Design and Fabrication of a Corn Hammer Mill with a Capacity of 120 kg/h for Household Farming

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ABSTRACT

This study presents the design, calculation, and fabrication of a corn hammer mill aimed at a theoretical capacity of 120 kg/h, specifically targeted at small-scale household poultry farming. Corn is a primary feed for poultry, and grinding it enhances digestibility and nutrient absorption. The machine was designed based on the physical and mechanical properties of corn and operates on the principle of impact milling. Kinematic and dynamic calculations determined a required hammer velocity of 28.56 m/s and a rotor speed of 2597 rpm, driven by a 3 kW electric motor. Experimental results indicated that the machine operates smoothly and produces high-quality feed, achieving a fine powder ratio of 94.4% with particle sizes suitable for poultry (0.5–1.5 mm). While the actual capacity reached 83.1–84.3 kg/h (approximately 83–84% of the target), the design provides a solid foundation for affordable and efficient agricultural processing equipment.

Keywords: *Corn, poultry, hammer mill, household farming.*

I. INTRODUCTION

The poultry industry is a cornerstone of global agricultural production, providing a critical source of protein for the growing world population. In developing economies such as Vietnam, poultry farming is predominantly characterized by small-scale, household-based operations, which contribute significantly to rural livelihoods. However, the economic efficiency of these enterprises is heavily influenced by feed management, as feed costs often represent 60% to 70% of total production expenses [1]. Among dietary components, yellow corn is the primary energy source, typically accounting for 30% to 50% of the total ration due to its high starch content and metabolizable energy.

To optimize the nutritional value of corn, mechanical processing is essential. Poultry cannot efficiently digest whole grains; thus, corn must be reduced to a specific particle size to increase the surface area available for enzymatic hydrolysis in the gastrointestinal tract. Research has demonstrated that feed particle size directly influences gizzard development, nutrient bioavailability, and the overall Feed Conversion Ratio (FCR) [2, 3]. For most poultry species, a particle size range of 0.5 mm to 1.5 mm is considered optimal to prevent selective feeding and ensure uniform nutrient intake. Smaller particles may lead to digestive issues or increased dustiness, while larger particles reduce the efficiency of nutrient absorption [4].

In the Vietnamese context, there is a significant technological gap regarding feed processing at the household level. While large-scale industrial mills utilize sophisticated, high-capacity machinery, smallholder farmers often lack access to equipment that is both affordable and technically efficient. Currently, many small-scale farmers rely on manual processing or low-quality generic grinders, which frequently produce inconsistent particle sizes and exhibit high energy consumption per unit of output. Furthermore, the lack of integrated safety features and the high cost of imported machinery remain major barriers to localized mechanization [5, 6]. There is, therefore, a clear demand for compact, robust, and cost-effective milling solutions tailored to the specific throughput requirements of household farms.

Among various milling technologies, the hammer mill is widely favored for its versatility and durability in processing cereal grains. The milling process involves a combination of high-speed impact and shear forces, where the final product size is primarily controlled by the screen aperture and rotor velocity. However, achieving a consistent output within the 0.5–1.5 mm range at a moderate capacity requires precise mechanical design and optimization of the grinding chamber components.

The objective of this study is to design and fabricate a specialized corn hammer mill with a target capacity of 120 kg/h, specifically engineered for household poultry farming. The design focuses on structural simplicity to facilitate local manufacturing and maintenance, while prioritizing operational safety and high-quality output. By providing a localized technological solution, this research aims to empower small-scale farmers to reduce feed costs and improve the sustainability of their poultry production systems.

II. Materials and Methods

A. Material Properties

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The physical properties of corn significantly influence the design. Corn has a moisture content typically ranging from 10% to 15%, a density of 1.25-1.35 g/cm?, and an average kernel size of 5-12 mm. The target output size is 0.5-1.5 mm. The image of the corn kernels used in the experiment is illustrated in the Figure 1.

Figure 1. *The image of the corn kernels used in the experiment*

B. Machine Structure and Milling Principle

The machine was designed as a hammer mill, consisting of a feeding hopper, a milling chamber (rotor, hammers, screen, and impact plates), a discharging mechanism, and a supporting frame. The working principle relies on high-speed impact: as the rotor spins, the attached hammers strike the corn kernels, breaking them apart until they are small enough to pass through the screen.

C. Design and Calculations

Mathematical modeling was used to determine the optimal parameters for the milling unit. Hammer Velocity: Based on multiple-impact theory, the required linear velocity for the hammers was calculated to be 28.56 m/s. Rotor and chamber: The optimal rotor diameter was designed at 210 mm with a width of 110 mm. The working clearance between the hammers and the screen was set to 3 mm. Hammers: The rotor features 16 rectangular hammers made of 5 mm thick steel, with dimensions of 50 x 20 x 5 mm. Power and Transmission: The required power for the milling process was calculated as 2.53 kW; thus, a standard 3 kW electric motor (1420 rpm) was selected. To achieve the required hammer velocity, a V-belt transmission system with a ratio of 0.54 was employed, producing a final rotor speed of 2597 rpm. Overall dimensions: The completed machine dimensions are 640 x 230 x 500 mm. A detailed summary of the primary design attributes and component specifications derived from the analytical modeling is presented in Table 1.

Table 1. A detailed summary of the primary design attributes and component specifications

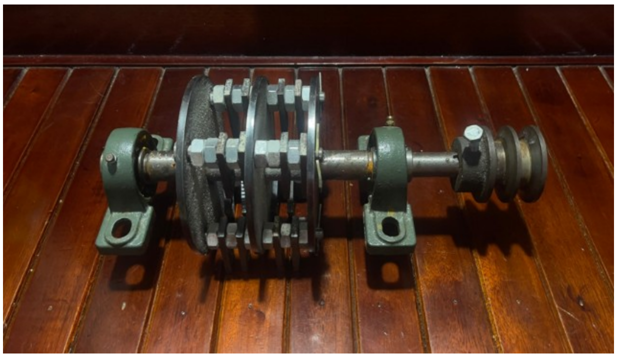
Parameter	Specification	Unit
Hammer Linear Velocity	28.56	m/s
Rotor Diameter / Width	210/110	mm
Hammer Quantity / Material	16/Steel	-
Working Clearance	3	mm
Calculated / Rated Power	2.53 / 3.0	kW
Transmission Ratio	0.54	-
Operational Rotor Speed	2597	rpm
Overall Dimensions	640×230×500	mm

III. Results and Discussion

A. Fabrication

Following the analytical design phase, the corn hammer mill was successfully fabricated and assembled, as illustrated in the final prototype. The machine's primary structure, including the grinding chamber and the rotor assembly, was constructed using high-strength steel to ensure structural integrity and durability under high-speed operational conditions. The final physical dimensions of the unit were measured at 640x230x500 mm, aligning perfectly with the theoretical footprint optimized for household-scale environments.

The primary structural and functional components of the milling unit, including the supporting frame, rotor assembly, high-speed hammers, and perforated screens, were fabricated using conventional manufacturing techniques. These processes integrated precision turning, metal cutting, and industrial welding to ensure dimensional accuracy, structural robustness, and operational stability under high-speed conditions. The detailed morphology and the final state of these fabricated components are illustrated in Figure 2. The final fabricated prototype of the corn hammer mill is presented in Figure 3.



2a. Working shaft and crushing hammer

2b. Feed hopper

2c. Grinding machine frame

2d. Grinding chamber

Figure 2. *The morphology of the fabricated parts*

Figure 3. *The final fabricated prototype of the corn hammer mill*

B. Performance Evaluation

Experimental Conditions: The performance of the fabricated corn hammer mill was evaluated through a series of experimental trials using yellow corn kernels with a standardized moisture content of 13–14%. To ensure operational consistency and assess stability, testing was executed in discrete batches of 1 kg, 2 kg, and 4 kg under a continuous feeding protocol.

Product Quality and Fineness: The final test iterations demonstrated superior comminution efficiency and output quality. The machine achieved a high-quality yield, with the fine powder fraction (target particle size) reaching 94.4%, while the coarse particle ratio was limited to a negligible 0.8%. Total material loss during the milling process was recorded at a minimal 4.8%. Beyond the quantitative metrics, the processed meal exhibited a high degree of physical uniformity and a smooth texture, meeting the stringent requirements for poultry feed production.

Throughput and Efficiency Analysis: The practical throughput of the machine was measured in the range of 83.1 to 84.3 kg/h, representing an operational efficiency of approximately 83% to 84% relative to the theoretical design target of 120 kg/h. This marginal discrepancy between the predicted and actual capacity can be attributed to the inherent dynamics of the manual feeding rate and the specific aerodynamic clearance between the perforated screen and the milling chamber walls. Despite this deviation, the observed capacity remains highly suitable for small-scale household applications.

C. Overall Operation

In terms of operational performance, the fabricated prototype demonstrated remarkable structural stability and mechanical reliability throughout the experimental trials. During high-speed milling cycles, vibration levels remained within strictly acceptable limits, a result primarily attributed to the precise dynamic balancing of the rotor assembly and the robust construction of the supporting frame. Furthermore, the low noise emission observed during operation is particularly advantageous for small-scale household environments, as it minimizes acoustic disruption during prolonged processing periods.

Nevertheless, to bridge the current discrepancy between the measured throughput and the theoretical target of 120 kg/h, further technical refinements are warranted. Future modifications should prioritize the optimization of the feeding mechanism; integrating an automated feeding system or an improved hopper design could ensure a more uniform and consistent mass flow rate into the grinding chamber. Additionally, investigating alternative hammer configurations—such as varying the hammer thickness or adopting a staggered arrangement—could significantly enhance the impact frequency and overall comminution efficiency. These targeted engineering adjustments are expected to elevate the machine's performance, ultimately enabling it to consistently achieve and maintain the designed capacity of 120 kg/h.

IV. Conclusion

A household-scale corn milling machine was successfully designed, calculated, and fabricated. The final prototype features a 3 kW motor, a 16-hammer rotor spinning at 2597 rpm, and an efficient belt drive system. Testing verified that the machine produces highly uniform feed (94.4% fine ratio) suitable for poultry, achieving a stable processing capacity of over 83 kg/h. This design provides a practical and economical solution to reduce manual labor for household farmers. Future optimizations should focus on enhancing the throughput to meet the exact 120 kg/h standard.

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