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Design and Construction of an Electric Motor-Driven Corn Shelling Machine and Productivity Analysis Compared to the Manual Shelling Method

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A B S T R A C T

Manual corn shelling, still widely practiced by smallholder farmers in Indonesia, is time-consuming, labor-intensive, and contributes to post-harvest losses of approximately 8% annually. This study aims to design, fabricate, and test the performance of an electric motor-driven corn shelling machine using a 200-Watt motor operating at 1236 rpm, a pulley and V-belt transmission system, and a shelling cylinder made from a 1.5-inch diameter pipe, and to compare its productivity with the manual shelling method. The research method followed the stages of literature study, design, fabrication, performance testing at three duration variations (5, 10, and 15 minutes), and quantitative data analysis. Test results show the machine produced 2.528 kg of shelled corn in 5 minutes, 6.040 kg in 10 minutes, and 8.280 kg in 15 minutes, with an average production capacity of 33.232 kg/hour. As a comparison, the manual method produced only 0.742 kg, 1.146 kg, and 1.324 kg over the same durations, equivalent to an average capacity of 7.03 kg/hour. This difference indicates an average productivity increase of 397.7% compared to the manual method. These results indicate that a small-capacity electric motor-based corn shelling machine is feasible as an appropriate technology solution at the household and small-to-medium farming enterprise scale to reduce post-harvest losses and lighten the operator's physical workload

INTRODUCTION

Corn (Zea mays L.) is one of Indonesia's strategic agricultural commodities, playing an important role in supporting national food security as the primary carbohydrate source after rice, as well as serving as a raw material for livestock feed and processing industries [1]. High national demand for corn drives increased production every year; however, this growth has not been matched by adequate post-harvest technology, so that constraints in the corn shelling stage are still frequently encountered at the farmer level [2].

Shelling is the process of separating corn kernels from the cob, which greatly determines the quality and quantity of the final product. Most farmers and home industries in Indonesia still shell corn manually by hand or with simple tools, a method that requires substantial labor, takes a long time, and produces low capacity, ranging from 20-25 kg/hour [3]. This manual method also contributes to significant post-harvest losses; several studies report that kernel damage due to improper post-harvest handling can reach 12-15%, while the shelling process itself contributes potential losses of about 8% of total annual production [3][4].

Mechanization of shelling through corn shelling machines has become a widely developed solution to address this problem. This machine works by utilizing a rotating cylinder that generates friction and impact forces against the corn cob so that the kernels are mechanically released [5]. Various studies report the advantages of shelling machines over manual methods, both in terms of production capacity, output uniformity, and reduced operator fatigue [4][6]. In terms of the drive system, the trend in shelling machine design has shifted from fuel-powered motors to electric motors due to their advantages in rotational stability, low noise levels, simple maintenance, affordable operating costs, and environmental friendliness [7].

Several previous studies have developed electric motor-based corn shelling machines with varying capacities, such as a 250-Watt motor at 712 rpm producing a capacity of 30 kg/hour [8], a ½ HP motor producing 25-30 kg/hour [7], and a solar panel-PLN hybrid system with a capacity equivalent to 45.6 kg/hour [9]. These studies confirm that the selection of motor power, rotational speed, and pulley-V-belt transmission ratio greatly determine the machine's final performance, with a correlation between rotational speed and working capacity reaching 0.977 [10]. Nevertheless, most commercial shelling machines are relatively expensive and less suitable for smallholder farmers, so an alternative design that is cheap, compact, and easy to operate is needed [7].

Based on this gap, this study aims to design, fabricate, and test a corn shelling machine driven by a 200-Watt electric motor using a technological engineering approach that emphasizes low cost, compact dimensions, and ease of operation for households and small farmers, and to quantitatively compare its productivity with the manual shelling method. The contribution of this research lies in the empirical test data on production capacity and the percentage increase in efficiency, which can serve as a reference for further development of small-scale shelling machines.

LITERATURE REVIEW

This study uses a technological engineering approach consisting of five main stages: literature study, design, machine fabrication, performance testing, and data analysis, as presented in the research flow diagram.

Literature Study and Design

A literature study was conducted on previous journals and publications regarding corn shelling machines, electric motor characteristics, and pulley-V-belt transmission systems as the basis for determining technical specifications. The design process included determining frame dimensions, component placement, the shelling mechanism, and calculation of power and shaft speed requirements.

Machine Specifications and Components

The machine was designed with compact dimensions: 34 cm high, 40 cm long, 17 cm upper width, and 20 cm lower width. The machine's main components consist of a single-phase AC electric motor with a power of 200 Watts and a rotational speed of 1236 rpm as the power source, a pulley and V-belt transmission system to transfer rotation to the shelling shaft, a shelling cylinder made from a 1.5-inch diameter pipe fitted with shelling fins/teeth, a frame made of angle iron and pipe, a hopper made of galvanized iron plate as the corn cob inlet, and bearings as shaft supports. The estimated total manufacturing cost of the machine was IDR 485,000, making it relatively affordable for small-scale enterprises.

Fabrication Process

The fabrication stage included measuring materials according to design specifications, cutting angle iron, pipe, and galvanized plate using a hand grinder, joining the frame through electric welding with RD 460 electrodes, and final assembly of moving components (motor, bearing, pulley, hopper) using a bolt-nut system to facilitate maintenance and component replacement.

Testing Procedure

Performance testing was carried out by running the machine using dried, husked corn. Corn cobs were fed into the hopper and pushed slowly toward the rotating shelling cylinder; after one side was shelled, the cob was turned over to shell the remaining side until all kernels were released. Testing was conducted at three duration variations, 5, 10, and 15 minutes and as a comparative control, manual shelling by an operator was also performed for the same durations. The shelling results (kernels and cobs) were weighed using a digital scale, and time was recorded using a stopwatch.

METHODOLOGY

Data Analysis

Test result data were analyzed quantitatively to obtain the machine's production capacity (kg/hour), which was compared with manual shelling capacity, and the percentage increase in efficiency was calculated. Production capacity was calculated using the following equation:

$$K = (W / t) \times 60 \ldots\ldots (1)$$

where K is production capacity (kg/hour), W is the weight of shelled corn (kg), and t is the test duration (minutes). The percentage increase in machine efficiency relative to the manual method was calculated using:

$$\eta = ((Km - Kn) / Kn) \times 100\% \text{ ...... (2)}$$

where η is the efficiency increase (%), Km is the machine capacity, and Kn is the manual capacity for the same duration.

RESULTS

Machine Design Results

The resulting corn shelling machine has a compact structure with dimensions of 34 cm high, 40 cm long, 17 cm upper width, and 20 cm lower width. The use of a 200-Watt electric motor at a speed of 1236 rpm, transmitted through a pulley and V-belt transmission, proved capable of driving the shelling cylinder stably and consistently throughout testing, without indication of transmission slippage or a significant reduction in rotational speed.

Machine Testing Results

Testing was conducted at three duration variations to observe the relationship between operating time and the amount of corn successfully shelled. The test results are presented in Table 1.

Table 1. Corn Shelling Machine Test Results

No	Test Duration	Kernel Weight (kg)	Cob Weight (kg)
1	5 minutes	2.528	0.500
2	10 minutes	6.040	0.628
3	15 minutes	8.280	1.608

The data in Table 1 show a consistent relationship between increased operating duration and increased amounts of shelled corn. At the 5-minute test, 2.528 kg was obtained, increasing to 6.040 kg at 10 minutes, and reaching 8.280 kg at 15 minutes. This consistent increase indicates that the 200-Watt electric motor at 1236 rpm was able to maintain stable rotation of the shelling cylinder throughout the test duration, so that the shelling process proceeded continuously without performance degradation.

Manual Shelling Test Results

As a comparison, manual shelling was performed for the same durations. The test results are presented in Table 2.

Table 2. Manual Shelling Test Results

No	Test Duration	Kernel Weight (kg)	Cob Weight (kg)
1	5 minutes	0.742	0.142
2	10 minutes	1.146	0.128
3	15 minutes	1.324	0.230

The manual shelling results were far lower than the machine at all test durations. In addition to requiring substantial physical effort, the manual method was also prone to performance decline due to operator fatigue, so that the increase in output from the 10th to the 15th minute was relatively small (from 1.146 kg to 1.324 kg), unlike the more proportional increasing trend seen with the machine.

Comparison of Machine and Manual Shelling Results

Table 3. Comparison of Machine and Manual Shelling Results

No	Test Duration	Machine (kg)	Manual (kg)
1	5 minutes	2.528	0.742
2	10 minutes	6.040	1.146
3	15 minutes	8.280	1.324

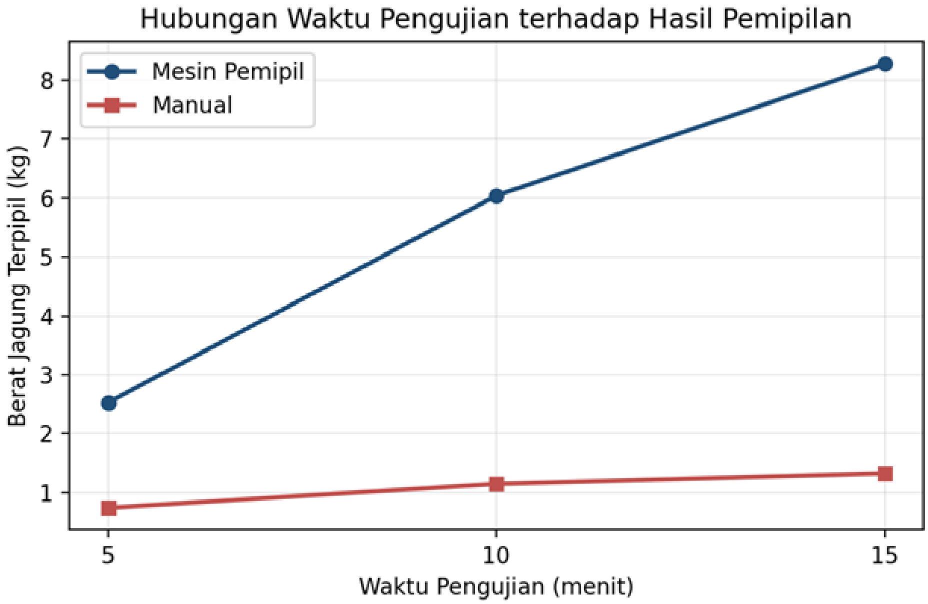

Figure 1. Relationship between Test Duration and Shelling Output (Machine vs Manual)

Figure 1 shows that the slope of the machine's curve is much steeper than that of the manual method, indicating a much higher shelling rate per unit time for the machine. At a duration of 15 minutes, the machine produced 8.280 kg of shelled corn, while the manual method produced only 1.324 kg a difference of 6.956 kg for the same test duration.

Production Capacity Analysis

The machine's production capacity was calculated using Equation (1) for each test duration, as follows:

K5 = (2.528 / 5) × 60 = 30.336 kg/hour
K10 = (6.040 / 10) × 60 = 36.240 kg/hour
K15 = (8.280 / 15) × 60 = 33.120 kg/hour

The machine's average production capacity was obtained as follows:

K average = (30.336 + 36.240 + 33.120) / 3 = 33.232 kg/hour

Using the same calculation method, the average manual production capacity was 7.03 kg/hour (8.904; 6.876; and 5.296 kg/hour at durations of 5, 10, and 15 minutes, respectively). A summary of the productivity of both methods is presented in Table 4.

Table 4. Machine and Manual Productivity (kg/hour)

No	Test Duration	Machine Capacity (kg/hour)	Manual Capacity (kg/hour)
1	5 minutes	30.336	8.904
2	10 minutes	36.240	6.876
3	15 minutes	33.120	5.296
	Average	33.232	7.030

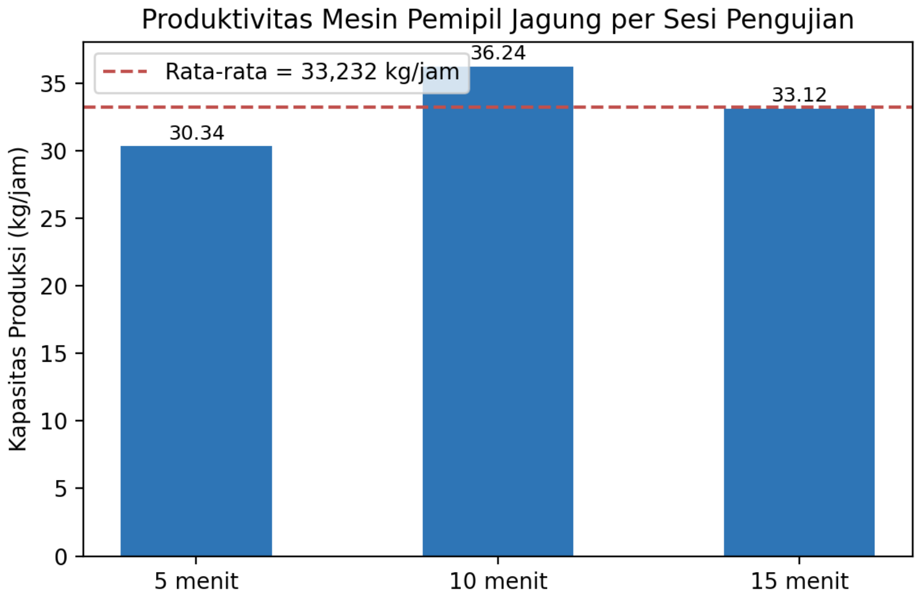

Figure 2. Productivity of the Corn Shelling Machine per Test Session

The variation in machine capacity across sessions (30.336-36.240 kg/hour) is relatively small and remains within a reasonable range due to non-mechanical factors such as variation in cob density and the technique used to feed corn into the hopper, so the average of 33.232 kg/hour can be considered representative of the machine's actual capacity.

Efficiency Improvement of the Machine over the Manual Method

The efficiency improvement was calculated using Equation (2) based on the capacity at each test duration:

$$\eta 5 = ((30.336 - 8.904) / 8.904) \times 100\% = 240.5\%$$

$$\eta 10 = ((36.240 - 6.876) / 6.876) \times 100\% = 427.1\%$$

$$\eta 15 = ((33.120 - 5.296) / 5.296) \times 100\% = 525.4\%$$

The average efficiency improvement of the machine over the manual method reached approximately 397.7%, or in other words, the machine's capacity was nearly 4.7 times that of the manual method. This finding is consistent with previous studies that also reported significant productivity increases for electric motor-driven shelling machines compared to manual methods [3][6], and reinforces the indication that the continuous rotation of the shelling cylinder together with the consistent friction force generated by the electric motor are the main factors behind the machine's superiority.

DISCUSSION

Overall, the test results prove that the 200-Watt electric motor-driven corn shelling machine with a speed of 1236 rpm is able to operate stably and significantly increase corn shelling productivity compared to the manual method. The average production capacity of 33.232 kg/hour achieved by this machine is comparable to, and even exceeds, several similar studies with equivalent motor power, such as a 250-Watt motor at 712 rpm producing a capacity of 30 kg/hour [8] and a ½ HP motor producing 25-30 kg/hour [7], indicating that the pulley-V-belt transmission design and shelling cylinder geometry used in this study are quite effective. This result also supports the finding of a strong correlation (0.977) between rotational speed and working capacity reported in previous research [10]: because the 1236 rpm rotational speed of the motor used in this study is relatively high compared to the two reference machines above, the shelling cylinder is able to generate more frequent friction and impact cycles against the corn cob per unit time, which directly translates into a higher kernel release rate without requiring a larger motor.

When compared with the solar panel-PLN hybrid shelling system that achieved a capacity of 45.6 kg/hour [9], the machine developed in this study is admittedly lower in absolute capacity. However, this comparison needs to be viewed proportionally: the hybrid system relies on a more complex power configuration and a higher investment cost, whereas the machine in this study only requires a single 200-Watt motor and an estimated manufacturing cost of IDR 485,000, far below typical commercial machine prices. This indicates a favorable capacity-to-cost ratio, positioning the machine as a rational choice for farmers who prioritize affordability and simplicity of operation over maximum throughput. In other words, the slightly lower capacity compared to the hybrid system is an acceptable trade-off given the substantial reduction in construction complexity and cost.

In addition to its capacity advantage, the use of the machine also reduces the operator's physical workload, since the shelling energy is supplied by the electric motor rather than repeated manual hand strength as in the manual method. This is consistent with findings that manual shelling risks causing physical fatigue that reduces work productivity over time [3], a pattern that is also clearly visible in this study's own data: the increase in manual shelling output slowed markedly between the 10th and 15th minute (from 1.146 kg to 1.324 kg), whereas the machine's output continued to rise in a near-proportional manner. This suggests that beyond simply increasing capacity, mechanization also helps sustain a more consistent work rate over longer operating durations, which is particularly relevant during the harvest season when large volumes of corn must be processed within a limited time. Reducing reliance on repetitive manual gripping and twisting motions may also lower the risk of hand and wrist strain among operators, although this study did not directly measure ergonomic or musculoskeletal load, and this remains an area for further investigation.

From an economic and practical standpoint, the machine's compact dimensions (34 × 40 × 17-20 cm) and relatively low manufacturing cost (IDR 485,000) further support the feasibility of applying this machine at the household and small-to-medium farming enterprise scale, in line with the direction of small-scale shelling machine development widely recommended in previous literature [7]. Using the average capacity difference of approximately 26.2 kg/hour between the machine and the manual method, a smallholder farmer processing even a moderate daily volume of corn could recover the estimated construction cost within a relatively short period through labor-time savings alone, making the machine an economically attractive investment even without accounting for the additional benefit of reduced post-harvest losses. This affordability also directly addresses the gap identified in the introduction, namely that most commercial shelling machines remain too expensive and impractical for small-scale farmers [7].

Nevertheless, this study still has limitations, including the absence of measurements of kernel damage/integrity after shelling and electrical energy consumption efficiency, as well as the lack of test data across variations in moisture content and cob size, both of which are known to influence shelling efficiency and grain quality in the field. The absence of a formal ergonomic or noise-level assessment during machine operation is a further limitation, since operator comfort and safety are important considerations for practical adoption. Additional data of this kind are needed to strengthen the feasibility of publication in a SINTA-accredited national journal, given that reviewers generally consider product-damage quantification and energy efficiency as important aspects in evaluating agricultural machine performance. Addressing these gaps in future work would also allow a more complete cost-benefit and technology-adoption analysis, strengthening the case for wider dissemination of this machine design among smallholder farming communities.

CONCLUSIONS AND RECOMMENDATIONS

A corn shelling machine driven by a 200-Watt electric motor at a rotational speed of 1236 rpm was successfully designed and fabricated using a pulley and V-belt transmission system and a shelling cylinder made from a 1.5-inch diameter pipe. Test results show an average production capacity of 33.232 kg/hour, far higher than the manual shelling capacity, which reached only an average of 7.03 kg/hour — equivalent to an average efficiency increase of 397.7%. The machine's compact dimensions and affordable manufacturing cost (IDR 485,000) make it a feasible appropriate-technology solution to support the corn post-harvest process at the household and small-to-medium farming enterprise scale.

FURTHER STUDY

Further research is recommended to measure kernel damage levels, energy consumption efficiency, and economic feasibility in order to comprehensively complete the machine's performance data.

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