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Article

# Effect of Boiling, Steaming, and Autoclaving Methods on the Physical Characteristics of Moringa (*Moringa oleifera*) Seed Flour

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### ABSTRACT

This study evaluated the effect of moist heat processing (boiling, steaming, autoclaving) on the physical properties of Moringa oleifera seed flour to determine the optimal pretreatment for product development. Exotesta of moringa seeds were removed, subjected to the treatments, oven-dried, grounded, and sieved (60 mesh). Moisture content, color (CIELab), bulk density, and angle of repose were analyzed. Results showed that all treatments increased moisture content compared to raw seeds (4,36–4,46%), with no significant difference among treatments. Autoclaving produced flour with the highest bulk density (0,4258 g/cm<sup>3</sup>) and lowest angle of repose (33,37°), indicating better flowability. Color analysis revealed darker flour in autoclaved and boiled samples due to Maillard reactions. Overall, autoclaving is the most effective pretreatment for producing denser, free-flowing Moringa seed flour suitable for functional food applications.

### Keywords

Moringa seed flour  
Moist heat processing  
Bulk density  
Angle of repose  
Color analysis

## 1. Introduction

Moringa (*Moringa oleifera*) seeds have been recognized as a potential source of nutrients and bioactive compounds to be developed into various functional food products. Moringa seeds are known to contain 18,4% carbohydrate, 31,4% protein, and 36,7% fat (Leone et al., 2016). Moringa seeds are also known to have high content of oleic acids, which is 71,98% (Salman et al., 2023), almost equal as olive oil (Inmuangkham et al., 2024). Moringa seeds are also known to have antioxidant and anti-inflammatory abilities because they contain phenolic and flavonoids compounds, as well as other phytochemical compounds (Gu et al., 2020). Processing moringa seeds into flour is one strategy to expand its application in food formulations because flour form is more stable, easy to mix, and has longer shelf life. Physical characteristics such as moisture content, color, angle of repose, and bulk density are important parameters that determine mixing properties, quality, packaging efficiency, and storage.

Before moringa seeds are processed into flour, pretreatment is required to improve their quality. Moist heat processing methods such as boiling, steaming, and autoclaving are commonly used to inactivate enzymes, degrade antinutritional compounds such as phytate and tannins, and soften the tissue structure (Rayan and Embaby, 2016). These pretreatments are also known to reduce the bitter taste of the seeds, making them more acceptable to consumers (Salman et al., 2023).

This pretreatment not only affects the chemical and functional aspects, but also have an impact on the physical properties of the processed materials, including the characteristics of the flour produced. Therefore, it is important to evaluate the effect of various moist heat processing on the physical properties of moringa seed flour in order to obtain the best treatment in the process of developing optimal moringa seed-based products.

## 2. Literature Review

The moringa tree (*Moringa oleifera*) is a fast-growing tree native to northern India. Currently, moringa plants are widely found in the Middle East and in African and Asian countries. Moringa plants have good adaptability, allowing them to spread to other areas, especially tropical and subtropical lands affected by drought (Leone et al., 2016).

All parts of the moringa tree (leaves, seeds, roots, and flowers) are edible for humans and animals. However, the most commonly utilized part of the moringa tree is its leaves. Moringa leaves are known to be rich in protein, minerals,  $\beta$ -carotene, and antioxidant compounds. Moringa seeds are round in shape with a diameter of 1 cm, brown in color, and

weigh an average of 0.3 grams each. Each moringa tree can produce 15,000–25,000 seeds annually (Idris et al., 2016). Moringa seeds contain 36.7% fat, 31.4% protein, and 18.4% carbohydrates. Moringa seeds are rich in fat, protein, vitamins B and C, and minerals such as calcium and phosphorus (Rayan & Embaby, 2016).

Food processing methods such as boiling and steaming are commonly used to increase the acceptance of food ingredients. Boiling, steaming, and autoclaving are common thermal treatments that differentially affect the nutritional, sensory, and functional properties of foods. Boiling, which immerses food in water at 100°C, often causes substantial losses of water-soluble and heat-sensitive nutrients (e.g., vitamin C and some minerals) due to leaching and thermal degradation, though it effectively softens texture and inactivates some antinutrients (Lee et al., 2017). Steaming, by exposing food to steam without direct water contact, better preserves vitamins, flavor compounds, and texture, producing milder physicochemical changes and often improved nutrient retention compared with boiling (Xu et al., 2016). Autoclaving, a high pressure treatment at elevated temperatures (121°C) serves primarily for sterilization but also alters macromolecules: it can denature proteins and, through autoclaving-cooling cycles, increase resistant starch and change pasting and digestibility profiles, offering potential functional and health benefits (Supriyadi et al., 2024). Each method presents trade-offs between nutrient retention, safety, texture, and functional properties, so selection depends on the desired nutritional, sensory, and processing outcomes.

## 3. Research Methodology

### 3.1 Materials

The main material used was moringa seeds from UD Agro Sejahtera, Kediri, East Java.

### 3.2 Sample Preparation and Analysis

#### 3.2.1. Preparation of Moringa Seed Flour

Moringa seeds were sorted and then exotesta removed. After that, pretreatment (boiling, steaming, autoclaving) is carried out by adapting the method by (Rayan & Embaby, 2016). Boiled seeds were made by cooking moringa seeds at boiling temperature using distilled water (1:10) for 40 minutes. Steamed seeds were made by steaming moringa seeds at boiling temperature using distilled water (1:10) for 40 minutes. The autoclaved seeds were made by cooking seeds in the autoclave at 121°C using distilled water (1:10) for 20 minutes after the temperature was reached. The treated moringa seeds and the raw moringa seeds as comparison were dried using oven at 50°C for 48 hours. After being dried, the seeds then grounded and sieved using a 60 mesh sieve to obtain moringa seed flour. The flour was packed in a plastic

container sealed with an aluminum foil and stored at refrigerator (4°C) until required for use.

### 3.2.2. Moisture Content Analysis

Measurement of moisture content is done by AOAC method. Aluminium cup was dried until it reached a stable weight, then cooled in a desiccator and weighed. The samples, pretreated moringa seed flour, are weighed on a cup. After that, the samples were dried in an oven at 105°C until they reached a stable weight, then were cooled in a desiccator and weighed. The moisture content of the sample was calculated with Eq. 1:

$$\text{Moisture content (\%)} = \frac{A - B}{A} \times 100$$

A = sample weight before drying

B = sample weight after drying

### 3.2.3. Color Analysis

Color analysis was performed with a Konica Minolta Chromameter. Measurement was made by bringing the color measuring camera closer to the sample and pressing *Target Color Set* button. The color analysis data, *L*, *a*, *b*, will be recorded. The *L* value represents the *lightness* parameter which has value from 0 (black) to 100 (white). The *a* value represents the reflected light that produces red-green mixed chromatic color with *+a* (positive) value from 0-100 for red and *-a* (negative) value from 0-(-80) for green. The *b* value expresses the chromatic color of blue-yellow mixed chromatic color with *+b* (positive) value from 0-70 for yellow and *-b* (negative) value from 0-(-70) for blue.

### 3.2.4. Bulk Density

10 grams sample were put into a 50 mL measuring cylinder. The cylinder then tapped until the volume is constant. The measured volume is then recorded and the bulk density value is calculated by dividing the sample weight (grams) per volume (mL).

### 3.2.5. Angle of Repose

The angle of repose measurement was carried out by pouring the flour into a funnel at a height of 20 cm. Pouring is done slowly to form a triangular pile. Then, the diameter (D) and the height of the pile (t) were measured using a caliper. The angle of repose was calculated with the equation  $\text{arc tan } 2t/D$ .

### 3.2.6. Data Analysis

Data analysis was conducted with Microsoft Excel and SPSS One way Analysis of Variance (ANOVA) to determine whether there was a difference or effect of each treatment and Duncan's Multiple Range Test (DMRT) was carried out if there was a difference with significance level ( $\alpha$ ) 0,05.

## 4. Results and Discussion

### 4.1 Moisture Content Analysis

Moisture content is one of the most important characteristics because it can affect the appearance, texture, and flavor of food. It also determines the freshness and shelf life of the food (Winarno, 2008).

Lower moisture content will lead to better storage stability in food ingredients. The result of moisture content can be seen in Table 1. The data obtained show that boiled, steamed, autoclaved treatment of moringa seed flour have higher moisture content than raw moringa seed flour but there is no significant difference between the treatments. The moisture content ranged from 3,96-4,46%, meets the SNI 3175:2018 which has a maximum moisture content limit of 14,55 for wheat flour.

**Table 1.** Moisture content of moringa seed flour

Sample	Moisture Content (%)
Raw Moringa Seed Flour	3,96 ± 0,01 <sup>a</sup>
Boiled Moringa Seed Flour	4,36 ± 0,03 <sup>b</sup>
Steamed Moringa Seed Flour	4,37 ± 0,02 <sup>b</sup>
Autoclaved Moringa Seed Flour	4,46 ± 0,05 <sup>b</sup>

\*All of the data were expressed as means ± standard deviation; Mean values with different letters were significantly different at a level of  $p < 0,05$  by DMRT

Flour with treatments have higher moisture content because the treatments will make the seed structure more porous (Moniharapon et al., 2017). This is in line with research conducted by (Pangastuti et al., 2013) which has stated that red bean flour that is given pretreatment by boiling for 90 minutes has a higher moisture content than red bean flour without pretreatment.

### 4.2 Color Analysis

A foods color can be measured using a colorimeter, spectrophotometer, or any other tools. However, these tools are usually limited for translucent liquid material. Food color analysis generally uses the CIE  $L^*a^*b$  or CIELab color units introduced by The Commission Internationale d'Eclairage (CIE). The *L* value represents the *lightness* parameter which has value from 0 (black) to 100 (white). The *a* value represents the reflected light that produces red-green mixed chromatic color with *+a* (positive) value from 0-100 for red and *-a* (negative) value from 0-(-80) for green. The *b* value expresses the chromatic color of blue-yellow mixed chromatic color with *+b* (positive) value from 0-70 for yellow and *-b* (negative) value from 0-(-70) for blue. The result in color analysis can be seen in Table 2.

**Table 2.** Color analysis of moringa seed flour

Sample	L	a	b
Raw	51,03 ±	3,38 ±	16,86 ±
Moringa Seed Flour	3,24 <sup>b,c</sup>	0,34 <sup>a</sup>	0,30 <sup>a</sup>
Boiled	49,06 ±	3,84 ±	17,80 ±
Moringa Seed Flour	1,01 <sup>a,b</sup>	0,00 <sup>b</sup>	0,72 <sup>b,c</sup>
Steamed	52,99 ±	3,63 ±	18,07 ±
Moringa Seed Flour	0,93 <sup>c</sup>	0,05 <sup>a,b</sup>	0,23 <sup>c</sup>

Autoclaved Moringa Seed Flour	47,43 ± 3,06 <sup>a</sup>	4,25 ± 0,40 <sup>c</sup>	17,43 ± 0,36 <sup>b</sup>
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\*All of the data were expressed as means ± standard deviation; Mean values with different letters within a column were significantly different at a level of  $p < 0,05$  by DMRT

Based on the result, moringa seed flour have medium lightness, with lightness value of ranged from 47,43-52,99 on a scale of 100. They all have a chromatic color *a* ranged from +3,38 to +4,25 which indicates that all flour have a tendency to red color rather than green color. In addition, moringa seed flour have a chromatic color *b* ranged from +16,36 to 18,07 which indicates that all flour have tendency to yellow color compared to blue color. The color of moringa seed flour can be seen in Fig 1.



**Fig 1.** Color of moringa seed flour

Boiled and autoclaved moringa seed flour have darker color than raw moringa seed flour. This primarily due to intensified Maillard reactions and caramelization, which are complex chemical processes that occur during heating. Autoclaving involves higher temperatures (typically 121°C) and pressure, which promote these chemical reactions involving sugars and amino acids, leading to the formation of brown pigments and darker coloration. This is more intense than in simple boiling or steaming because of the severity of the heat and pressure applied (Pedrosa et al., 2021).

#### 4.3 Bulk Density Analysis

Bulk density is one of physical characteristics that compares the weight of material with the volume it occupies which usually written in unit of  $\text{kg/m}^3$  or  $\text{g/cm}^3$ . Bulk density is important because it affects the processing, packaging, and transportation (Ding et al., 2020). The higher bulk density value indicates that food ingredients is denser. Based on the result (Table 3), autoclaved moringa seed flour has the highest bulk density value, which is  $0,4258 \text{ g/cm}^3$ .

**Table 3.** Bulk density of moringa seed flour

Sample	Bulk density ( $\text{g/cm}^3$ )
Raw Moringa Seed Flour	$0,3167 \pm 0,0319^a$
Boiled Moringa Seed Flour	$0,3829 \pm 0,0362^b$
Steamed Moringa Seed Flour	$0,3454 \pm 0,0168^a$
Autoclaved Moringa Seed Flour	$0,4258 \pm 0,0128^c$

\*All of the data were expressed as means ± standard deviation; Mean values with different letters were significantly different at a level of  $p < 0,05$  by DMRT

Treated moringa seed flour have higher density than raw moringa seed flour because during the treatment, the cooking processes cause the seeds to absorb water and undergo structural changes that reduce internal air spaces. When seeds are exposed to heat through boiling, steaming, or autoclaving, they take up moisture, which fills the gaps and voids inside the seed structure, making it more compact (Dang et al., 2022). Autoclaving, which involves both high temperature and pressure, further compresses the seed tissues and expels trapped air, increasing density even more compared to boiling or steaming.

#### 4.4 Angle of Repose Analysis

The angle of repose is defined as the steepest angle relative to the horizontal plane at which a pile of granular material can be stacked without the material sliding down; it is essentially the maximum slope angle at which the material remains stable. This angle is influenced by particle size, shape, surface roughness, moisture content, and cohesion among particles. In the context of food ingredients, the angle of repose is primarily used to assess the flowability of powdered or granular food materials such as spices, flour, sugar, and feed ingredients. It helps to understand how easily these materials will flow and be handled during processing, transportation, and storage. For example, ingredients with a lower angle of repose flow more easily, while those with a higher angle indicate greater cohesiveness and poorer flow characteristics (Pekel et al., 2022).

Based on the result (Table 4), it can be seen that the angle of repose of moringa seed flour ranged from  $33,37^\circ$ - $37,97^\circ$ , with autoclaved moringa seed flour has lowest degree. These values indicating flowability that spans from good to fair categories. Based on (Shah et al., 2023), angles between  $31^\circ$  and  $35^\circ$  are associated with good flow properties, while angles from  $36^\circ$  to  $40^\circ$  correspond to fair or passable flowability. Autoclaving involves high temperature and pressure treatment, which can reduce moisture variability, change seed surface texture, and potentially degrade some surface roughness or adhesive forces among seed particles. This results in less friction and cohesion between seeds, facilitating easier sliding and thus a lower angle of repose.

**Table 4.** Angle of repose of moringa seed flour

Sample	Angle of repose ( $^\circ$ )
Raw Moringa Seed Flour	$35,90 \pm 0,48^b$
Boiled Moringa Seed Flour	$34,01 \pm 1,38^a$
Steamed Moringa Seed Flour	$37,97 \pm 0,49^c$
Autoclaved Moringa Seed Flour	$33,37 \pm 0,48^a$

\*All of the data were expressed as means  $\pm$  standard deviation; Mean values with different letters were significantly different at a level of  $p < 0,05$  by DMRT

## 5. Conclusion

Based on the result, moist heat processing has significant impact on the physical properties of moringa seed flour. The autoclaved treatment produced flour with the highest bulk density and lowest angle of repose, indicating better flowability and denser particles. Color analysis showed that autoclaved treatment produced darker flour. Autoclaved treatment can be the most effective choice in improving the quality of moringa seed flour.

## References

- Dang, B., Zhang, W.-G., Zhang, J., Yang, X.-J., & Xu, H.-D. (2022). Effect of Thermal Treatment on the Internal Structure, Physicochemical Properties and Storage Stability of Whole Grain Highland Barley Flour. *Foods*, *11*(14), 2021. <https://doi.org/10.3390/foods11142021>
- Ding, H., Li, B., Boiarkina, I., Wilson, D. I., Yu, W., & Young, B. R. (2020). Effects of morphology on the bulk density of instant whole milk powder. *Foods*, *9*(8). <https://doi.org/10.3390/foods9081024>
- Gu, X., Yang, Y., & Wang, Z. (2020). Nutritional, phytochemical, antioxidant,  $\alpha$ -glucosidase and  $\alpha$ -amylase inhibitory properties of Moringa oleifera seeds. *South African Journal of Botany*, *133*, 151–160. <https://doi.org/10.1016/j.sajb.2020.07.021>
- Idris, M. A., Mohammed, S. J., Ademola, M. H., & Jamal, P. (2016). *Moringa oleifera seed extract: a review on its environmental applications*. *11*(6), 1469–1486. <https://www.researchgate.net/publication/312069731>
- Inmuangkham, N., Sukjarernchaikul, P., Thepwater, S., & Iemsam-Arng, J. (2024). Fatty acid profiles of olive oil and moringa oil and their influence on nanoemulsion formation via D-phase emulsification using bakuchiol as a model active compound. *Industrial Crops and Products*, *209*, 118052. <https://doi.org/10.1016/J.INDCROP.2024.118052>
- Lee, S., Choi, Y., Jeong, H. S., Lee, J., & Sung, J. (2017). Effect of different cooking methods on the content of vitamins and true retention in selected vegetables. *Food Science and Biotechnology*. <https://doi.org/10.1007/s10068-017-0281-1>
- Leone, A., Spada, A., Battezzati, A., Schiraldi, A., Aristil, J., & Bertoli, S. (2016a). Moringa oleifera seeds and oil: Characteristics and uses for human health. In *International Journal of Molecular Sciences* (Vol. 17, Issue 12). MDPI AG. <https://doi.org/10.3390/ijms17122141>
- Leone, A., Spada, A., Battezzati, A., Schiraldi, A., Aristil, J., & Bertoli, S. (2016b). Moringa oleifera Seeds and Oil: Characteristics and Uses for Human Health. *International Journal of Molecular Sciences*, *17*(12), 2141. <https://doi.org/10.3390/ijms17122141>
- Moniharapon, E., Nendissa, S. J., & Laiyan, D. (2017). Karakterisasi sifat kimia tepung kacang lawa merah (*Phaseolus vulgaris* L.) dengan beberapa perlakuan pendahuluan. *AGRITEKNO, Jurnal Teknologi Pertanian*, *6*(1), 21. <https://doi.org/10.30598/jagritekno.2017.6.1.21>
- Pedrosa, M. M., Guillamón, E., & Arribas, C. (2021). Autoclaved and Extruded Legumes as a Source of Bioactive Phytochemicals: A Review. *Foods*, *10*(2), 379. <https://doi.org/10.3390/foods10020379>
- Pekel, A., Kızıl, A., Çalık, A., Kuter, E., Ahsan, U., Alataş, M., & Kahraman, O. (2022). Classification of commonly used feed ingredients based on flow properties. *International Agrophysics*, *36*(2), 123–130. <https://doi.org/10.31545/intagr/149295>
- Rayan, A. M., & Embaby, H. E. (2016). *Effects of dehulling, soaking, and cooking on the nutritional quality of Moringa oleifera seeds* (Vol. 22, Issue 3). <http://>
- Salman, A. N., Prangdimurti, E., & Hunaefi, D. (2023). Peningkatan potensi biji kelor (*Moringa oleifera*) sebagai pangan pencegah hiperkolesterolemia. *Jurnal Ilmu Pertanian Indonesia*, *28*(4), 525–533. <https://doi.org/10.18343/jipi.28.4.525>
- Shah, D. S., Moravkar, K. K., Jha, D. K., Lonkar, V., Amin, P. D., & Chalikwar, S. S. (2023). A concise summary of powder processing methodologies for flow enhancement. *Heliyon*, *9*(6), e16498. <https://doi.org/10.1016/j.heliyon.2023.e16498>
- Supriyadi, E. A., Azhari, A., & Widiyanto, N. (2024). The effect of autoclaving method on sago starch as a functional food source: a review from a gastronomy perspective. *Journal of Gastro Tourism*, *2*(1), 1–10. <https://doi.org/10.52465/jogasto.v2i1.236>
- Xu, Y., Chen, Y., Cao, Y., Huang, W., Zhang, S., Xia, W., & Jiang, Q. (2016). Effect of Steam Cooking on Textural Properties and Taste Compounds of Shrimp (<i>Metapenaeus ensis</i>). *Food Science and Technology Research*, *22*(1), 75–81. <https://doi.org/10.3136/fstr.22.75>