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Effect of Moisture and Grain Type on the Capacity, Specific Energy and Particle Size of Hammer Mill

Aanand L. LAKHANI[1], Basim Aboud ABBAS[2]*, Pranay SARKAR[3]

[1]Department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, Junagadh Agricultural University, Junagadh, Gujarat, INDIA
[2]Department of Animal Production, College of Agriculture, University of Diyala, IRAQ
[3]Agricultural and Food Engineering Department, Indian Institute of Technology Kharagpur, West Midnapore, INDIA

[1]https://orcid.org/0009-0006-9552-4561, [2]https://orcid.org/0000-0003-3193-6824, [3]https://orcid.org/0000-0001-9367-9988

Corresponding Author: basimabbas@uodiyala.edu.iq

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ABSTRACT

The grinding of feed components is the first step in the process of preparing and manufacturing feed because it minimizes energy waste during feed intake. This paper presents the effect of moisture and grain type on the capacity, energy and particle size of a hammer mill. Specific capacity, specific energy, geometric mean diameter, and size reduction degree were measured. Two moisture levels of the grain (8.2 and 13.4 %) and three types of grain (wheat, barley and yellow corn) were used. Results showed that increasing grain moisture from 8.2 to 13.4 % led to no significant effect on specific capacity and specific energy. On the other hand, a significant increase in the geometric mean diameter of grinding and decreased size reduction degree, with changing the grain type (wheat, barley and yellow corn) recorded a significant effect in all the indicators studied. The best results was achieved at the moisture of grains 8.2 % and yellow corn grains, the highest specific capacity was 2.80 $kg.kWh^{-1}$, the least specific energy was 0.36 $kWh.kg^{-1}$, Also least geometric mean diameter was 428.2 µm, and the highest size reduction degree was 48.24. It was concluded that when grain moisture was raised, there was no significant effect in specific capacity, specific energy, a significant increase in the geometric mean diameter of grinding and decreased size reduction degree, with changing the grain type (wheat, barley and yellow corn) recorded a significant effect in all the indicators studied.

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INTRODUCTION

Cereal crops are the world's most consumed food source (Ahmad et al., 2024). Wheat a vital cereal crop is crucial to global agriculture. It contributes over 30% of the world's total grain production and accounts for half of the grain traded globally (Khater et al., 2023; Maity and Shrivastav, 2024), and wheat grain is an important staple crop that supplies 20% of the world's nutritional energy and protein, also wheat is a significant source of energy for animals (Fanelli et al., 2024). Barley is widely used across all worlds (Rozanova et al., 2023), and its performance as a grain feed crop is essential to animal feed (Neshumaeva et al., 2024). Yellow corn is one of the important crops in the world because of its essential place in the food chain, which comes after wheat and rice (Ali et al., 2018). It is considered the crop that presides the universal feed list because of its highest production, which makes it preferred over other grains (Ali et al., 2020).

According to Hancock (2000) the grinding of feed components is the first step in the process of preparing and manufacturing feed. Feed is made in mash, pellets, or possibly various forms for poultry (Bander et al., 2024). Because it minimizes feed waste and energy waste during feed intake, the physical feed form improves poultry performance. The physical form of the mash has a significant impact on feed intake, growth rate, and production (Jasim et al., 2023). The poultry has higher vitamin and protein content than other foods, it is regarded as a basic form of human consumption (Abdulalwahhab et al., 2020; Bander et al., 2023). Because of this, it is crucial to use feed as efficiently as possible when feeding (Ali et al., 2020).

Grain processing involves harvesting, cleaning, milling or grinding, and separating the constituent parts to obtain products like flour and bran (Fanelli et al., 2024). Grinding is the main processing method used for meals made with grains. Thus, it is crucial to have an efficient machine for achieving these goals (Ibrahim et al., 2017). A hammer mill, also called a grains miller, is a device with a rotating head hammers or beaters that crush hard, dry materials like grains into predetermined sizes through a perforated screen. The hammers also smash the grains before they can pass through the screen that surrounds the hammers (Mohammed et al., 2023). The grain is ground by the repetitive impact of the hammers hitting the grain with sieve and the grinder walls. The fineness of the mash is controlled by utilizing sieves with varying screen diameters. The mash will flow through the sieve and separate from the remainder of the grain as soon as the diameter of the mill sieve holes is decreased to a smaller size (Jasim et al., 2024). Hammer mills are widely used in agricultural fields and animal feed factores because they have the ability to grind materials to number levels of fineness (Khudher et al., 2021). According to Djuro et al. (2016), the machine's basic operating concept is based on the materials' size being decreased by the collision force, or mechanical impact force. One of the most popular types of grinders is the hammer mill because of its many benefits, which include easy part replacement, a broad range of grinding degrees, straightforward design, low cost, and great productivity (Abbas, 2012). Theoretically, grinding improves grain's feed surface area, and digestibility which benefits grain use and animal feeding (Kim et al., 2018). Reducing the grain size of cereals is the first step in the preparation and production of feeds (Al-Juboory and Abbas, 2009; Abdullah et al., 2010). According to Ahmed et al. (2006) one of the key variables influencing the machine's capacity and electricity consumption is the type of grain. That each volume of particles requires energy during the grinding process and that energy causes the grinding zone's temperature to rise as a result of force and friction (Ali et al., 2019b). Size is typically described as the fineness of feed grinding or as the average particle size distribution of the feed's constituent parts (Amerah et al., 2007). In a study on the impact of grain type and moisture on particle size, it was demonstrated that changing from wheat to barley and then to maize had a significant impact on particle size; the minimum particle size with maize was 0.174 mm, and that increasing the grain moisture from 8.2 to 13.4% resulted in a significant increase in particle size from 0.180 to 0.183 mm (Hasan et al., 2025). That the low grain moisture led to ground grain particle size decrease (Dabbour et al., 2015). Ali et al. (2024a) Explained that specific energy is the power consumed (power consumed during a known fixed time) per unit weight, also defined specific capacity as the amount of material produced per unit energy. Hasan and Abbas (2013) found that the grain type is one of the factors affecting the specific capacity of the grinding machine. This paper aimed to study the effect of moisture and grain type on the capacity, specific energy and particle size of hammer mill.

MATERIAL and METHOD

Experimental Procedures

The experiment was carried out in the laboratorys of Animal Production Department at College of Agriculture, University of Diyala, 2022. Two moistures of the grain (8.2 and 13.4%) and three type of grain (Wheat, Barley and Yellow corn), with three replications has been used.

Hammer Mill Description

The grains were grinded individually using a machine of Chinese origin (Model FZ102) with maximum operating speed of 1400 rpm and voltage of 220 volts. The diameter of the hammer cylinder is 100 mm, The working diameter of the hammer cylinder is 92 mm, Number of hammers 4, dimensions of the used sieve (length × width) 55 × 31 mm, the diameter of the sieve used in the grinding process was 2 mm. A picture of hammer mill used in this study shown in Figure 1.

Figure 1. The hammer mill used in this study

Grains Used

Three types of grain (wheat, barley and yellow corn) were used in this study, was purchased for the experiment from the local market.

The physical properties of grain types used are presented in Table 1.

Table 1. Physical properties of different grains

Grain types	Grain diameter (mm)	Weight of one grain (g)	Grain Bulk density (g.cm^{-3}), (moisture 8.2 %)	Grain Bulk density (g.cm^{-3}), (moisture 13.4 %)
Wheat	4.08	0.047	5.24	4.66
Barley	5.57	0.046	3.35	3.28
Yellow corn	8.42	0.353	4.46	4.18

Statistical Analysis

The least significant difference (LSD) test at the probability level of (0.05), by a complete randomized design (CRD) has been used to test the differences between the treatments. SAS (2009) program for the statistical analysis was used.

Parameters Measured

The calculated parameters of grinding process were as follows:

Specific Capacity (kg.kWh^{-1})

First, the mill capacity was calculated by using a timer watch and electronic scale for every unit trial according to Radwan et al. (2021), by the equation 1:

$$C = \frac{W}{T} \quad (1)$$

Where:

C is capacity (kg.h^{-1}), W is Weight of Sample (kg), T is Grinding Time (h).

Unit meanwhile A digital clamp meter was used for measuring electric current intensity and voltage, to record the consumed power change during the grinding process according to Abbas (2017), and the specific capacity was calculated by the equation 2 that used by Ali et al. (2024b):

$$Sc = \frac{C}{P} \quad (2)$$

Where:

Sc is Specific capacity (Kg.kWh^{-1}), C is Capacity (Kg.h^{-1}), P is Power consumption (kW).

Specific energy (kWh.kg^{-1})

The required electric power for working motor mill load was calculated according to Ali et al. (2018), by measuring the power consumed per machine capacity at fixed time by the equation 3:

$$P = I * \frac{V * 1.73 * PF}{1000} \quad (3)$$

Where:

P is Power consumption (Kilowatt), I is Electrical current (Ampere), *1.73* is the constant coming from the division of the motor phases, V is Voltage (Volt), PF is Power Factor (if unknown, supposed to equal 0.93).

The specific energy is power per unit productivity, it was as calculated according to Ibrahim et al. (2019) by the equation 4:

$$Se = \frac{P}{C} \quad (4)$$

Where:

Se is Specific energy (kWh.kg^{-1}), P is Power consumption (kW), C is Capacity (Kg.h^{-1}).

Geometric Mean Diameter (μm)

Each experimental unit received 100 g of samples, which were then sieved using sieves arranged in descending order of diameter, starting with the largest and working down to the smallest, Use a set of 5 sieves with diameters of (1.18, 0.85, 0.28, 0.15 and 0.121

mm), (Figure 2). The materials were then weighed in each sieve and recorded. The equation 5 proposed by Ali et al. (2019a) was used to get the geometric mean diameter.

$$Dg = Log^{-1} \left[\!\left[\frac{\Sigma(wi\ Log\ D\bar{i})}{\Sigma wi} \right]\!\right] \qquad (5)$$

Where:

Dg is geometric mean diameter (µm), *wi* is particles weight in the sieve (i) (g), Di^{-} is geometric mean diameter of the particles in the sieve (i) (µm), i is the sieve number,

$$Di^{-} = (Di \ * D(i+1)0.5 \qquad (6)$$

Where:

Di is diameter of the sieve perforations (µm), *Di+1* is the perforations diameter of the next sieve bigger than the sieve (i) (that is on the top in sequence /order).

Figure 2. The sieves used in this study

Size Reduction Degree

Represents the size reduction degree (Figure 3), is the initial grain diameter divided by the particle diameter after grinding and is calculated according to Perry et al. (1984) using the equation 6:

$$Srd = \frac{Dg}{Dp} \qquad (7)$$

Where:

Srd is size reduction degree, *Dg* is diameter of the grains (mm), *Dp* is diameter of the particles (mm).

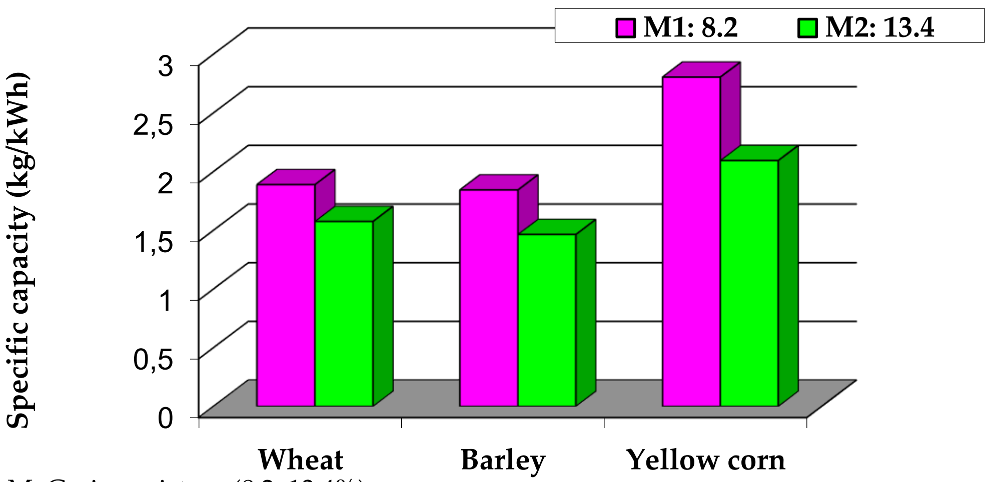
Maize Wheat Barley

Figure 3. Size reduction degree

RESULTS and DISCUSSION

Specific Capacity (kg.kWh^{-1})

Figure 3 shows effect of a moisture and grain type on specific capacity. With increasing the moisture of grain from 8.2 to 13.4 % the mill specific capacity had not a significant affected. While it is clear from Figure 1 that the changing grain type from wheat to barley then to yellow corn led to a significant effect in the on specific capacity, the highest specific capacity was 2.44 kg.kWh^{-1} with yellow corn compared to wheat and barley grains was 1.73 and 1.65 kg.kWh^{-1}. The reason for this is the difference in the flow properties of the grains, as the angle of stability of yellow corn grains is less than that of wheat and barley, The angle of stability, sometimes called the angle of slope, is the angle created by the base's diameter and the side of the conical shape that results from a mass of grains falling freely on a particular base. The value of this angle also reflects the degree of internal friction, or the smooth friction that grains encounter with one another during motion, this result is corresponding with Hasan et al. (2025).



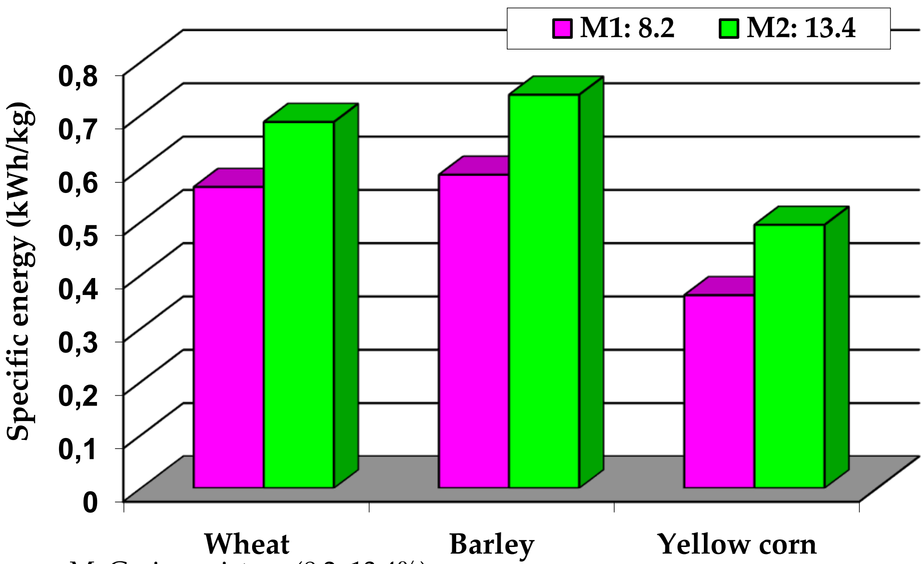
M: Grain moisture (8.2, 13.4%).

Figure 3. Effect of moisture and grain type on specific capacity (kg.kWh-1), M: Grain moisture (8.2, 13.4%).

In addition, Figure 3 shows the effect of moisture and grains type have on specific capacity. The highest specific capacity was 2.80 kg.kWh^{-1} with moisture of grains 8.2 % and yellow corn grains type. Whereas the least specific capacity was 1.46 kg.kWh^{-1} with moisture of grains 13.4 % and barley grains type.

Specific Energy (kWh.kg^{-1})

Figure 4 shows effect of moisture and grain type on specific energy. With increasing the moisture of grain from 8.2 to 13.4%, the mill specific energy was not significantly affected. While it is clear from Figure 4 that the changing of grain type from wheat to barley then to yellow corn led to a significant effect on the specific energy, the least specific energy was 0.42 kWh.kg^{-1} with yellow corn compared to wheat and barley grains was 0.62 and 0.66 kWh.kg^{-1}. The reason for difference is attributed to the grinding corn gave the highest productivity while grinding barley gave the lowest productivity, and the relationship between productivity and specific energy is an inverse relationship, with the decrease in productivity, the energy requirements of the mill motor per unit weight increase, this result is corresponding with Ali et al. (2024a); Idan et al. (2025).



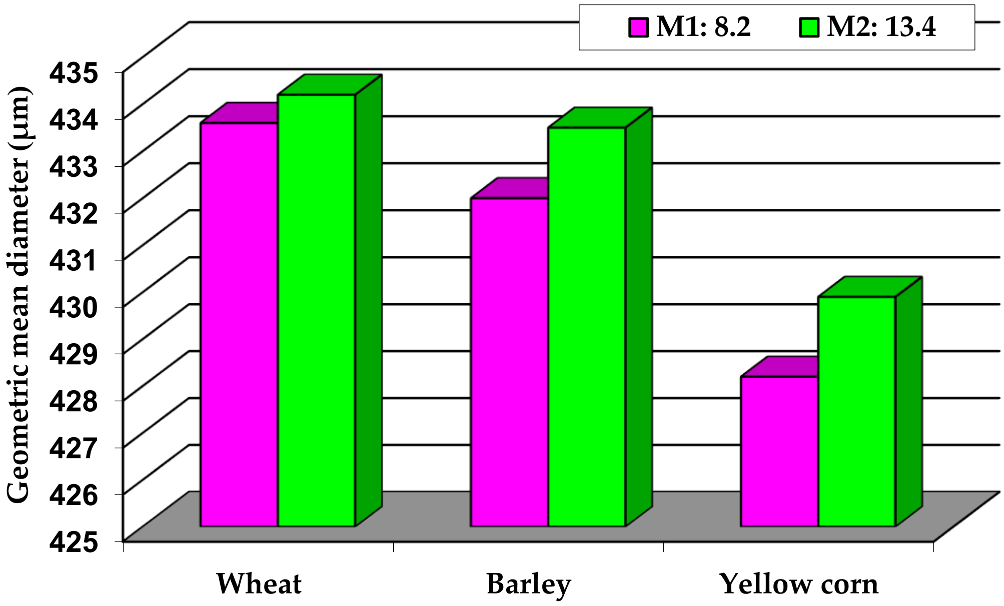
M: Grain moisture (8.2, 13.4%).

Figure 4. Effect of moisture and grain type on specific energy (kWh.kg^{-1})

In addition, Figure 4 shows the interaction the moisture and grain type has on the specific energy. The least specific energy yellow corn was 0.36 kWh.kg^{-1} with grains moisture of 8.2 %. Whereas the highest specific energy of the barley grains was 0.73 kWh.kg^{-1} with grains moisture of 13.4 %.

Geometric Mean Diameter (µm)

Figure 5 shows the effect of the moisture and grains type on the geometric mean diameter. increasing grains moisture from 8.2 to 13.4%, led to a significant increase in the geometric mean diameter of particles from 431.3 to 432.5 µm. the reason for this is that decrease in grain moisture during grinding leads to rapid and easy disintegration of grain parts, and thus the diameter of the particles decreases further this led to decreases of geometric mean diameter with low moisture, this result corresponds with Dabbour et al. (2015). Also Figure 5 shows that, changing grain type from wheat to barley then to maize caused a significant change in geometric mean diameter of particles, yellow corn, was superior by having the lowest average geometric diameter of the particles 429.0 µm compared to, barley and wheat, In which the highest geometric mean diameters of 432.7 and 433.9 µm were recorded. That is due to the crystalline nature of maize grains, which break down into small parts it is easier and faster when compared to other grains and their low fibre content, this is a result that agrees with Hasan et al. (2025).



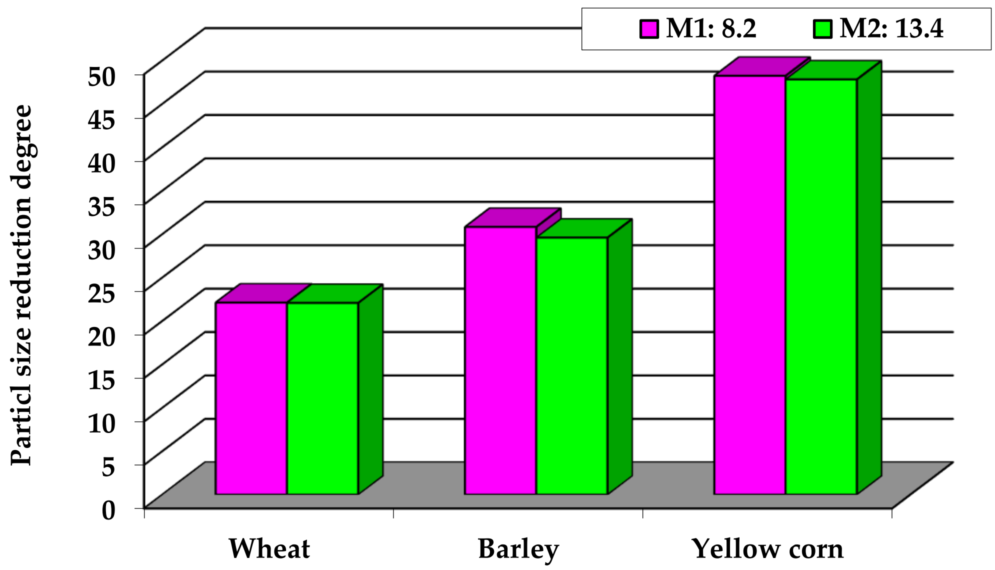
M: Grain moisture (8.2, 13.4%).

Figure 5. Effect of moisture and grain type on geometric mean diameter (µm)

On the interaction between the grain moisture and type of grains on the geometric mean diameter a significant effect of is shown in Figure 5. The lowest geometric mean diameter of particles reached 428.2 µm with moisture of grains 8.2 % and yellow corn grains. Whereas the highest geometric mean diameter of particles was recorded as 433.6 µm with the moisture of grains 8.2% and wheat grains.

Size Reduction Degree

Figure 6 shows the effect of moisture and grains type on the size reduction degree, it is clear that increasing grains moisture from 8.2 to 13.4% led to a significant decrease in the size reduction degree from 33.73 to 33.17, the reason for this is that increase in grain moisture led to a decrease in the grains hardness, this result corresponds with Dabbour et al. (2015). Also Figure 6 shows that changing of the type of grain from wheat to barley then to yellow corn, led to a significant effect in the size reduction degree, the yellow corn grains were distinguished by recording the highest size reduction degree was 48.03 compared to wheat and barley grains by the amount 30.22 and 22.10 respectively, the reason for this is the crystalline nature of maize grains, which break down into small parts easier and faster compared to other grains and their low fibre content. This is a result that agrees with Hasan et al. (2025).



M: Grain moisture (8.2, 13.4%).

Figure 6. Effect of moisture and grain type on particle size reduction degree (M: Grain moisture (8.2, 13.4%)

In addition, Figure 6 shows a significant effect of interaction between the grain moisture and grains type on the size reduction degree. The highest size reduction degree reached 48.24 with the moisture of grains 8.2% and yellow corn; whereas the lowest size reduction degree was recorded at 22.08 with the moisture of grains 13.4% and barley.

CONCLUSION and RECOMMENDATIONS

The results showed that when grain moisture was raised from 8.2 to 13.4%, there was no significant effect in specific capacity and specific energy, on the other hand a significant increase in the geometric mean diameter of grinding and decreased size reduction degree, with changing the grain type (wheat, barley and yellow corn) recorded a significant effect in all the indicators studied. The best results were achieved in the yellow corn experiment at the highest specific capacity of 2.80 $Kg.kWh^{-1}$, the least specific energy was 0.36 $kWh.kg^{-1}$, also highest geometric mean diameter was 428.2 μm, and the highest size reduction degree was 48.24 with grains moisture 8.2 %. It was concluded that the moisture and grain type are affecting factors on the grinding process and particle size.

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Conflict of Interest

The authors declare that they have no conflict of interest.

Authors Contribution

All authors contributed equally to this manuscript. BA, conducted the experiment and collected the data. AL, performed data analysis, writing, and review. PS, conducted the textual review.

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