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Research Article

Efficiency of the Cattle Feed Chopper Machine

Oknovia Susanti[1a], Rispandi[2a], Muhammad Ghazi Al Ghifary[3a]*

Department of Mechanical Engineering, Universitas Andalas, Limau Manis, Padang 25163

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E-mail: oknovia.s@eng.unand.ac.id

A B S T R A C T

Feed efficiency is very important because feed costs can reach up to 80% of total production costs. In addition, farmers face limited feed availability at the moment, with a silage requirement of around 3-5 kg per head of cattle per day. This condition complicates large-scale feed preparation and underscores the need for an effective feed chopper. This study evaluated the performance of a feed chopper developed on the farm by assessing chopping speed, chop quality, chop length percentage, fuel consumption, chopping capacity, noise level, and overall machine efficiency across different elephant grass types and load treatments. The results showed that controlled chopping using dry elephant grass (moisture content 20.3%) at 3600 rpm produced the best performance, with an average chopping capacity of 806.08 kg/hour, a proportion of chopped material ≤ 50 mm of 73%, fuel consumption of 1.23 L/hour, a noise level of 94.34 dB, a chopping capacity efficiency of 79%, and a fuel consumption efficiency of 69%. This confirms that controlled chopping of dry elephant grass yields the highest efficiency compared to uncontrolled chopping or chopping wet grass.

1. INTRODUCTION

Improving efficiency in cattle feed preparation is a crucial issue in livestock production and agricultural mechanization. In livestock systems, feed availability, feed quality, and processing efficiency are key factors affecting livestock productivity and long-term sustainability. Various studies report that feed costs can reach 70–80% of total production costs in cattle farming systems, especially in small- to medium-scale businesses in developing countries. (1)(2)(3). Therefore, inefficiency in feed preparation directly increases production costs and reduces farmers' competitiveness (4)(5)(6).

In Indonesia, cattle farming plays a strategic role in meeting national animal protein needs, supporting rural livelihoods, and strengthening food security. However, this sector is still dominated by small-scale farmers who rely on traditional feeding practices and manual labor. Fresh forage and silage are the main sources of feed, but their utilization is often suboptimal due to limited processing capacity (7). One important step in feed preparation is chopping forage into smaller, more uniform pieces, which can improve digestibility, accelerate the fermentation process in silage production, and facilitate homogeneous mixing with concentrates (8)(9). Therefore, mechanization at this stage is essential to improve feed efficiency and reduce labor intensity (10).

Feed chopper machines represent an important form of appropriate technology designed to address these challenges. By converting bulky forage materials into uniformly chopped feed, these machines

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improve handling efficiency, feeding consistency, and nutrient utilization. Within the context of sustainable livestock systems, the adoption of feed chopper machines aligns with broader goals of reducing production costs, increasing productivity, and improving resource efficiency.

Recent developments in agricultural machinery, particularly in small-scale feed processing equipment, have focused on improving capacity, energy efficiency, and operational reliability. Advances in blade design, transmission systems, and power sources have enabled feed chopper machines to achieve higher throughput while maintaining consistent cutting quality. Internal combustion engines and electric motors are commonly used as prime movers, with power ratings typically ranging from 3 HP to 10 HP, depending on the intended operating scale.

Several studies have highlighted the importance of optimizing machine parameters, including blade configuration, rotational speed, feed rate, and material characteristics, to enhance chopping performance. Improved blade geometry and cutting mechanisms have been shown to reduce energy consumption while increasing chopping capacity. Additionally, recent research has emphasized the need for machines that are compatible with locally available forage types, such as elephant grass (11), which is widely used in Indonesian cattle farming.

The integration of appropriate technology principles has also gained attention, particularly for rural applications. Machines are increasingly designed to be simple, affordable, easy to maintain, and adaptable to local conditions. These developments underscore the growing recognition that technological solutions must not only deliver high performance but also be practical and accessible for smallholder farmers.

Previous research on feed chopper machines has employed various approaches to evaluate machine performance, including capacity analysis, energy consumption measurement, cutting efficiency, and operational cost assessment. Many studies focus on the relationship between engine power, rotational speed, and chopping capacity, demonstrating that higher power inputs generally result in increased throughput, although not always in a linear manner (12).

According to Tafsin (11), He has researched the role of feed choppers in improving feed preparation efficiency on small-scale cattle farms and reported a significant reduction in labor time and operating costs compared to manual chopping methods. Their findings confirm that mechanical feed preparation allows for more consistent feed provision and supports better livestock nutrition management. Nipa also reported similar conclusions (13) and Dalmis (14), who emphasized that forage choppers significantly increase productivity and reduce the physical workload of farmers (12), developed a feed chopper machine powered by a 5.5 HP gasoline engine and reported a chopping capacity of approximately 200 kg/h. While this capacity represented an improvement over manual methods, the authors noted that it may still be insufficient to meet the demands of farms with larger herd sizes or continuous feeding requirements. Comparable capacity ranges were also reported in studies by (15) and (16), indicating that machine performance is strongly influenced by blade configuration, rotational speed, and feed material characteristics.

Other researchers have expanded performance evaluation by incorporating efficiency metrics such as specific energy consumption, mechanical efficiency, and overall system efficiency (17). These studies underline that increasing machine capacity without considering energy efficiency may lead to higher operational costs. Furthermore, Andrean et al (18) and Liza et al. (19), demonstrated that forage particle size significantly affects digestibility, intake, and silage quality, reinforcing the importance of effective chopping mechanisms.

In the broader context of livestock production systems, sustainable feed processing has been linked to improved resource utilization and reduced environmental impact (20). Appropriate technology adoption, particularly in developing countries, has also been recognized as a key driver of agricultural productivity and rural development (21).

Although substantial progress has been made in the development of feed chopper machines, several gaps remain in the existing literature. First, many studies report machine capacity without thoroughly analyzing efficiency parameters, such as the relationship between load variation, power utilization, and operational effectiveness. Second, performance evaluations are often conducted under controlled laboratory conditions, which may not accurately reflect actual farm environments.

In the specific context of Galanggang Raya, previous observations indicate that feed preparation remains a bottleneck in daily operations. Farmers are required to supply approximately 3–5 kg of silage and 1–2 kg of concentrate per animal per day. Yet, the continued reliance on manual tools limits production continuity and leads to nutritional imbalances. Although a feed chopper machine has been previously developed and implemented at this location, its performance efficiency under real operating conditions has not been systematically evaluated (22).

Furthermore, existing machines with capacities around 200 kg/h may not adequately meet local demand, particularly during peak feeding periods (23). There is therefore a need for a comprehensive performance evaluation that considers capacity, efficiency, and practical usability to determine whether the machine can effectively support farm operations or requires further optimization.

The novelty of the present study lies in its focus on evaluating the operational efficiency of an existing feed chopper machine under actual field conditions, rather than solely on design and fabrication. Unlike previous studies that primarily report capacity figures, this research integrates performance analysis with efficiency assessment, providing a more holistic understanding of machine effectiveness.

By conducting a detailed evaluation, this study offers context-specific insights into how feed chopper machines perform in smallholder farming environments. The findings contribute novel empirical data on machine efficiency, capacity adequacy, and operational feasibility, which are often underreported in the literature. This approach enhances the practical relevance of the research and supports evidence-based decision-making for technology adoption and improvement.

The main objective of this study is to evaluate the performance and efficiency of the previously developed cattle feed chopper. Specifically, the research aims to assess the performance of the cattle feed chopping machine in terms of chopping speed, output length percentage, energy consumption, chopping capacity, machine noise level, and machine efficiency under actual field conditions, rather than solely emphasizing design and fabrication. Unlike previous studies that primarily report capacity figures, this research integrates performance analysis with efficiency assessment, providing a more holistic understanding of machine effectiveness.

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2. MATERIALS AND METHODS

2.1. Time and Location of the Study

This study was conducted over a three-day experimental period from 26 September to 28, 2025. All experimental activities were carried out in Nan Balimo Village, Tanjung Harapan District, Solok

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City, Indonesia. This location was selected because it represents typical smallholder cattle farming conditions in the region and has previously implemented a feed chopper machine for daily feed preparation. Direct experimentation on the farm enabled evaluation of the machine's performance under real operating conditions, thereby increasing the practical relevance and applicability of the results.

2.2. Tools and Materials

The tools used in this study were selected to ensure accurate measurement of mechanical, operational, and performance parameters of the feed chopper machine. The primary equipment was a cattle feed chopper machine powered by a gasoline engine. Supporting measuring instruments included a weighing scale to measure feed mass, a tachometer to measure the rotational speed of the pulley and shaft, a caliper for dimensional measurements, and a stopwatch to record chopping time. A measuring tape was used to determine physical dimensions, and a moisture meter was used to measure the forage's moisture content before testing. A sound level meter was used to measure machine noise during operation, providing information on operational comfort and safety. Fuel consumption was measured with a measuring cylinder and hose to accurately quantify gasoline usage during each test.

The materials used in this research consisted of Elephant grass (Pennisetum purpureum), which is commonly used as cattle feed in Indonesia, and gasoline as the fuel for the feed chopper. Napier grass was chosen because it represents the dominant forage type available at the study location and reflects the actual feeding practices of local farmers.

2.3. Research Parameters

Several key parameters were observed to comprehensively evaluate the performance and efficiency of the feed chopper machine. These parameters included pulley rotational speed, chopping time, and the quality of the chopped output, assessed by uniformity and suitability for feed and silage preparation. The machine noise level was measured to assess operational comfort and potential occupational exposure. Fuel consumption was recorded to determine fuel usage during the chopping process, which was subsequently used to calculate fuel efficiency. The load slip was evaluated to analyze the relationship between the applied load and power transmission performance. In addition, chopping capacity efficiency was determined to assess the machine’s ability to process forage relative to time and input conditions.

2.4. Equipment Figure

Figure 1 illustrates the cattle feed chopper machine used in this study, including its main components and overall configuration, which served as the primary equipment evaluated during the experimental testing.



Figure 1. Cattle feed chopper machine

2.5. Data Analysis

The data obtained from the experimental tests were analyzed using mathematical and statistical approaches. Mathematical analysis was applied to calculate performance indicators such as chopping capacity, fuel efficiency, and load slip. Statistical analysis was used to compare the effects of different material conditions, load variations, and feeding methods on machine performance. The results of the analysis were then interpreted to evaluate the overall efficiency and suitability of the feed chopper machine for use in smallholder cattle farming operations.

2.6. Testing Procedure

The experimental testing procedure was conducted in a systematic and structured manner. Testing began with measuring forage moisture content using a moisture meter to classify the material into two conditions: dry grass with moisture content less than or equal to 30% and wet grass with moisture content greater than or equal to 30%. This classification was intended to represent variations in material conditions commonly encountered during feed preparation.

After moisture classification, the elephant grass was weighed on a scale to obtain predetermined load values ranging from 3 kg to 15 kg. These load variations were selected to represent different feeding rates and operational demands placed on the machine. The weighed forage was then introduced into the feed chopper machine through the hopper using two different feeding methods. The first method was a controlled load condition, in which the grass was gradually fed into the hopper and manually pushed to regulate the feeding rate. The second method was an uncontrolled load condition, in which the grass was tied into bundles and directly inserted into the hopper without controlling the feeding rate.

During the chopping process, the machine was operated under steady conditions, and relevant parameters, including chopping time, pulley rotational speed, fuel consumption, and noise level, were measured. Upon completion of each test, the chopped output was collected and evaluated for quality and uniformity. This procedure was repeated for each combination of moisture conditions, load variations, and feeding methods to ensure data consistency and reliability.

3. RESULTS AND DISCUSSION

This section presents the experimental results and their discussion in an integrated manner to evaluate the performance of the tested cattle feed chopper. The discussion emphasizes the main findings relevant to the study's objectives, particularly the effects of material conditions (dry and wet grass), feeding methods (controlled and uncontrolled), and load variations on machine performance. The evaluated performance indicators include rotational speed, transmission slip, fuel consumption, chopping quality, noise level, power requirement, and overall machine efficiency. Excessive raw data and detailed calculations are not presented; instead, the results are interpreted to highlight meaningful performance trends and operational implications.

3.1. Drive Motor

The drive motor used in this machine is a gasoline-powered engine with an air-cooled system and a four-stroke QHV single-cylinder configuration with a horizontal shaft, designed to deliver reliable, stable performance during operation. This engine produces a maximum power output of 7.5 horsepower at 3600 revolutions per minute, with a peak torque of 12.4 N·m at 2500 revolutions per minute. In addition, the engine is equipped with a 3.1-liter fuel tank for continuous operation and a 0.6-liter oil reservoir to ensure proper lubrication and engine durability.

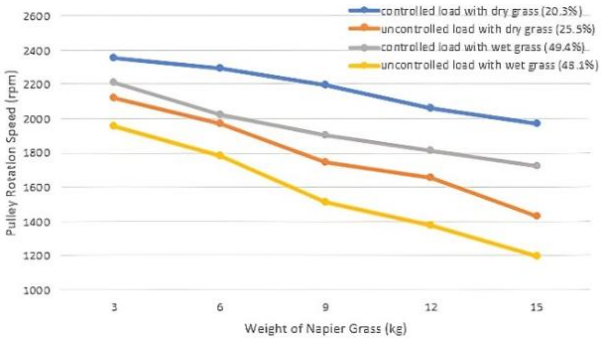


Figure 2. The effect of load on pulley rotational speed

Based on Figure 2, the rotational speed of the driven pulley decreases as the load of elephant grass increases. At the lowest load (3 kg), the pulley speed remains high, ranging from 1958 rpm to 2350 rpm. However, at the highest load (15 kg), the speed drops significantly, from 1973 rpm to 1193 rpm. This indicates that higher loads create greater resistance on the cutting blades, causing the engine speed to decrease.

When comparing the load variations, the controlled load with dry grass (20.3% moisture) produces the highest speed across all load levels. This is because

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dry material has lower moisture content, making the fibers easier to cut, and the controlled feeding ensures stable loading, allowing the machine to maintain its speed more effectively.

In contrast, the uncontrolled load with wet grass (48.1% moisture) results in the lowest speeds. The high moisture content makes the grass tougher and heavier to cut, and the uncontrolled feeding causes fluctuating loads on the engine, which quickly reduces its rotational speed.

3.2. Transmission

The machine uses two pulleys in the transmission system: a driving pulley and a driven pulley. The driving pulley has a diameter of 68 mm, while the driven pulley has a diameter of 102 mm, resulting in a pulley ratio of 1:1.5.

3.3.Pulley and Belt Transmission

In this study, power is transmitted from the driving to the driven pulley using a Mitsubishi A-61 V-belt with a width of 12 mm, selected to ensure efficient power transfer, reliable traction, and stable system operation during the machine's operation.

Table 1. Pulley size and rotational speed

Component	Size (mm)	Rotational Speed (rpm)
Pulley 1	68	3600
Pulley 2	102	2400

Based on Table 1, the outer diameter of the pulley affects its rotational speed. The first pulley, with an outer diameter of 68 mm, rotates at 3600 rpm, while the second pulley, with an outer diameter of 102 mm, rotates more slowly at 2400 rpm. This is supported by (7), who states that the smaller the diameter of the driven pulley, the higher the rotational speed produced. Conversely, the larger the pulley diameter, the lower the rotational speed generated.

3.4. Load Slip

Slip is a condition in which the belt fails to transmit power from the driving to the driven pulley. This occurs when the pulley rotates, but the belt does not follow. A slip occurs when there is insufficient friction between the belt and the pulley. This lack of friction is usually caused by belt looseness in the transmission system, which prevents the belt from gripping the pulley properly. Slip can also occur when the load applied to the machine exceeds its capacity.

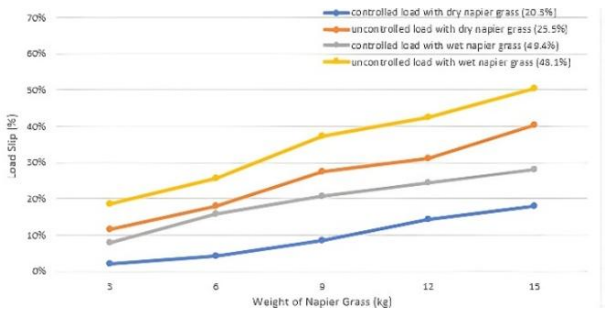


Figure 3. The effect of load on belt slippage

Based on Figure 3, load slip increases as the chopping load becomes heavier. This is reasonable because the more elephant grass inserted, the greater the resistance acting on the cutting blades, which increases the load on the transmission system and causes more slip.

The controlled dry-load condition (20.3%) produces the lowest slip, ranging from 2% to 18%. This indicates that with dry material and stable feeding, the power transmission works more smoothly and efficiently. The controlled wet-load (49.4%) and uncontrolled dry-load (25.5%) conditions exhibit moderate slip, with maximum slips of 28% and 40%, respectively. The uncontrolled wet-load condition (48.1%) has the highest slip, reaching up to 50% at a 15 kg load. This occurs because wet material is tougher to cut, and uncontrolled feeding causes the machine speed to fluctuate, sharply increasing slip. Overall, the slip trend across all variations shows that as the load increases, transmission stability decreases. Therefore, choosing the optimal load is important to reduce energy losses.

3.5. Chopping Process

3.5.1 Fuel Consumption

The fuel used in this study was gasoline. Fuel consumption was measured by connecting a hose

from the engine's fuel valve to another hose attached to a measuring cylinder filled with gasoline. Each decrease in the gasoline level inside the measuring cylinder was recorded to determine the machine's fuel consumption.

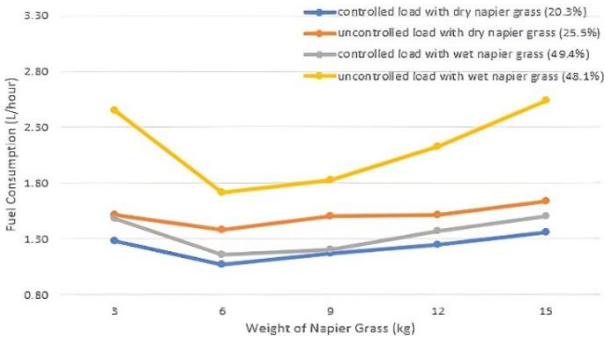


Figure 4. The effect of load on fuel consumption

Based on Figure 4, fuel consumption increases as the chopping load becomes heavier. This happens because a larger mass of grass requires more power for the blades to cut through it, which, in turn, increases fuel consumption.

The uncontrolled wet-load condition (48.1%) produces the highest fuel consumption, reaching 2.54 L/hour at a 15 kg load. This is because wet grass is tougher to cut, and the uncontrolled feeding causes unstable machine performance, requiring more energy. The controlled wet-load (49.4%) and uncontrolled dry-load (25.5%) conditions show moderate fuel consumption, with final values of 1.50 L/hour and 1.64 L/hour at a 15 kg load. The controlled dry-load condition (20.3%) has the lowest fuel consumption, ranging from 1.07 L/hour to 1.36 L/hour. This indicates that controlled feeding and dry material reduce the machine's workload, making fuel use more efficient.

3.5.2 Quality of Chopped Output

The percentage calculation of chopped output length is used to determine how much of the chopped material meets the standard size. This process is carried out by separating the chopped grass by cut length, weighing each group, and comparing each group's weight to the total weight of the chopped material. The resulting percentage indicates how efficiently the machine produces pieces of the desired size. The higher the percentage, the better the machine's performance. This percentage can be calculated using the following equation (18).

$$POL = \frac{W_1}{W_1+W_2} x100\% \quad (1)$$

Where,
POL = Percentage of output length (%)
W1 = Weight of chopped output ≤ 50 mm (gram)
W2 = Weight of chopped output ≥ 50 mm (gram)

The quality of the chopped output is determined by the percentage of pieces that meet the standard size of ≤ 50 mm. A higher percentage means better chopping quality for livestock feed.

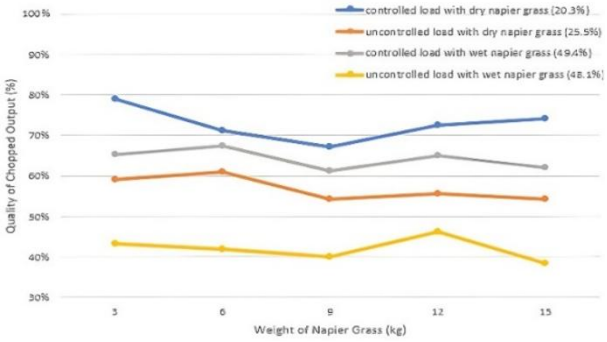


Figure 5. The effect of load on quality of output

Based on Figure 5, the percentage of chopped output varies with material condition and feeding method. In general, the quality of the chopped output tends to decrease as the load increases. However, at certain loads (12 to 15 kg), some variations show a slight increase because the machine operates more steadily as it approaches its optimal capacity.

The controlled dry-load condition (20.3%) produces the best quality, with 67% to 79% of the chopped material meeting the standard size. This is because the low moisture content makes the fibers easier to cut, and controlled feeding helps keep the machine stable. The controlled wet-load condition (49.4%) yields medium results, ranging from 61% to 67%. Even though the material has high moisture content, controlled feeding keeps the chopping process stable, resulting in better quality than under uncontrolled conditions.

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The uncontrolled dry-load condition (25.5%) yields lower percentages (54% to 61%) than the controlled condition, indicating that the feeding method significantly affects chopping quality. The uncontrolled wet-load condition (48.1%) produces the lowest quality, with only 39% to 46% meeting the standard size. High moisture content makes the grass tougher and more elastic, and uncontrolled feeding results in uneven cutting.

3.5.3 Machine Noise

Machine noise is an important parameter when evaluating the performance of a feed chopper because it affects operator comfort and must comply with safe noise exposure limits set by occupational health standards (OSHA recommends a limit of 90 dB for an 8-hour workday).

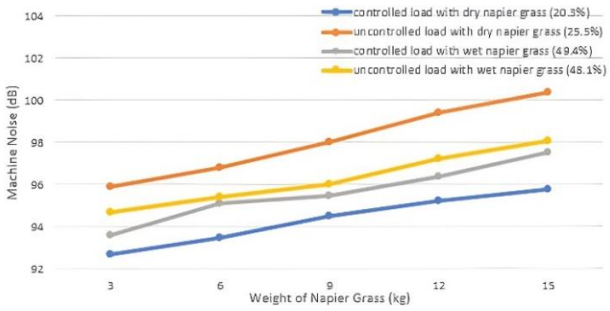


Figure 6. The effect of load on machine noise

Based on Figure 6, the machine's noise level increases with chopping load across all material conditions and feeding methods. This occurs because a larger amount of grass creates higher cutting resistance and friction between the blades and the material, resulting in stronger vibrations and louder noise.

The controlled dry-load condition (20.3%) produces the lowest noise level, ranging from 92.7 dB to 95.8 dB. This indicates that controlled feeding helps the machine operate more smoothly with reduced vibration. Wet-load conditions, both controlled and uncontrolled, produce medium noise levels (93.6-98.1 dB). The high moisture content in wet grass makes the material tougher and more resistant to cutting, which increases friction and blade noise. Overall, controlled dry feeding results in the lowest noise level because the machine operates more steadily and generates less vibration.

3.5.4 Power

Power is defined as the amount of work produced by a machine over a certain period of time. In an internal combustion engine, power is generated by combustion in the cylinder. This power results from the reciprocating motion of the piston within the cylinder. During this process, the chemical energy of the fuel is converted into mechanical energy acting on the piston. Therefore, engine power represents the amount of work performed by the engine per unit time. The unit of power used in this study is horsepower (HP).

The prime mover in this system is an internal combustion engine with an air-cooled, four-stroke QHV configuration and a single-cylinder, horizontally oriented shaft. The engine has a maximum power output of 7.5 HP at 3600 rpm. Therefore, the power acting in the system can be calculated using the following equation. (24).

$$P = \eta_f \ \dot{m}_f \ Q_{HV} \tag{2}$$

Where:
QHV = heating value of the fuel (kJ/kg). Based on Dharmanasa (16)The QHV value of Pertalite gasoline is 44.260.12 kJ/kg.
η_f = thermal efficiency

Therefore, the thermal efficiency can be determined using the following equation(16).

$$\eta_f = \frac{3600\ kj/kwh}{sfc\ x\ Q_{HV}} \tag{3}$$

Where:
sfc = specific fuel consumption obtained from the specifications of the engine used, which is 360 g/kW·h.
$\dot{m}f$ = fuel mass flow rate in kg/s, which can be determined using the following equation(16)

$$\dot{m}_f = \rho\ x\ FC\ x\ \frac{1\ m^3}{1000\ L}\ x\ \frac{1\ hour}{3600\ s} \tag{4}$$

Where:
ρ = density of gasoline, according to the specification data sheet from Pertamina, is 740 kg/m³ for Pertalite gasoline.
FC = Fuel Consumption (L/Hour)

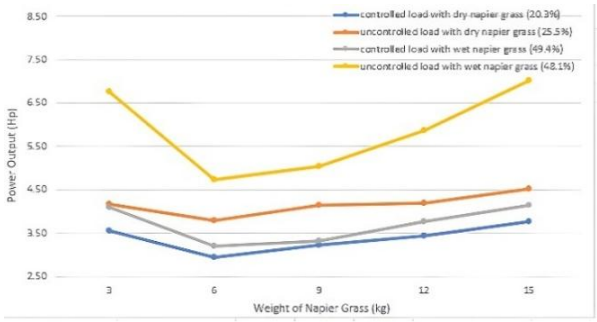


Figure 7. The effect of load on Power Output

Based on Figure 7, variations in load and material condition significantly affect the engine's power output. Under the controlled dry load condition (20.3%), the power usage exhibits a specific fluctuation pattern. Power decreases from 3.54 HP at a load of 3 kg to 2.94 HP at 6 kg. This reduction occurs because at low loads, the available engine power is not yet fully utilized. The power then gradually increases, reaching 3.76 HP at a load of 15 kg. This increase indicates that at medium-to-high loads, the engine operates more effectively in handling the material mass, resulting in higher power consumption.

Under the uncontrolled dry load condition (25.5%), the power requirement is relatively higher than that of the controlled dry condition, starting at 4.08 HP at a load of 3 kg. The power decreases to its lowest value of 3.20 HP at 6 kg, then increases again to 4.13 HP at 15 kg. This trend indicates that, although the material feed is uncontrolled, there is an optimal load (6 kg) at which power absorption is minimal. However, further increases in load to 15 kg require more engine power for the chopping process.

For the controlled wet load condition (49.4%), the power used is generally higher than in both dry conditions, reaching 4.18 HP at 3 kg and decreasing to 3.79 HP at 6 kg. The power then increases steadily, reaching 4.51 HP at 15 kg. This overall increase in power consumption is influenced by the high moisture content of the wet grass, which causes the engine to require more power to overcome additional resistance, such as increased friction.

The uncontrolled wet-load condition (48.1%) has the highest power values among all variations. The power starts at 6.76 HP at a load of 3 kg, decreases sharply to 4.72 HP at 6 kg, and then increases sharply again to a maximum value of 7.01 HP at 15 kg. The very high power demand at higher loads indicates that the combination of high moisture content and uncontrolled material volume forces the engine to work much harder, resulting in near-maximum engine power utilization as the load increases.

3.6. Machine Efficiency Level

3.6.1 Fuel Efficiency

Fuel efficiency describes how much feed can be chopped per liter of fuel consumed. This parameter assesses how efficiently the machine uses fuel during chopping. The formula for fuel efficiency is shown below:

$$\eta Fuel = \frac{FC_{used}}{FC_{initial}} x100\% \quad (5)$$

Where:
FC_{used} = the amount of fuel used during testing with load (L/hour)
$FC_{initial}$ = the amount of fuel used when operating without load (L/hour)

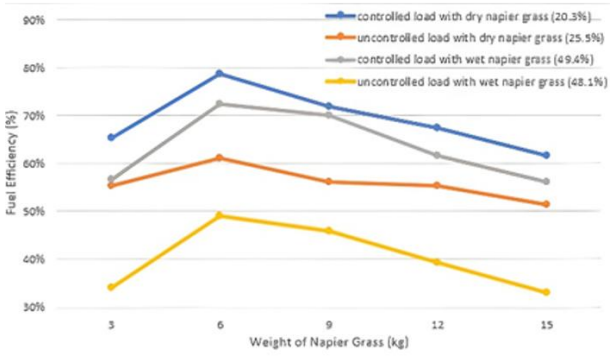


Figure 8. The effect of load on fuel efficiency

Based on Figure 8, fuel efficiency increases across all conditions until it reaches an optimal point at a 6 kg load, then gradually decreases as the load increases up to 15 kg. This indicates that a 6 kg load

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is the most efficient operating point for the chopper machine in terms of fuel usage.

Under the controlled dry-load condition (20.3%), fuel efficiency is relatively high, ranging from 65% to 79%. The highest efficiency occurs at the 6 kg load, at 79%, before gradually decreasing to 62% at the 15 kg load. This shows that 6 kg is the optimal load for controlled dry grass, as the machine operates most efficiently at this load.

For the controlled wet-load condition (49.4%), fuel efficiency ranges from 57% to 72%. Similar to the dry condition, the highest efficiency occurs at the 6 kg load (72%) and then decreases to 59% at the 15 kg load. This indicates that even with higher moisture content, controlled feeding can still improve fuel efficiency.

In the uncontrolled dry-load condition (25.5%), fuel efficiency ranges from 51% to 61%. The highest value is again at the 6 kg load (61%), before dropping to around 51% at the 15 kg load. Although the pattern is similar to controlled feeding, the efficiency values are lower due to unstable material flow, which reduces the machine's effectiveness.

The lowest fuel efficiency is found in the uncontrolled wet-load condition (48.1%), with values ranging only from 33% to 49%. The highest efficiency occurs at the 6 kg load (49%), then sharply decreases to 33% at the 15 kg load. The low efficiency under these conditions is due to high moisture content and uncontrolled feeding, which cause the machine to work harder and consume more fuel.

3.6.2 *Chopping Capacity Efficiency*

Chopping capacity efficiency is the ratio of the actual chopping capacity to the machine's theoretical capacity. This parameter indicates how effectively the machine utilizes its designed chopping capacity in accordance with its specifications. The formula for calculating the theoretical chopping capacity is as follows.

$$C_{theoretical} = \frac{\rho_f A_t L_c \lambda_c \omega_c}{6\ x\ 10^8}\ x\ 3600 \quad (6)$$

Where:
ρf = density of elephant grass (kg/m³). According to Fernando Jose(25). The average density of elephant grass is 216 kg/m³.
λc = number of blades used.
ωc = machine speed (rpm).

At is the cutting area, which can be calculated using the following equation (17):

$$A_t = L_{blade}\ x\ d_{shaft} \quad (7)$$

Where:
L_{blade} = blade length (mm).
d_{shaft} = shaft diameter (mm).

The following equation gives the formula for production-time efficiency (17)

$$\eta chopping\ capacity = \frac{C_{actual}}{C_{theoretical}} x100\% \quad (8)$$

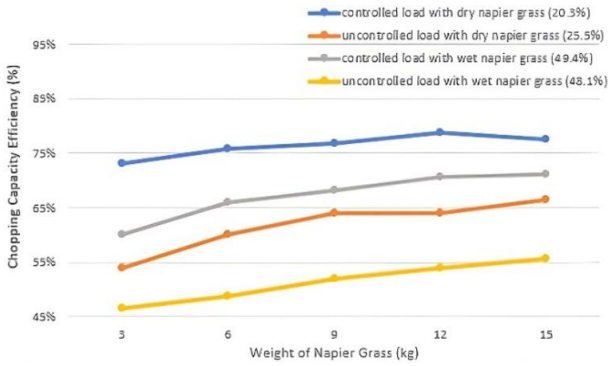


Figure 9. The effect of load on chopping capacity efficiency

Based on Figure 9, chopping capacity efficiency tends to increase with chopping load across all test conditions, although the rate of increase varies by condition. This indicates that at low loads, the machine does not operate at full or optimal performance, resulting in a relatively low actual capacity. However, as the load is gradually increased, the machine operates more steadily, allowing the motor's energy to be used more effectively for chopping.

The controlled dry load (20.3%) produces the highest capacity efficiency, ranging from 73% to 79%. This shows that dry material with a consistent, regulated feeding rate allows the machine to operate more optimally, bringing the actual capacity closer to its theoretical capacity. The uncontrolled dry load (25.5%) results in lower efficiency, ranging from 54% to 66%. Irregular feeding causes uneven load distribution in the cutting chamber, preventing the machine from reaching optimal capacity.

The controlled wet load (49.4%) shows fairly good efficiency, ranging from 60% to 71%. Although the high moisture content makes the material tougher and slows down the chopping process, proper load control helps maintain stable machine performance. Meanwhile, the uncontrolled wet load (48.1%) shows the lowest efficiency, ranging from 46% to 56%. Wet material combined with unregulated feeding causes the machine to become overloaded more quickly, increases the chance of slipping, and significantly reduces the actual capacity.

CONCLUSION

The cattle feed chopper operates well, especially when processing dry material at a controlled feed rate. This is shown by the good chopping quality (≤ 50 mm) reaching 73% and an average capacity of 806.08 kg/hour. Fuel consumption increases with load, averaging 1.23 L/hour, while noise levels reach 94.34 dB, indicating an ideal operating time of around 4.97 hours. The material condition, feeding method, and input weight influence the machine's efficiency. Dry grass with controlled loading provides more stable performance, better fuel efficiency, and reduces slipping and component wear. Both capacity and fuel efficiency vary; the highest values are achieved under controlled loading with dry material, while the lowest occur under uncontrolled loading with wet material.

The machine should ideally be operated under controlled loading with dry material, as this setup provides better chopping quality and higher efficiency. Operators are advised to limit the input load to avoid slipping, excessive noise, and fuel waste. Because the noise level is quite high, ear protection is strongly recommended, and operating time should be limited in accordance with safety guidelines. For future research, it is recommended to test variations in blade design and the transmission system to increase capacity, reduce slipping, and lower the machine's noise level.

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