that reported for the Bambara groundnut (Mpotokwane et al., 2008), jackbean (Eke et al., 2007) and the soybean (Polat et al., 2006).

Gravimetric and frictional properties of Morama beans

Morama beans are much heavier than most other oil seeds and legumes (Table 3). Knowledge of the specific mass of the beans is important as it is an essential parameter for storage, handling and processing of the product and it is required for calculation of the critical velocity,

Table 8. Effect of variety and roasting on the colour of Morama flour[1].

Colour parameter	Morama variety		Nature of flour[2]	
	Dark brown	Light brown	Unroasted	Roasted
Lightness (L)	82.4 ± 1.2^{a}	83.0 ± 0.6^{b}	83.5 ± 0.1^{a}	81.9 ± 0.6^{b}
F-ratio	9.99		85.32	
p-value	0.0075		0.0000	
Partial eta squared	0.4344		0.8678	
Hue angle ($\tan^{-1}(b/a)$)	88.1 ± 1.0^{a}	88.0 ± 0.8^{b}	87.3 ± 0.1^{a}	88.8 ± 0.2^{b}
F-ratio	8.71		737.36	
p-value	0.0113		0.0000	
Partial eta squared	0.4011		0.9827	
Chroma $[(a^2 + b^2)^{1/2}]$	25.6 ± 1.1^{a}	26.8 ± 0.1^{b}	26.7 ± 0.1^{a}	25.7 ± 1.2^{b}
F-ratio	13.61		9.37	
p-value	0.0027		0.0091	
Partial eta squared	0.5114		0.4190	

[1] Values are mean ± standard deviation. In each column different superscripts in each row indicate significant difference ($P < 0.05$).

[2] Combined effect of unroasted (dark and light) and roasted (dark and light).

should pneumatic method be used in processing (Alcali et al., 2006). The considerable difference between the bulk and true densities of both the dark brown and light brown beans is a good indication of compressibility (Alcali et al., 2006). The porosity is a property of the beans which depends on its bulk and kernel densities (Mpotokwane et al., 2008).

The implication of the higher repose angle from the cement surface is that the storage of Morama on a cement surface will lead to the maximum utilization of space.

Effect of variety and roasting on the nutritional composition of Morama bean flour

The high fat content of Morama bean was within the range reported in the literature by earlier researchers (Keegan and van Staden, 1981; Monagham, 1995; Amarteifo and Moholo, 1998). The high protein content was within the range reported in the literature (Keegan and van Staden, 1981; Bower et al., 1988; Monagham, 1995). Morama flour is therefore rich in protein, fat and ash, hence it can contribute significantly to the nutritional needs of consumers of products made from it. The relatively high ash and fat content indicates that it could be a good source of minerals and oil.

Roasting did not affect the moisture and fat content significantly. This perhaps was because the bean was roasted with the shell intact thereby reducing moisture and oil loss.

Effect of variety and roasting on the functional properties of Morama bean flour

Water and oil absorption capacity: The ability of a substance to associate with water under a limited water condition is WAC (Singh, 2001). The WAC of Morama bean obtained in this study is less than that reported in literature for other legume (Ghavidel and Prakash, 2006; Ahenkora et al., 1990). Differences in WAC of different legumes could be due to the differences in the content of polar amino acid residues of proteins or charged side chains which have an affinity for water molecules (Kinsella, 1976; Jitngarmkusol et al., 2008). It is also known that polysaccharides, which are hydrophilic greatly, affect water absorption (Ghavidel and Prakash, 2006). The high lipid content in Morama could also exert high negative effect on its WAC. Increased WAC as a result of heating have been reported for winged bean (Narayana and Narasinga Rao, 1985), cowpea (Giami, 1993), velvet bean (Ahenkora et al., 1999), kernel flour (Akuboret al., 2000), green gram, cowpea, lentil and Bengal gram (Ghavidel and Prakash, 2006), benniseed and Bambara (Yusuf et al., 2008) . Cheftel et al. (1985) reported that WAC of protein can be improved by partial denaturation. Thus the increase in WAC of roasted Morama flour may be due to partial denaturation of proteins. Furthermore, major proteins dissociate into subunits during roasting (Akubor et al., 2000), which might have more binding sites than the native or oligomeric proteins. In addition, gelatinization of carbohydrates and swelling of crude fibre may occur during roasting, leading to increased WAC (Akubor et al., 2000).

This increase in OAC may be attributed to the solubilisation and dissociation of the proteins into subunits and subsequently increasing the number of binding sites (Ghavidel and Prakash, 2006). The higher the moisture content of unroasted Morama flour the higher the OAC (R = 0.835, p = 0.039).

Emulsifying activity and stability

It is known that the emulsification properties of legume flours may result from both soluble and insoluble protein, as well as other components, such as polysaccharides (McWatters and Cherry, 1977; Jitngarmkusol et al., 2008). Protein can emulsify and stabilize the emulsion by decreasing surface tension of the oil droplet and providing electrostatic repulsion on the surface of the oil droplet (Sikorski, 2002; Wong, 1989), while some types of polysaccharides can help stabilize the emulsion by increasing the viscosity of the system (Dickinson, 1994). The emulsifying activity of unroasted Morama flour positively correlated with moisture content (R = 0.0.915, p = 0.011). However, emulsifying activity of roasted Morama flour negatively correlated with protein content (R = -0.848, p = 0.033). The negative correlation of emulsifying activity with protein content implies that the emulsification activity of roasted Morama flour does not only depend on the quantity of protein, but may also rely on protein characteristics, such as its hydrophilic-hydrophobic portion. The enhanced emulsion stability of Morama flour could be due to the unfolding of the protein during heating exposing the hydrophobic residues causing the protein molecules to be better adsorbed on the oil-water interface. In addition, viscosity increase due to enhanced hydration and swelling of starch and non-starch polysaccharides in the heated sample could occur, thereby retarding coalescence (Jitngarmkusol et al., 2008).

pH and protein solubility

The acidity of Morama bean flour was in agreement with the pH values of many legumes flours. The negative correlation of pH of raosted Morama flour with WAC suggests that using roasted Morama flour in a more acid medium may improve its WAC, OAC, emulsifying activity and stability properties.

The positive correlation of unroasted Morama flour protein solubility with WAC, OAC and emulsifying activity suggests that the WAC, OAC and emulsifying activity of unroasted Morama flour may be due to solubilized proteins. A similar relationship has been reported for soybean, groundnut and guar proteins (Yusuf et al., 2008).

Least gelation concentration

The least gelation concentration (4%) of Morama bean flour is very low compared to the 10% reported for soybean flour (Padilla et al, 1996). Roasting had no significant effect on the least gelation concentration. A minimum protein concentration is required for gelation to take place, as the concentration is increased above this minimum, the time required for gelation is reduced (Alfaro, Alvarez, El Kho and Padilla, 2004). Gelation is however not only related to the quantity of protein, but also the type of protein and non-protein components of the flour.

Effect of variety and roasting on the colour of Morama flour

Roasting had a significant effect on the lightness, hue and chroma values of Morama flour. However, the effect on chroma with partial eta squared of less than 0.5 appears to be by chance. Roasting resulted to a decrease in the lightness and chroma value of the flour and an increase in the hue angle. The lower lightness (81.9) and chroma (25.7) values of the roasted flour indicates that the colour of the roasted flour is darker and less saturated than that of the unroasted flour.

Conclusion

Morama bean is longer than Bambara, chickpea, and African bread fruit; but shorter than Jack bean and the Egyptian peanut. In terms of width Morama bean is significantly wider than all the other seeds. Morama bean is thicker than the other seeds except for Egyptian peanut. Morama flour is rich in protein (31.7 - 33.1%), fat (36.4 - 39.0%) and ash (2.9%). Both raw and roasted Morama bean flours are nutritionally valuable sources of protein, oil and minerals. The flours possess good functional properties which can be incorporated into human diets not only as protein supplements, but also as in processed foods such as weaning, baked and soup products. Food processing technologies for exploiting the utilization of Morama bean flours should be promoted.

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