



Research Article

Comparative evaluation of the physical characteristics of three sesame (*Sesamum indicum* L.) varieties in Vietnam

Le Pham Tan Quoc*, Pham My Hao, Pham Thi Quyen, Lam Bach Bao Phuong

Institute of Biotechnology and Food Technology, Industrial University of Ho Chi Minh City, Ho Chi Minh City 700000, Vietnam

Abstract This study investigated the seed morphology and selected physical properties of three Vietnamese sesame (*Sesamum indicum* L.) varieties: white sesame (WS), yellow sesame (YS), and black sesame (BS). Visual analysis revealed distinct seed color differences among the varieties: WS with dazzling white seeds, YS with beige to light brown seeds, and BS with deep black seeds, while maintaining similar elongated seed shapes. Moisture content varied significantly, with WS having the lowest value (2.11%), followed by YS (3.13%) and BS (4.61%). Physical properties such as 1,000-seed weight, bulk, and particle density also differed significantly. WS exhibited the highest particle density (798.11 g/cm³), while YS had the lowest (659.62 g/cm³). Dimensional parameters (length, width, and thickness) and derived values like equivalent diameter, surface area, and volume showed notable variations. BS had the largest surface area and volume, along with higher sphericity (59.08%) than WS (52.24%). The friction coefficient and angle of repose were also the highest in YS and BS, suggesting varietal differences in flowability. The findings provide fundamental physical and morphological insights that are essential for seed classification, handling, and processing design.



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Keywords physical properties, sesame, oil, varieties

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*Corresponding author

Le Pham Tan Quoc
Tel: +84-28-38940 390-666/555/891

E-mail: lephamtanquoc@iuh.edu.vn

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1. Introduction

Sesame seeds (*Sesamum indicum* L.), a small but nutritious oilseed, have long been used in many culinary and traditional medicine cultures around the world (Elleuch et al., 2011). In Vietnam, sesame is widely grown in the Mekong Delta, such as An Giang, Dong Thap, and Nghe An, and has become an important ingredient in food processing (sesame salt, sesame candy, and sesame oil) as well as in traditional medicine. In traditional medicine, sesame is used to support the treatment of various conditions, such as constipation, hypertension, hair loss, fatigue, and to enhance liver and kidney function due to its antioxidant and anti-inflammatory properties (Mili et al., 2021; Quang et al., 2024).

Sesame oil stands out for its high oxidative stability, even though it consists of about 85% unsaturated fatty acids-compounds typically prone to oxidation (El-Beltagi et al., 2022). The protein in sesame (18-25%) has a high biological value, containing all essential amino acids (Mustafa and Hüseyin, 2023). In particular, sesame seeds are rich in unique antioxidant compounds such as sesamin, sesamol, and sesamol, along with many important minerals such as calcium, magnesium, iron, and zinc (Majdalawieh et al., 2017). Due to their beneficial constituents, sesame seeds are extensively used in food products, but also in pharmaceutical and cosmetic formulations. In the culinary sector, sesame is an essential component of various traditional Vietnamese foods such as sesame salt, sesame candy, sesame sweet soup, and sesame rice paper. It is also a primary

ingredient in modern functional products, including premium sesame oil, sesame-based milk, and nutritional powders (Asghar et al., 2014). In the pharmaceutical field, sesame is employed in the formulation of cardiovascular supplements, laxatives, and calcium-enriched products. In addition, the cosmetics industry incorporates sesame oil into skincare and anti-aging products, leveraging its strong antioxidant capacity (Huang et al., 2022).

Although Vietnam is considered a developing sesame-producing country (Pham et al., 2010), there is a notable lack of systematic studies on the physical properties of native sesame varieties-key parameters for the optimization of postharvest processing, storage, and equipment design. Existing research has predominantly focused on cultivation techniques, varietal traits, genetic diversity, or nutritional composition, with limited attention to physical attributes (e.g., flowability, hardness, dehulling efficiency) and physicochemical changes such as oxidative stability or water activity during storage (Binh and Lieu, 2016). This gap hinders the development of optimized technologies tailored to local production and post-harvest handling systems.

Therefore, this study aims to characterize the morphological and physical properties of Vietnamese sesame seeds, thereby addressing the current knowledge gap and providing a foundation for improving domestic processing technologies. The results may also reveal distinct traits compared to foreign cultivars, supporting the development of value-added sesame-based products tailored to local conditions.

2. Materials and methods

2.1. Materials

The three sesame (*Sesamum indicum* L.) varieties employed in this study were “Me Trang” (WS), “Me Den” (BS), and “Me Vang” (YS) from Dien Bien province, Vietnam. To determine their physical and chemical qualities, the seed samples were carefully chosen to make sure they were undamaged, free of contaminants, and stored in compliance with the preparation procedure.

2.2. Determination of the moisture content of sesame seed

WS, YS, and BS sesame seed samples were tested for moisture content using a halogen moisture balance (Sartorius,

Göttingen, Germany). The sesame samples were ground into a fine powder before measurement. After that, roughly 2 g of the ground material were precisely weighed and put into the apparatus. It was then dried at 105°C until it achieved a constant weight (Fridh et al., 2014).

2.3. Determination of the mass of 1,000 seeds of sesame seed

The mass of 1,000 seeds can be calculated using a modified method described by Hao et al. (2025). An enhanced technique is used to estimate the mass of 1,000 seeds by selecting 200 representative seeds at random, calculating their masses, and then using proportionate multiplication to infer the mass of 1,000 seeds. The following formula can be used to get a mass of 1,000 seeds.

$$M_{1000} = \frac{M_{\text{sample}}}{N} \times 1,000$$

where:

M_{1000} : mass of 1,000 grains (g)

M_{sample} : mass of sample (g)

N: number of grains

2.4. Determination of the bulk density of sesame seed

Determining bulk density necessitates standardization of the particle pouring method, as described by Quoc et al. (2021). This method may be calibrated in the following ways: Pour the particles into a cylindrical container with a known volume, about 1 cm above the mouth. Use a ruler to level off any excess particles at the container's mouth. Then, determine the mass of the particles in the container. The calculation was done using the formula:

$$\rho_b = M / V$$

where:

ρ_b : bulk density (g/cm³)

M: particle mass in the container (g)

V: Volume of container (cm³)

2.5. Determination of the size of the sesame seed

Use a pair of electronic Vernier callipers (Mitutoyo, model

CD-15APX, Kawasaki, Japan) to measure the seed's length (L), width (W), and thickness (T) to an accuracy of 0.05 mm.

2.6. Determination of the sphericity of sesame seed

The sphericity, which ranges from 0 to 1, is a measurement of the particles' size in proportion to a sphere, with a sphere being the optimum shape (Ixtaina et al., 2008). As the value gets closer to 1, the particle shape becomes more spherical. The equivalent geometric diameter (ED) is used to compute the sphericity (S). The following formula is used to determine the results:

$$ED = (L \times W \times T)^{\frac{1}{3}}$$

$$S = \frac{ED}{L} \times 100$$

where:

ED: equivalent geometric diameter (mm)

S: sphericity (%)

W: width (mm)

L: length (mm)

T: thickness (mm)

2.7. Determination of the surface area and volume of sesame seeds

The surface area and volume of the seed described by Dursun et al. (2006) were calculated by using the following equations:

$$S = \pi \times ED^2$$

$$V = \frac{\pi \times ED^3}{6}$$

where:

S: surface area of seed (mm²)

V: volume of seed (mm³)

2.8. Determination of the angle of repose of sesame seeds

On a level surface, position the cylindrical hollow tube with both ends vertically, then fill it with particles until it

reaches the mouth. Pulling the tube up gently will cause the particles to glide against one another and create a natural angle of repose. The following formula is used to calculate the gathered findings (Ileleji and Zhou, 2008):

$$\theta_r = \tan^{-1} (h/r)$$

where:

θ_r : angle of repose (°)

h: height of the grain pile (cm)

r: radius of the grain pile (cm)

2.9. Determination of the coefficient of friction of sesame seed

Eboibi and Urugu (2018) outlined the frictional properties, adjusting for the experimental conditions. The behavior of sesame seeds was examined on various sliding surfaces, including steel. Ten seeds from each type (WS, YS, and BS) were positioned on a controllable sliding platform set horizontally. The platform was elevated until the first seed began to slide. Each seed had a specific angle noted where sliding commenced. The tests proceeded until all remaining seeds were seen sliding down. The sliding angle was recorded, and the coefficient of friction was calculated by using the following formula:

$$\mu = \tan(\theta)$$

where:

μ : coefficient of friction

θ : sliding angle (°)

2.10. Statistical analysis

Statistical analyses were performed using STATGRAPHICS Centurion XV software, version 15.1.02 (StatPoint Technologies, Inc., Warrenton, Virginia, USA). The experiment was conducted with ten replications per treatment to ensure statistical reliability. Analysis of variance (ANOVA) and mean comparisons were carried out at a 95% confidence level ($p < 0.05$) using the least significant difference (LSD) method. Results are expressed as mean $\pm$ standard deviation (SD).

3. Results and discussion

3.1. Seed morphology of three sesame seed varieties

When viewed with the naked eye, one can easily see the distinct color differences between the three sesame varieties: WS has the lightest color, followed by YS with a light beige/brown tone, and finally BS with the darkest color (Fig. 1). These visual observations are completely consistent with the measured color values (Table 1). Specifically, the L^* (lightness) value accurately reflects the lightness and darkness perceived by the naked eye: WS has the highest L^* value (75.48), confirming its outstanding brightness, while BS has the lowest L^* value (15.05), representing a deep black color. YS (51.95) falls in the middle, exactly as we see in the intermediate color. The a^* (red-green) and b^* (yellow-blue) values also provide more detailed information about the color shades that the naked eye can distinguish, such as the reddish tendency of BS ($a^*=1.58$) or the yellowish hue of YS ($b^*=24.42$). Thus, the color system provides an objective quantitative method to confirm and accurately describe the color differences we observe with the naked eye.

3.2. Moisture content of three sesame seed varieties

The results of moisture analysis showed significant differences among the three sesame varieties (Table 2). The WS exhibited the lowest moisture content (2.11%), followed by the YS with 3.13%, and the BS had the highest moisture content (4.61%). This trend suggests that there are differences

Table 1. Color parameters of three sesame seed varieties

Color parameters	WS ¹⁾	YS	BS
L^*	75.48±0.37 ^{2)c3)}	51.95±0.37 ^b	15.05±0.67 ^a
a^*	0.86±1.05 ^b	9.79±0.88 ^c	-1.46 ±0.17 ^a
b^*	20.04±2.38 ^b	24.42±0.62 ^c	3.32±0.44 ^a

¹⁾WS, Me Trang; YS, Me Vang; BS, Me Den from Dien Bien province, Vietnam.

²⁾All values are mean±SD (n=10).

³⁾Different superscript letters (^{a-c}) in the same rows indicate significant differences ($p<0.05$) between samples.

Table 2. Moisture content of three sesame seed varieties

Sesame varieties	WS ¹⁾	YS	BS
Moisture (%)	2.11±0.32 ^{2)a3)}	3.13±0.48 ^b	4.61±0.54 ^c

¹⁾WS, Me Trang; YS, Me Vang; BS, Me Den from Dien Bien province, Vietnam.

²⁾All values are mean±SD (n=10).

³⁾Different superscript letters (^{a-c}) in the same rows indicate significant differences ($p<0.05$) between samples.

in water retention capacity or natural moisture loss rate among these sesame varieties during growth and postharvest.

When compared with sesame from other regions, the moisture content of Vietnamese sesame in this study was in the same or lower range. Specifically, Brazilian sesame had a moisture content of 5.46–6.60% (Araujo et al., 2018), while Iranian sesame had a moisture content of 2.7–4.7% (Karem et al., 2022). Compared with other seeds, the moisture content of all three sesame varieties was significantly lower than that of black and white chia seeds (6.6–7.2%) and haricot beans (Ixtaina et al., 2008; Wodajo et al., 2021).

This difference reflects the diversity in composition and



Fig. 1. Three sesame seed varieties. (A), black sesame (BS, Me Den); (B) yellow sesame (YS, Me Vang); (C), white sesame (WS, Me Trang).

physical structure among agricultural products. Sesame seeds, as typical oilseeds, generally contain lower moisture content (often below 8%) compared to carbohydrate- and protein-rich seeds such as chia and common beans (Eboibi and Urugu, 2018; Ixtaina et al., 2008). The low moisture content in sesame plays a critical role in prolonging shelf life by limiting hydrolytic and oxidative reactions, as well as inhibiting the activity of spoilage-related enzymes such as lipase and peroxidase, which are involved in rancidity and quality deterioration (Elleuch et al., 2011). Additionally, reduced moisture inhibits microbial growth, particularly mold and bacterial contamination, thus maintaining product safety during storage. These significant differences in moisture content between sesame and other seeds also imply distinct storage requirements and processing strategies, such as drying temperature, packaging material, and humidity control, to optimize postharvest handling and preserve quality for each type of seed (Kibar and Ozturk, 2008).

3.3. Weight of 1,000 seeds and bulk density of three sesame seed varieties

Table 3 presents the mass and density characteristics of sesame seeds of three different varieties (WS, YS, BS). The results showed that the 1,000-seed mass of sesame seeds differed significantly among the cultivars, with WS (3.20 g), YS (3.12 g), and BS (3.16 g). When compared with studies from other regions of the world, the 1,000-seed mass of Vietnamese sesame cultivars in this study (3.12-3.20 g) was in the same range as that of Iranian sesame seeds (2.9-4 g/1,000 seeds) reported by Soureshjani et al. (2019). However, these values were slightly higher than those of Brazilian sesame seeds (2.4-2.8 g/1,000 seeds) reported by Araujo et al. (2018) and Nigerian sesame seeds (2.03 g/1,000 seeds)

Table 3. Weight of 1,000 seeds and bulk density of three sesame seed varieties

Sesame varieties	WS ¹⁾	YS	BS
Weight of 1,000 seeds (g)	3.20±0.02 ^{2)c3)}	3.12±0.03 ^a	3.16±0.01 ^b
Bulk density (g/cm ³)	0.9525±0.0134 ^b	0.9170±0.0113 ^a	1.0108±0.0141 ^c

¹⁾WS, Me Trang; YS, Me Vang; BS, Me Den from Dien Bien province, Vietnam.

²⁾All values are mean±SD (n=10).

³⁾Different superscript letters (^{a-c}) in the same rows indicate significant differences (p<0.05) between samples.

according to the study of Tunde-Akintunde and Akintunde (2004). This suggests that the Vietnamese sesame varieties studied may have larger seed sizes than some sesame varieties from Brazil and Nigeria but are still within the general size range of sesame seeds. In addition, the mass of our 1,000 sesame seeds is also significantly larger than that of chia seeds (1.263-1.387 g/1,000 seeds), confirming the distinct difference in seed size and mass between the two plants (Ixtaina et al., 2008).

The bulk density of three sesame varieties in this study (WS: 0.9525 g/cm³, YS: 0.9170 g/cm³, and BS: 1.0108 g/cm³) showed significant differences among varieties, with BS having the highest bulk density, implying a tighter packing capacity. When compared to Nigerian sesame, the bulk density of Vietnamese sesame (0.9170-1.0108 g/cm³) was also significantly higher than the value of 0.580 g/cm³ (Tunde-Akintunde and Akintunde, 2004).

The observed variations in grain weight and density among Vietnamese sesame varieties, as well as when compared with other oilseeds such as chia, Brazilian sesame, and Nigerian sesame, highlight considerable intra- and interspecific diversity in physical traits (Araujo et al., 2018; Tunde-Akintunde and Akintunde, 2004). These differences likely reflect variations in internal structure, seed coat thickness, and oil/protein composition, which in turn affect processing characteristics such as dehulling efficiency, drying behavior, and storage performance. Understanding these properties is crucial for selecting appropriate varieties for specific industrial applications, including oil extraction, roasting, and incorporation into functional food formulations.

3.4. Size and physical properties of three sesame seed varieties

Table 4 shows the variation in physical characteristics among the three sesame cultivars (WS, YS, and BS). In terms of geometric dimensions, the seed length (L) varied from 2.80 to 3.12 mm (from YS to WS). The width (W) ranged from 1.67 to 1.83 mm (from BS to YS), while the seed thickness (T) ranged from 0.69 to 0.83 mm (from WS to BS). However, these observed differences were not significant. For the equivalent geometric diameter (ED), with the lowest value in WS (1.63 mm) and the highest in BS (1.79 mm). When compared with previous studies, the Vietnamese sesame varieties showed similar or slightly larger sizes.

Table 4. Size and physical properties of three sesame seed varieties

Physical properties	WS ¹⁾	YS	BS
Length (L, mm)	3.12±0.15 ^{2)a3)}	2.80±0.23 ^a	3.03±0.10 ^a
Width (W, mm)	1.82±0.10 ^b	1.83±0.13 ^b	1.67±0.10 ^a
Thickness (T, mm)	0.69±0.08 ^a	0.75±0.06 ^a	0.83±0.11 ^a
Equivalent diameter (ED, mm)	1.63±0.03 ^a	1.68±0.02 ^b	1.79±0.08 ^c
Surface area (S, mm ²)	8.35±0.31 ^a	8.87±0.21 ^b	10.06±0.90 ^c
Volume (V, mm ³)	2.27±0.13 ^a	2.48±0.09 ^b	3.00±0.40 ^c
Sphericity (%)	52.24±0.49 ^a	60.74±0.84 ^b	59.08±0.46 ^b
Angle of repose (θ_r , °)	19.46±0.15 ^a	24.67±0.58 ^b	23.67±0.63 ^b
Sliding angle (θ , °)	21.62±1.53 ^a	28.90±0.13 ^b	27.08±1.86 ^b
Coefficient of friction (μ)	0.39±0.03 ^a	0.55±0.01 ^b	0.51±0.04 ^b

¹⁾WS, Me Trang; YS, Me Vang; BS, Me Den from Dien Bien province, Vietnam.

²⁾All values are mean±SD (n=10).

³⁾Different superscript letters ("a") in the same rows indicate significant differences ($p < 0.05$) between samples.

Specifically, the length (3.019-3.074 mm), width (1.844-1.935 mm), and thickness (0.724-0.771 mm) of Iranian sesame seeds are according to the report of Darvishi (2012). In comparison, the ED of Vietnamese sesame varieties (ranging from 1.63 to 1.79 mm) is generally larger than that of Nigerian sesame (ED=1.56 mm) (Tunde-Akintunde and Akintunde, 2004). However, the ED of Vietnamese sesame is equivalent to that of Brazilian sesame (ED=1.65 mm) (Araujo et al., 2018). In contrast, the diameter of Iranian sesame (1.589-1.659 mm) is smaller than that of Vietnamese sesame varieties (Darvishi, 2012).

The surface area and volume of Vietnamese sesame varieties showed a close correlation with ED. The BS variety had the largest ED (1.79 mm) and the largest surface area (10.06 mm²), and volume (3.00 mm³). In contrast, WS with the smallest ED (1.63 mm) had the lowest corresponding values (8.35 mm² and 2.27 mm³). In comparison, the surface area and volume values of Vietnamese sesame (S: 8.35-10.06 mm², V: 2.27-3.00 mm³) were significantly larger than those of Nigeria sesame (S: 7.8 mm², V: 1.67 mm³) (Tunde-Akintunde and Akintunde, 2004). This suggests that Vietnamese sesame has a larger overall size and higher physical mass per seed than some sesame varieties from other regions.

In terms of sphericity, Vietnamese sesame varieties (52.24-60.74%) show diversity. This value is comparable to that of Nigerian sesame (56%) (Tunde-Akintunde and Akintunde,

2004) and Brazilian sesame (58.8%) (Araujo et al., 2018). However, compared to Turkish sesame (42.36-43.84%), according to Yilmaz et al. (2012), Vietnamese sesame varieties have significantly higher sphericity. When compared to other seeds, the sphericity of Vietnamese sesame is lower than that of chia seeds (62.2-66.0%) but is similar to the range of 57.32-57.39% in faba bean seeds (Dilmac et al., 2016; Ixtaina et al., 2008). This relatively moderate sphericity suggests that sesame seeds may exhibit intermediate flowability and packing behavior during handling and storage. Seeds with lower sphericity tend to have more irregular shapes, which can influence friction, compaction, and equipment calibration in postharvest processing (Kibar and Ozturk, 2008). This difference reflects the morphological characteristics specific to each variety and may affect the flowability of the seeds.

For flowability-related properties, all Vietnamese sesame varieties had an angle of repose (θ_r) below 30° (WS: 19.46°, YS: 24.67°, BS: 23.67°), which was classified as having good free-flowing ability according to the classification of Ileleji and Zhou (2008). These values were similar to the angle of repose of Turkish sesame (20.03-27.05°) according to Yilmaz et al. (2012) but significantly lower than that of Nigerian sesame (32°) according to the study of Tunde-Akintunde and Akintunde (2004), indicating that the flowability of Vietnamese sesame was better.

The sliding angle of Vietnamese sesame varieties on a steel surface ranges from 21.62° (WS) to 28.90° (YS), showing the difference in friction between sesame seeds and the material surface. The coefficient of friction (μ) ranges from 0.39 (WS) to 0.55 (YS). Notably, the coefficient of friction on glass for Nigerian sesame is also reported as 0.39 (Tunde-Akintunde and Akintunde, 2004), which is comparable to that of the WS variety. Similarly, Turkish sesame exhibits a coefficient of friction on galvanized steel ranging from 0.45 to 0.46 (Yilmaz et al., 2012), which is higher than that of WS but closely matches those of YS and BS. These similarities suggest that the frictional properties of sesame seeds can vary depending on both variety and contact surface, a factor that plays a critical role in the design of the equipment for handling and storage.

In summary, the remarkable differences in physical properties between Vietnamese sesame varieties and those in other studies indicate a diversity in physical properties. These properties are important, as they can influence important

technological properties such as water absorption, germination rate, and efficiency in processing, storage, and transportation.

4. Conclusions

The morphological and physical characterization of three Vietnamese sesame varieties revealed distinct varietal differences, particularly in seed color, moisture content, and density-related properties. White sesame had the lowest moisture content and highest particle density, suggesting better post-harvest drying efficiency and denser internal structure. In contrast, black sesame showed the highest moisture content and volumetric properties, indicating a potentially more porous structure. Differences in seed length, sphericity, and surface area among varieties also imply functional diversity in processing behavior. Overall, these insights contribute to a better understanding of the varietal characteristics of sesame seeds and can guide cultivar selection for specific agricultural, industrial, and nutritional purposes. Therefore, in-depth research on the properties of sesame seeds combined with appropriate agricultural policies can improve productivity and quality. This will bring positive impacts to the sesame processing industry in Vietnam.

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Conflict of interests

The authors declare no potential conflicts of interest.

Author contributions

Conceptualization: Quoc LPT. Methodology: Quoc LPT, Hao PM, Quyen PT. Formal analysis: Quyen PT, Phuong LBB. Validation: Quoc LPT. Writing - original draft: Hao PM, Phuong LBB. Writing - review & editing: Quoc LPT.

Ethics approval

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ORCID

Le Pham Tan Quoc (First & Corresponding author)

<https://orcid.org/0000-0002-2309-5423>

Pham My Hao

<https://orcid.org/0000-0003-2797-3139>

Pham Thi Quyen

<https://orcid.org/0000-0003-3695-3703>

Lam Bach Bao Phuong

<https://orcid.org/0009-0004-4152-609X>

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