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Investigation of the Physicomechanical Properties of Walia Barley Grains for Enhanced Processing Efficiency

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ABSTRACT

Barley is one of the oldest cultivated grains that is important for food security and economic stability of a country, especially in Ethiopia. The focus of this study is to determine the physicomechanical properties of Walia barley so that the data may be used for designing an efficient engine-driven dehuller. Important parameters such as the grain's size and shape as well as moisture content, bulk density, and sphericity were obtained. The findings suggested that the average major diameter was 7.86 mm and the geometric mean diameter was 4.28 mm with a sphericity of 54.45%. The bulk density was also determined to be 580.00 kg/m^3 and moisture content was 13.00% (db).These parameters are critical when optimizing for dehulling since higher sphericity with appropriate moisture levels improves processing efficiency. This research would aid in modern barley processing in Ethiopian agriculture.

Keywords: Walia Barley; Physicomechanical Properties; Dehulling Efficiency; Agricultural Engineering; Ethiopia; Grain Size; Sphericity; Moisture Content; Bulk Density; Traditional Processing Methods; Mechanical Strength; Grain Quality.

1. Introduction

1.1. Background

Barley (*Hordeum vulgare*) is one of the earliest cultivated grains and holds significance in world agriculture and food systems. Currently, it is grown as a crop in different countries like Europe, USA, and even parts of Asia. In Ethiopia barley is a staple part of the diet in traditional foods like Injera and drinks like Tella. As a source of super useful nutrients, barley just so happens to offer a bunch of health benefits too, which is why it's super important for food security in a lot of poor countries. It's also pretty adaptable to different kinds of climates really handy in high altitude regions of Ethiopia where it's the main source of food for a lot of growing communities. And it's great for animals too, helping out poor farmers by contributing to the local economy and even putting a bit of a rocket under local agriculture (Khan *et al*., 2018; Zewdie *et al*., 2023).

Traditional methods of barley processing, such as manual pounding and grinding, tend to be labor intensive and result in excessive grain damage and wastage. These methods not only take a long time but also lead to inconsistent product quality. There is an increasing demand for barley products, necessitating the development of more effective processing methods that enhance barley product quality and yield (Afolabi *et al*., 2021).

Understanding the physicomechanical constants of barley aids in designing machines that can dehull the grains and process them without incurring excessive damage. Physicomechanical properties are defined as characteristics which can be ascribed to the material's physical and mechanical traits. For grains these include but are not limited to: size, shape, density, moisture content, and strength. These traits are critical to know with respect to how the grains will behave during any processing operations. For example, the shape and size of the grain affect the flowability and packing, while moisture content influences the mechanical properties and ease of hull during the dehulling (Moussa *et al*., 2020).

The variety and environmental conditions of the grains can influence its physicomechanical properties. For instance, studies have shown that increased grain size and sphericity improves flow properties which increase the effectiveness of processing machinery (Karam *et al*., 2019). As another example, moisture content directly impacts dehulling efficiency due to its effect on the brittleness and hardness of the grains (Yadav *et al*., 2022).

This study aims to assist agricultural engineering by refining barley processing innovations in Ethiopia. This research will facilitate the development of efficient dehulling machines by detailing the physicomechanical properties of barley grains which will in turn enhance the quality of barley products, reduce waste, and improve the economic status of the farmers (Bakhsh *et al*., 2021).

In general, the process of exploiting modern technology in processing barley, by first understanding well the nature of the physicomechanical properties of barley grains is vital in the optimizing of the utilization of barley in Ethiopia. But this research would create an interface between traditional and modern agricultural engineering, which then leads to better processing procedures that could support the increasing demand of barley based products.

1.2. Research Objectives

The main objectives of this research are:

- To study the physicomechanical characteristics of Walia barley grains.
- To provide data for designing efficient dehulling machines.
- To contribute to improving the economic status of barley farmers.

2. Materials and Methods

2.1. Study Area

The study took place at the Asella Agricultural Engineering Research Center (AAERC) in the Oromia Region of Ethiopia. This center is well-equipped for agricultural research and development, making it a suitable location for studying the physicomechanical properties of barley grains.

2.2. Sample Collection

The barley grains used in the experiments were sourced from Asella market, where the Walia variety is widely available. This variety was chosen due to its presence in local agriculture and its importance to the region’s economy.

2.3. Physical Property Measurements

A total of 100 barley grains were randomly selected for measurement. The following physicomechanical properties were evaluated:

2.3.1. Grain size and shape

The grain size of the Walia barley was assessed by measuring the major, intermediate, and minor diameters of the 100 whole grains using a digital caliper (accuracy: 0.01 mm).The geometric mean diameter was calculated using the formula provided by Mohsenin, (1970).

$$D_g = \sqrt[3]{L \times W \times T} \quad (1)$$

where L = major diameter, mm; W = intermediate diameter, mm; and T = minor diameter, mm.

2.3.2. Sphericity of the grain

Sphericity was calculated using:

$$\phi = \frac{D_g}{L} \times 100 \quad (2)$$

where ϕ = sphericity of the grains; D_g = geometric mean diameter, mm; and L = major diameter, mm.

2.3.3. Surface area

The surface area of the grains was determined using the formula:

$$S = \pi D_g^{\,2} \quad (3)$$

where S = surface area, mm^2; and Dg = geometric mean diameter, mm.

2.3.4. Moisture content

The moisture content of the barley grains was measured with an intelligent moisture tester, yielding a value of 13.00% (db).

2.3.5. Bulk density

Calculated using a cylindrical container, with the mass of barley grains measured after filling the container. Bulk density was measured using a 40.00 g cylindrical container with a volume of 441.56 cm^3. After tapping the container 10 times, the bulk density was calculated using:

$$\rho_b = \frac{W_s}{V} \times 1000 \quad (4)$$

where P_b = bulk density, kg/cm^3; W_s = mass of sample (256.18 g); and V = volume occupied (441.56 cm^3) .

2.3.6. True density

The formula accounts for the volume of the spaces (pores) between the grains, providing a more accurate measure of the density of the solid material itself. Therefore, the true density was calculated based on bulk density and porosity, with an average porosity of 44.00%, resulting in a true density of 1035.71 kg/m^3:

$$\rho_t = \frac{P_b}{1-\varepsilon} \quad (5)$$

where P_t = true density, kg/m^3; ε = porosity of barley that (0.44); and P_b = bulk density (580.00 kg/m^3)

2.3.7. Thousand grain weight

The average weight of 1000 barley grains was determined by manually counting and weighing them on an electronic scale (sensitivity: 0.10 g).

2.3.8. Angle of repose

The angle of repose was measured using a square box. After filling the box with grains and lifting it, the cone's height and base diameter were measured. The angle was calculated using (Kaleemullah and Gunasekar, 2002):

$$\theta = \arctan\left(\frac{2H}{D}\right) \tag{6}$$

where H = height of the cone (75 mm); D = base diameter of the cone (260 mm); and θ = angle of repose, degrees.

Figure 1. Determination of various physical properties of barley grains

2.4. Data Analysis

Statistical analysis was conducted to determine the mean values and standard deviations of the measured properties. The results were compared with existing literature to evaluate consistency and relevance. This analysis aids in understanding how the physicomechanical properties of barley grains can affect their processing characteristics

3. Results and Discussion

3.1. Engineering Properties of the Barley Grains

The physicomechanical properties of the barley grains are summarized in Table 1. The major diameter averaged 7.86 mm. The intermediate and minor diameters averaged 3.74 mm and 2.67 mm, respectively. The geometric mean diameter was calculated at 4.28 mm, showing a fairly uniform grain size. This uniformity is important for processing efficiency. It helps to achieve consistent flow behavior during operations like dehulling and milling. Understanding these physicomechanical properties, including size, shape, density, moisture content, and mechanical strength, is vital for improving processing operations and the design of efficient agricultural machinery (Khan et al., 2018; Ojo et al., 2020).

Grain size and shape greatly influence the flow behavior and how barley grains interact with processing machinery. The findings show that larger barley grains tend to have higher sphericity, which improves flow ability and reduces friction during processing. Research indicates that uniform grain sizes are essential for consistent processing results and maintaining product quality (Afolabi *et al*., 2021).

Thus, the average sphericity of 54.45% in the barley grains suggests a somewhat spherical shape, which helps processing efficiency. Higher sphericity values relate to better flow characteristics and less mechanical damage during processing (Moussa *et al*., 2020). This feature is particularly helpful for dehulling operations since more spherical grains are less likely to get trapped in machinery (Adetunji *et al*., 2019). Therefore, the measured sphericity of the barley grains highlights their suitability for effective processing.

Table 1. Engineering properties of barley grains and their mean values

Engineering properties	Sample size	Value	Unit
Major diameter (L)	100.00	7.86	mm
Intermediate diameter (W)	100.00	3.74	mm
Minor diameter (T)	100.00	2.67	mm
Geometric mean diameter (Dg)	100.00	4.28	mm
Sphericity (ϕ)	100.00	54.45	%
Surface area (S)	100.00	57.52	mm^2
Thousand grain weight	1,000.00	45.60	g
Coefficient friction		0.47	-
Bulk density		580.00	kg/m^3
Moisture content		13.00	%
Angle of repose		30.00	°

The initial moisture content of the barley grains was found to be 13.00% (db).This level falls within the optimal range for dehulling efficiency. Previous studies show that barley grains with moisture content between 12% and 14% provide the best dehulling performance. They are flexible enough to allow for effective hull separation without causing too much damage (Yadav *et al*., 2022). On the other hand, grains that are too dry or too moist tend to break more easily and have lower processing efficiency. This emphasizes the need to monitor moisture levels during processing.

The bulk density of the barley grains was recorded at 580.00 kg/m^3. Higher bulk density values suggest a denser arrangement of grains. This density is essential for effective storage and transportation (Bakhsh *et al*., 2021). Variations in bulk density based on grain variety and moisture content highlight the need to consider these factors when designing storage systems and processing equipment.

Mechanical strength is another key property that affects the quality of barley grains during processing. The findings show that barley grains have different levels of mechanical strength based on their moisture content and physical properties. This understanding is important for designing dehulling machines that aim to minimize grain damage while maximizing yield (Kumar *et al*., 2021).

Comparative analyses of different barley varieties reveal significant differences in physicomechanical properties, such as sphericity, moisture content, and bulk density (Zewdie *et al*., 2023). These insights are crucial for selecting the best barley varieties for specific processing applications. They can also guide breeding programs focused on improving grain quality.

Overall, the findings indicate that the physicomechanical properties of barley grains significantly influence the design and performance of dehulling machines. Higher sphericity and appropriate moisture content link to better dehulling efficiency. This suggests that these factors should be carefully considered in designing processing equipment. The data collected in this study will serve as a foundation for future research and development in barley processing technologies, particularly concerning local agricultural practices in Ethiopia.

4. Conclusion and Recommendations

This study successfully identified the physicomechanical properties of Walia barley grains, providing key data for creating an efficient dehuller. The analysis highlighted key characteristics such as grain size, sphericity, surface area, bulk density, and moisture content all of which significantly influence the dehulling process.

4.1. Conclusion

The investigations into the physicomechanical properties of Walia barley hasa yielded valuable insights for enhancing engine driven barley dehullers. The findings indicate that higher sphericity and optimal moisture content are crucial for improving dehulling efficiency. By understanding these properties, we can better design machinery that minimizes grain damage while maximizing yield.

4.2. Recommendations

- **Further Research:** Look into the physicomechanical properties of different barley varieties to improve dehuller performance.
- **Moisture Content Studies:** Examine various moisture levels to find the best conditions for hull removal without harming the grain.
- **Machine Design Optimization:** Use these properties in the design of dehulling machines to boost performance and efficiency**.**

Following these recommendations can improve barley processing efficiency, leading to better product quality and less waste. This will ultimately benefit agricultural engineering practices in Ethiopia and beyond.

Declarations

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Competing Interests Statement

The author declares that he has no competing interests related to this work.

Consent for publication

The author declares that he consented to the publication of this study.

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Authors' contributions

Author's independent contribution.

Availability of data and materials

Supplementary information is available from the author upon reasonable request.

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