Agric Res J **61** (4): 603-608, *August* 2024
DOI: 10.5958/2395-146X.2024.00074.1

TECHNO-FUNCTIONAL PROPERTIES OF TWO VARIETIES OF MORINGA SEEDS

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ABSTRACT

The understanding of the physical properties of seeds is crucial for the design and optimization of processing equipment and techniques. This study compares the physio-mechanical properties of two varieties of *Moringa oleifera* seeds: a local cultivar and the hybrid K-8. Various physical properties, including seed dimensions (length, width, thickness), arithmetic and geometric mean diameters, 1000-seed weight, sphericity, unit volume, aspect ratio, surface area, colour, bulk density, true density, and porosity, were measured. Additionally, frictional properties such as the angle of repose and coefficients of static friction were also determined. The average length, width, and thickness of the local cultivar seeds were found to be 8.08 mm, 5.55 mm, and 5.05 mm, respectively. In contrast, the hybrid K-8 exhibited slightly larger dimensions, with averages of 10.33 mm, 8.76 mm, and 7.58 mm, respectively. Similarly, the arithmetic and geometric mean diameters for the local cultivar were 6.22 mm and 6.07 mm, respectively, whereas the K-8 had slightly larger values of 8.89 mm and 8.80 mm. Other measured properties were also compared between the two varieties. K-8 exhibited higher water absorption and oil absorption capacities than the local cultivar. However, functional properties such as water solubility index, emulsion activity, emulsion stability, swelling power, and foaming capacity were comparable between both varieties. The superior functional properties of the K-8 suggest that its flour is particularly well-suited for the development of a wide range of food products.

Keywords: Mechanical properties, Physical properties, Seed dimensions, Sphericity

Moringa oleifera is one of the most widely recognized and extensively cultivated species in the Moringaceae family. It is commercially grown across various agro-climatic regions of India and is also found in the wild (Anwar *et al.*, 2007). Known by different names in various parts of the world, it is often referred to as the “drumstick tree” or “horse radish tree,” while in some regions, it is called the “kelor tree” (Anwar and Bhanger, 2003). In the Indian subcontinent, it is commonly known as *Sehjan* while in Punjab it is called *Sohanjna*. India is the largest producer of *Moringa* fruits, with an annual yield of approximately 1.3 million tonnes, cultivated over an area of 38,000 hectares (Pandey *et al.*, 2011). The southern states of Tamil Nadu, Kerala, and Karnataka are the primary regions where *Moringa* is grown in India. All parts of the *Moringa* tree, the leaves, seeds, roots, and flowers, are edible and considered safe for consumption. Fresh *Moringa* seeds can be roasted, ground, or pressed to produce high-quality, non-desiccating oil known as *benoil*.

Moringa seed extracts have demonstrated a protective effect against liver peroxides (Pagadala and Shankar 2020). A comprehensive study examining extracts from various parts of the Moringa plant, including the whole pods, coat, pulp, and seeds, revealed that the seeds exhibited the most significant effect in lowering blood pressure compared to other parts of the plant (Anwar *et al.*, 2007). Additionally, Moringa seed extracts are known to contain specific proteins beneficial for hair and skin care. Active ingredients extracted from the seed oilcake have been identified for potential use in the cosmetics industry. These extracts are particularly effective in combating early skin aging and protecting the skin from environmental damage (Anwar and Bhanger, 2003). Moringa seed oil is increasingly recognized for its potential to replace conventional vegetable oils due to its unique properties and diverse applications.

Once *Moringa* seeds are harvested and collected, they must be cleaned to remove foreign matter. For further processing, it is crucial to determine the physical and mechanical properties of the seeds. This knowledge is particularly valuable to agricultural engineers, as it helps balance the complexities of modern processing technologies with the growing economic significance of *Moringa*-based food products. A review of the existing literature reveals that limited research has been conducted on the measurement of the physio-mechanical and functional properties of *Moringa* seeds. Therefore, the aim of this study is to investigate the techno-functional properties of two varieties of *Moringa* seeds and to explore their potential applications in food product development.

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Date of receipt: 14.08.2023, Date of acceptance: 18.07.2024

MATERIALS AND METHODS

The K-8 variety of *Moringa* seeds was obtained from an authorized seed supplier in Dehradun, while the local cultivar was sourced from the campus of Punjab Agricultural University in Ludhiana. The seeds were meticulously cleaned by hand to remove any foreign particles, then sun-dried to reduce moisture content. After drying, the seeds were stored at room temperature for further analysis.

Geometric properties

For shape and size measurements, 20 *Moringa* seeds were randomly selected, and a digital caliper (with a precision of 0.01 mm) was used to measure each seed's length, breadth, and thickness. The longest dimension was recorded as the seed length, while the thickness was measured as the longest dimension perpendicular to the length-width plane. The width was considered the longest dimension perpendicular to the length. This measurement approach follows the method outlined by Tabatabaeefar (2003). The length, breadth and width values were used to find geometric and arithmetic mean diameters, sphericity, unit volume, aspect ratio and surface area using the following formulas:

Arithmetic mean diameter (D_a) = (L+W+T)/3

Geometric mean diameter (D_g) = $(LWT)^{1/3}$

Sphericity(Φ) = (D_g/L)x100

Surface Area (S) = πD_g^2

Aspect Ratio (R_a) = (W/L)

where, L = length, w = width, T = thickness.

Gravimetric properties

In order to calculate bulk density, a 30 ml cylinder was filled with seeds poured from a specific height, followed by tapping and then weighing the sample. It was calculated as:

Bulk Density = Weight of sample/Volume occupied

The true density of the seeds was determined using the water displacement method. A measuring cylinder containing 20 mL of water was filled with a known quantity of the *Moringa* seed sample. The true seed volume was then calculated by measuring the rise in water level caused by the displacement of the seeds. This volume change directly correlates to the true volume of the seeds. The true density was calculated as:

True density = Weight of the sample/ Volume of water displaced

The values of bulk density and true density were used to calculate porosity of the seed (Mohsenin, 1986).

Porosity = (True Density - Bulk Density/ True Density) × 100

A digital electronic balance with a precision of 0.01 g was used to calculate the weight of 1000 seeds. A random sample of 100 seeds was weighed, and the resulting weight was then multiplied by 10 to obtain the total weight for 1000 seeds.

Frictional properties

The cylindrical pipe method was employed to calculate the angle of repose of *Moringa oleifera* seeds. In this method, the seeds were poured into a bottomless cylinder, which was then gradually raised to allow the seeds to form a cone-shaped pile. The angle of repose was determined based on the height and radius of the resulting cone (Abubakar *et al*., 2019). The height and radius of this cone was measured and the angle of repose was computed by the following equation:

$\theta = \tan^{-1}\dfrac{h}{r}$, where h = height of the heap, r = radius of base.

The coefficient of static friction of *Moringa* seeds was measured using various surfaces, including aluminum, plywood, galvanized iron, and mild steel. A cylinder with dimensions of 75 mm in diameter and 50 mm in height was placed on an adjustable tilting plate, facing the test surface. A sample weighing 150 g was deposited inside the cylinder. To prevent the cylinder from touching the surface, it was slightly lifted. The surface was then gradually tilted until the cylinder just began to slide. The tilt angle at which this occurred was measured using a graduated scale (Karimi *et al.*, 2009).

Coefficient of static friction (μ) = tan θ, where θ is tilt angle.

Mechanical properties

A Texture Analyzer was used to determine the mechanical parameters, including rupture force and energy absorbed by the *Moringa* seeds. Each individual seed was placed between the probe and the bottom plate of the analyzer and subjected to compression until rupture occurred. The point of rupture, indicated by the bio-yield point (N) on the force-deformation curve, was recorded. The amount of energy absorbed by the seed (in kJ) was calculated using the method outlined by Singh *et al.* (2012).

Functional properties

To determine the functional properties, manually dehulled *Moringa* seeds were first dried in a hot air oven at 50 ± 2°C for 4 hours. The dried seeds were then ground and sieved using a 36 BSS mesh sieve. Water and oil absorption capacities were assessed by adding 10 mL of water and soybean oil, respectively, to 1 g of flour. The mixtures were then centrifuged at 3000 rpm for 15 minutes. After centrifugation, the supernatant was separated and collected in pre-weighed Petri dishes, which were subsequently oven-dried to measure the soluble solids. The residual weight was used to calculate the water solubility index. Water absorption capacity (WAC), Water Solubility Index (WSI) and Oil Absorption Capacity (OAC) were calculated as per methods given by Kaur *et al.* (2017), according to the given formulas:

$$\text{WAC (g/g)} = \frac{\text{weight of pellet}}{\text{weight of sample}}$$

$$\text{WSI (\%)} = \frac{\text{weight of dissolved solids in supernatant}}{\text{weight of sample}} \times 100$$

$$\text{OAC (g/g)} = \frac{\text{weight of pellet}}{\text{weight of sample}}$$

Foaming capacity was determined by taking a 10 g flour sample and blending it with 100 mL of distilled water using a hand blender for 2 minutes. The volume of foam generated was measured to assess the foaming capacity of the *Moringa* seed flour. Foaming capacity was calculated as:

$$\text{Foaming Capacity} = \frac{\text{final volume after mixing} - \text{initial volume}}{\text{initial volume}} \times 100$$

About 3 g of the sample was dispersed in 30 mL of distilled water and placed in a water bath at 80°C for 30 minutes. After the sample cooled to room temperature, it was subjected to centrifugation at 3000 rpm for 15 minutes. The supernatant was carefully removed, and the final weight of the paste was recorded (Lin *et al.*, 1974). The swelling power was calculated as:

$$\text{Swelling power (g/g)} = \frac{\text{weight of pellet}}{\text{weight of sample}}$$

A pre-weighed centrifuge tube containing 1 g of the sample was filled with 10 mL of distilled water and 10 mL of soybean oil. The mixture was then maintained at 30°C for 30 minutes. After this, the sample was centrifuged at 3000 rpm for 15 minutes. The percentage of emulsion activity was calculated by measuring the ratio of the emulsion layer height to the total height of the mixture (Yasumatsu *et al.*, 1972).

$$\text{Emulsion activity (\%)} = \frac{\text{Height of emulsion layer}}{\text{Height of total mixture}} \times 100$$

To test the emulsion stability, the emulsion in the centrifuge tube was heated for 30 minutes at 80°C in a water bath. After heating, the tube was cooled for approximately 15 minutes under running tap water. This process allowed for the assessment of the emulsion's ability to maintain its structure under heat.

$$\text{Emulsion stability (\%)} = \frac{\text{Height of emulsion after heating}}{\text{Height of total mixture}} \times 100$$

RESULTS AND DISCUSSION

The dimensional properties of Moringa seeds (Fig 1a and 1b) are presented in Table 1. The length, width, and thickness of the seeds were measured to be 8.08 ± 0.93 mm, 5.55 ± 0.42 mm, and 5.05 ± 0.79 mm, respectively. The arithmetic and geometric mean diameters were determined to be 6.223 ± 0.52 mm and 6.071 ± 0.52 mm, respectively. Additionally, the aspect ratio was found to be 0.698, the sphericity was 75.178%, and the unit volume was 0.957 mm³. These findings are consistent with those reported by Ajav and Fakayode (2013), who investigated the physical properties of *Moringa oleifera* seeds for the design of an oil expeller.

Table 1. Comparative dimensional properties of moringa seeds (Local vs. K-8)

Physical property	Unit	Cultivar	
		Local cultivar	K-8
Length	mm	8.08 ± 0.209^{b}	10.33 ± 0.241^{a}
Width	mm	5.55 ± 0.095^{b}	8.76 ± 0.171^{a}
Thickness	mm	5.05 ± 0.179^{b}	7.58 ± 0.151^{a}
Arithmetic mean diameter (Da)	mm	6.223 ± 0.118^{b}	8.89 ± 0.118^{a}
Geometric mean diameter (Dg)	mm	6.071 ± 0.117^{b}	8.80 ± 0.113^{a}
Sphericity	%	75.64 ± 1.394^{b}	85.71 ± 1.491^{a}
Unit volume	mm^3	0.957 ± 0.056^{b}	2.88 ± 0.111^{a}
Surface area	mm^2	116.54 ± 4.503^{b}	243.83 ± 6.273^{a}
Aspect ratio	-	0.70 ± 0.026^{b}	0.85 ± 0.020^{a}

Within rows, means±SE (n=10) followed by different alphabets differ significantly at $p \leq 0.05$

(a) (b)

Fig. 1. (a) Local cultivar, (b) K-8

The results of the dimensional analysis revealed that the K-8 variety exhibits a larger size, with its length, width, and thickness being significantly ($p≤0.05$) greater than those of the local cultivar. Consequently, the surface area of the K-8 variety (243.83 mm^2) was also significantly higher.

The gravimetric properties indicated no significant differences between the two varieties in terms of bulk density and porosity. However, the local cultivar exhibited a significantly higher true density compared to the K-8 variety, while the 1000-seed weight was found to be greater for the K-8 variety.

The angle of repose showed no significant difference between the two varieties. However, the coefficient of friction was higher for the K-8 variety on plywood (0.46) and aluminum (0.40) surfaces, while no significant difference was observed between the varieties on mild steel.

The texture analysis (Fig. 2a and 2b) revealed that the hardness of the K-8 variety was higher, as indicated by the rupture force values, which were significantly different from those of the local cultivar. Additionally, the energy absorbed also showed significant differences between the two varieties.

The functional properties of Moringa seed flour revealed that the K-8 variety exhibited significantly ($p≤0.05$) higher water and oil absorption capacities compared to the local cultivar. However, other functional properties, including water solubility index, emulsion activity, emulsion stability, swelling power, and foaming capacity, were similar between the two varieties. Water absorption capacity (WAC) refers to the flour's ability to absorb moisture and achieve the desired consistency in various food products. Both excessively high and

Table 2. Gravimetric properties of moringa seeds from local and K-8 cultivar

Physical property	Unit	Cultivar	
		Local cultivar	K-8
Bulk density	g/ml	0.468±0.004[a]	0.436±0.011[a]
True density	g/ml	0.933±0.004[a]	0.886±0.004[b]
Porosity	%	49.854±0.546[a]	50.833±1.220[a]
1000 seed weight	g	101.7±3.10[b]	195.4±4.22[a]

Within rows, means±SE (n=5) followed by different alphabets differ significantly at $p≤0.05$

Table 3. Frictional properties of moringa seed from local and K-8 cultivar

Physical property	Cultivar	
	Local cultivar	K-8
Angle of repose	23.67±0.882[a]	25.67±0.882[a]
Coefficient of static friction on:		
i. Plywood	0.58±0.009[a]	0.46±0.009[b]
ii. Aluminium	0.45±0.006[a]	0.38±0.009[b]
iii. Galvanisediron	0.55±0.012[a]	0.40±0.015[b]
iv. Mildsteel	0.51±0.015[a]	0.46±0.012[a]

Within rows, means±SE (n=5) followed by different alphabets differ significantly at $p≤0.05$

Table 4. Mechanical properties of moringa seed from local and K-8 cultivar

Parameter	Unit	Cultivar	
		Local cultivar	K-8
Rupture force	N	3784.43±52.296^{b}	6590.40±142.042^{a}
Energy absorbed	kJ	15096.82±238.170^{b}	31152.05±122.983^{a}

Within rows, means±SE (n=10) followed by different alphabets differ significantly at *p≤0.05*

Table 5. Functional properties of moringa seeds from local and K-8 cultivar

Parameter	Unit	Cultivar	
		Local cultivar	K-8
WAC	g/g	1.56±0.068^{b}	1.86±0.015^{a}
OAC	g/g	1.93±0.031^{b}	2.08±0.012^{a}
WSI	%	25.09±0.312^{a}	26.32±0.645^{a}
Emulsion activity	%	26.60±0.681^{a}	25.11±1.507^{a}
Emulsion stability	%	15.467±0.055^{a}	17.213±0.041^{a}
Swelling power	g/g	1.51±0.882^{a}	1.58±0.577^{a}
Foaming capacity	%	8.67±.882^{a}	10±0.577^{a}

Within rows, means±SE (n=3) followed by different alphabets differ significantly at *p≤0.05*

low water absorption can negatively impact the quality characteristics of food products. This hydration is facilitated by the hydrophilic interactions and hydrogen bonding of starch and protein molecules. The lower WAC of the local cultivar may indicate a lower presence of polar amino acids in the flour, whereas the K-8 variety likely contains more hydrophilic components, such as polysaccharides. This property is particularly relevant for products involving dough handling (Iwe *et al*., 2016). K-8's higher WAC value (1.86 g/g) supports the increased viscosity and thickening effect of the flour.

Oil absorption capacity measures the ability of the non-polar side chains of proteins to bind fat or oil. This property contributes to the pleasant mouthfeel and flavour transmission in the final product. It is particularly relevant in foods such as pastries, whipped toppings, and sausages, where it enhances the sensory properties (Chandra and Singh, 2013). The foaming capacity of the flour also plays a crucial role in improving smoothness and palatability by facilitating the volatilization of flavours in the foam. Therefore, understanding foaming capacity is important. While K-8 exhibited a higher foaming capacity (10%), no significant difference was observed between the two varieties.

Batter emulsion activity and stability are essential for the production of specific products, such as beverages and meat analogues (Zayas, 1997). Both the local cultivar and K-8 exhibited comparable emulsion activity and stability. During food preparation, the proteins interact with the water and/or oil present, contributing to the texture and flavour of the final product.

CONCLUSION

The results indicated that the K-8 variety had bolder grains and a higher 1000-seed weight compared to the local cultivar, which was more friable, as evidenced by its lower rupture force and energy absorbed values. Techno-functional properties play a crucial role in food processing, influencing both manufacturing efficiency

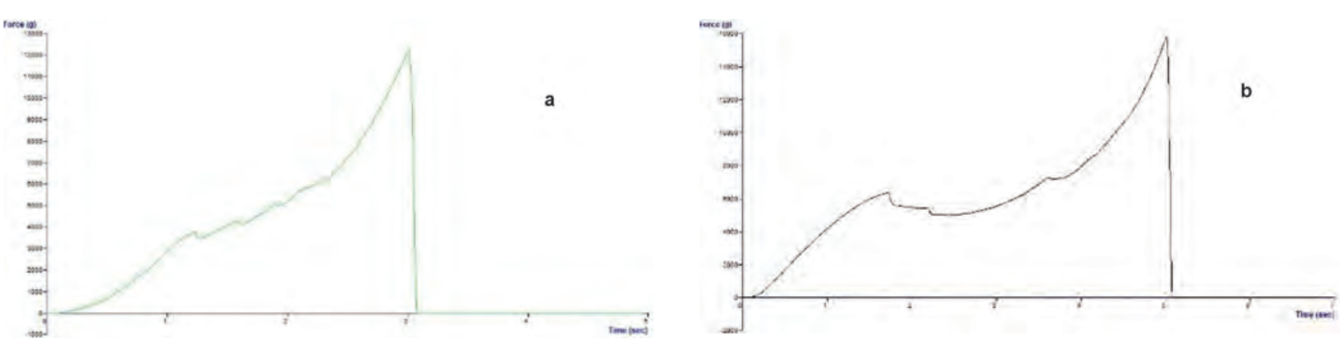

Fig. 2. Texture analysis of (a) local cultivar, (b) K-8

and product quality. Water-binding capacity, for instance, determines how much moisture food products retain during processing and storage, which is essential for maintaining freshness, preventing dehydration, and extending shelf life. Emulsifiers and stabilizers, which are key techno-functional ingredients, help create and maintain stable emulsions and suspensions in food products. The superior techno-functional properties of K-8 variety flour make it suitable for the development of various food products. Further research is needed to fully validate its potential applications.

Conflicts of interest: Authors declare that they have no conflicts of interest.

Authors' contribution

Conceptualization of research work and designing of experiments (D, JR); Execution of field/lab experiments and data collection (D, JR); Analysis of data andinterpretation (D, JR),Preparation ofmanuscript (D, JR).

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