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Design And Development Of A Napier Grass Chopping Machine Based On A Rotary Blade Mechanism And Pull Roll System With A Capacity Of 1 Ton/Hour

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ABSTRACT

The study purpose was to design, develop, and evaluate an elephant grass chopping machine that integrates a rotary blade mechanism and a pull roll system to improve feeding stability, productivity, and chopping uniformity in ruminant feed processing. Traditional manual chopping methods are labor-intensive, time-consuming, and produce inconsistent particle sizes, which reduce feed efficiency. This research aimed to develop a farm-scale machine with a target capacity of 1 ton/hour that is technically and economically feasible for farmers.

Materials and methods. This study used an engineering-based research and development approach consisting of design, fabrication, and performance testing. The prototype was powered by a GX 220 gasoline engine and equipped with strip-type carbon steel rotary blades, a pull roll feeding system, and a pulley–V-belt transmission. Performance testing was conducted using elephant grass at three blade rotational speeds (1,120 rpm, 1,680 rpm, and 2,240 rpm). The observed parameters included chopping time, output mass, chopping capacity, and distribution of chopped sizes.

Results. The machine achieved an optimal working capacity of approximately 1,080 kg/hour at a blade speed of 1,680 rpm, meeting the design target. Higher blade speeds reduced processing time and increased the proportion of smaller chopped particles, while lower speeds resulted in longer and less uniform cuts. The pull roll system effectively stabilized material feeding and enabled continuous operation.

Conclusions. The developed machine improved labor efficiency, productivity, and feed chopping uniformity, indicating good potential for farm-scale application. However, further design improvements are required to reduce frame vibration, optimize hopper design, and enhance blade mounting safety.

Keywords: Elephant grass, chopping machine, rotary blade, pull roll, feed processing

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INTRODUCTION

The availability of sufficient and uniform forage is an essential prerequisite for the sustainability of ruminant livestock farming, as it is closely related to feed consumption efficiency and animal productivity. Elephant grass (including the dwarf or "Mott" variety) is widely recognized as a commonly used forage source due to its potential as ruminant feed (Sirait, 2018). In addition to forage quantity, the physical quality of feed—particularly particle size—plays an important role in determining ease of intake and the efficiency of feed utilization. In the context of forage production, environmental factors such as drought can also affect the resilience and characteristics of forage crops (Rianto, 2007), thereby necessitating more efficient feed management, including at the chopping stage before the feed is offered or further processed.

In field practice, the chopping of elephant grass is still frequently performed manually. This method generally requires substantial time and labor, poses occupational safety risks, and produces less consistent chopping sizes. Such conditions become a constraint for farmers when daily feed demand increases and supply continuity must be maintained. On the other hand, non-feed biomass such as organic waste and crop residues is often not optimally managed, making local chopping

technology innovations relevant to improving work efficiency while supporting more productive biomass utilization (Warsito et al., 2020).

The development of grass chopping machines has been widely conducted, both for composting and livestock feed purposes, with various design approaches and operating parameters such as the number and inclination of blades as well as cutting configurations (Mukhlis, 2019). Several design and development studies have also reported the use of specific cutting mechanisms, for example reel-type blades for chopping elephant grass (Sugandi et al., 2016), the design of grass choppers for general livestock feed applications (Hanafie et al., 2016), and the implementation of chopping machines to improve feed consumption effectiveness at the user level (Margono et al., 2021). Nevertheless, common challenges include maintaining a stable material feeding rate and achieving consistent chopping size during continuous operation. When feeding still relies on manual pushing, fluctuations in the material flow rate can result in variations in particle size and reduce actual throughput.

Based on these needs, this study focuses on the design and construction of an elephant grass chopping machine with a capacity of 1 ton/hour for livestock farming in the Purwakarta region, integrating a rotary blade mechanism and a pull roll system. The pull roll concept is intended to stabilize material feeding into the chopping chamber, while the rotary blades provide repeated cutting actions that support productivity and uniformity of the chopped material. The design also refers to established principles of machine elements and power transmission systems commonly applied in mechanical engineering (Anshory, 2017; Sularso & Suga, 2004), including considerations of maintenance and machine reliability for field applications (Hadi, 2019).

Accordingly, the objectives of this study are to: (1) design and construct a prototype elephant grass chopping machine based on rotary blades and a pull roll system with a target capacity of 1 ton/hour; (2) evaluate the machine performance based on chopping results at various rotational speeds; and (3) assess its practical implications for improving the operational efficiency of feed chopping in the target livestock farms.

METHOD

Research Design

This study employed a design-and-build method (engineering-based research and development) to produce a prototype elephant grass chopping machine with a target capacity of 1 ton/hour, combining a rotary blade mechanism and a pull roll system. The research stages followed the workflow presented in the flowchart (Chapter III), which included: literature review and field study, user needs analysis, conceptual and technical design, material selection, fabrication and assembly processes, performance testing, and conclusion formulation.

Location and Time of Study

The research was conducted at the residence of Riyan Dw Saputro, located in Ketileng Timur Neighborhood, Ketileng Village, Cilegon Subdistrict, Cilegon City. The study duration was three months (approximately April–June 2025), as described in Chapter III.

Data Collection Techniques

Data collection was carried out using two main approaches:

Field Observation and Interviews (User Needs Study)

Observations were conducted by examining references to similar machines (including those from social media) and by observing field conditions, accompanied by interviews with livestock farmers in the Purwakarta–Cilegon area. The interview questions provided in the PDF included: (a) the preferred chopping quality for livestock, (b) daily feeding frequency, (c) the use of additional fermentation, (d) feed mass requirements per feeding and per day, and (e) efficiency comparisons between manual and machine-based chopping methods.

Literature Review

The literature review was conducted by referring to undergraduate theses, final projects, journal articles, books, and internet sources as the basis for design considerations, machine element calculations, and comparisons with previous studies.

Research Materials and Equipment

Prototype Manufacturing Materials

The main materials used for the design and fabrication of the machine (as detailed in Chapter III) included: 4×4×3 mm angle steel for the frame, 2 mm steel plate for the casing and blade housing, shafts, bearings, pulleys and V-belts for the transmission system, bolts and nuts for joints, strip blades made of carbon steel, hinges, and wheels for mobility.

Fabrication Tools

The fabrication equipment included: a welding machine, a grinder, a 90° square, a measuring tape, chalk, an internal combustion engine, and a magnetic square.

Performance Testing Instruments

The performance testing instruments included:

- A stopwatch to measure chopping time (Margono et al., 2021).
- A digital scale to measure the mass of raw material and chopped output (Margono et al., 2021).
- A tachometer to measure rotational speed (rpm) of the blade/shaft (Hadi, 2019).
- Plastic containers/basins to collect the chopped material.

Prototype Machine Specifications

The prototype specifications refer to the section "Elephant Grass Chopping Machine Specifications" (Chapter III), with the main components as follows:

- **Chopping blades:** strip-type blades with a rectangular shape (20 cm in length and 6 cm in width), made of carbon steel.
- **Transmission system:** a combination of a small pulley (±2.5 inches) and a large pulley (±10 inches) to transmit rotation from the blade system to the pull roll, using a V-belt.
- **Drive motor:** GX 220 internal combustion engine as the main power source.
- **Frame:** angle steel (L-profile) with dimensions of 4×4×3 mm.
- **Pull roll:** functions to automatically draw grass from the hopper, thereby stabilizing the feeding process.

Performance Test Procedure

Performance testing was conducted at the research location (Cilegon) using three treatments as described in Chapter III. Each treatment used the same material load (5 kg of elephant grass) with different blade rotational speeds (rpm):

- **P1:** 5 kg of elephant grass, blade speed of 2,240 rpm
- **P2:** 5 kg of elephant grass, blade speed of 1,680 rpm
- **P3:** 5 kg of elephant grass, blade speed of 1,120 rpm

Measured Parameters

For each treatment, the following parameters were measured:

- Chopping time (seconds) using a stopwatch.
- Mass of chopped output (kg) using a digital scale.
- Blade rotational speed (rpm) using a tachometer to ensure consistency with the treatment conditions.
- Chopping quality, referring to the size classification used in the Results section of the PDF (small/medium/large), if required for performance reporting.

Capacity Testing

In the PDF, capacity testing was defined as chopping elephant grass for 1 hour to obtain output in kg/hour. Operationally, the working capacity was expressed as:

$$\text{Capacity (kg/hour)} = \frac{\text{Output mass (kg)}}{\text{Processing time (hour)}}$$

This definition is consistent with the concept of machine working capacity as the ability to process material per unit time.

Data Analysis Technique

The test data (rpm, processing time, output mass, and chopped size distribution) were analyzed using descriptive quantitative methods by comparing performance among treatments (P1–P3). The working capacity values were calculated in kg/hour and then interpreted to assess the

achievement of the design target and the trend of the effect of rpm variation on chopping productivity.

FINDING AND DISCUSSION

Results of Prototype Design and Development

This study resulted in a prototype elephant grass chopping machine that integrates an input hopper, an automatic pull roll, and a rotary blade unit. The prototype has dimensions of 530 mm × 410 mm × 600 mm with an approximate weight of ±25 kg. The frame is constructed from angle steel, while the cover/casing is made of 2 mm thick carbon steel plate. The chopping system uses strip blades operating against a fixed blade with a working clearance of approximately 1 mm, allowing the cutting process to occur through a combination of shear and impact forces as the material passes through the cutting area.

The distinctive feature of the design lies in the use of a pull roll, which functions to draw material into the chopping chamber more stably than a manual pushing system. This feeding rate stability is important because fluctuations in feeding can result in variations in chopping size and a reduction in chopping productivity during continuous operation.

Results of Working Capacity Testing

Capacity testing showed that at a blade rotational speed of 1,680 rpm, the machine produced an output of 18 kg within 60 seconds. The conversion of working capacity based on this test result is as follows:

18 kg / 60 seconds = 18 kg/minute

18 kg/minute × 60 minutes = 1,080 kg/hour

This value is equivalent to approximately 1 ton/hour, indicating that the planned capacity target was achieved under the tested conditions. This finding suggests that the combination of the rotary blade mechanism and the pull roll is capable of maintaining process continuity, resulting in actual throughput within the design capacity range.

Results of Performance Testing and Chopping Quality

Performance testing was conducted using 5 kg of elephant grass at three blade speed variations: 2,240 rpm, 1,680 rpm, and 1,120 rpm. The chopped material was classified into three categories: small (1–5 cm), medium (5–10 cm), and large (10–15 cm). A summary of the results is presented in Table 4.4 as follows.

No	Blade speed (rpm)	Material	Time (s)	Small 1–5 cm (kg)	Medium 5–10 cm (kg)	Large 10–15 cm (kg)
1	2,240	5 kg	12	4.0	0.7	0.3
2	1,680	5 kg	16	3.5	1.0	0.5
3	1,120	5 kg	25	2.8	1.4	0.8

Quantitatively, increasing blade speed reduced processing time (25 s → 16 s → 12 s) and increased the proportion of small-sized chopped material (2.8 kg → 3.5 kg → 4.0 kg). Conversely, at lower blade speeds, the proportions of medium and large categories increased, indicating that the chopped size tended to be longer and more varied.

This pattern is consistent with the principles of mechanical cutting, where higher rotational speeds increase the frequency of blade–material contact per unit time, thereby increasing the likelihood of repeated cutting on a single segment of material. Accordingly, in this machine configuration, higher speeds are more effective for producing shorter (finer) chops, while lower speeds tend to generate longer chopped pieces.

Characteristics of Test Materials and Factors Affecting Chopping Quality

The elephant grass used in the tests had an average length of approximately ±150 cm. During initial trials, it was observed that stems with larger diameters were relatively easier to chop than thinner parts, particularly leaves and fine stems. This phenomenon can be explained from the perspective of

cutting mechanics and chopping chamber design: stiffer and thicker materials provide sufficient resistance to become "locked" in the cutting zone, making them more susceptible to shear forces from the blades, whereas thinner materials are more easily pushed or carried by the material flow without undergoing effective cutting, especially when clearance gaps exist in the blade–material interaction area.

These findings confirm that chopping quality is influenced not only by rotational speed (rpm) but also by the mechanical properties of the material (stiffness and thickness) and design parameters such as blade geometry, number of blades, and the suitability of clearance for variations in material cross-section.

Operational Implications, Feasibility, and Engineering Limitations

Based on the test results, the integration of the pull roll and rotary blades provides two main operational implications. First, the pull roll improves feeding continuity, reducing the need for operators to continuously push the material manually. Second, chopping productivity achieved a capacity of approximately 1,080 kg/hour at the 1,680 rpm test condition, thereby supporting feed chopping requirements at the farm scale.

From an operational economic perspective, a comparison of costs before and after machine use indicates a reduction in operational costs and improved work efficiency. The summarized results indicate a machine investment cost in the range of IDR 2–3 million, a potential payback period of 1–2 months, and an estimated operational cost saving of approximately IDR 3 million per month in the context of the partner farm.

Nevertheless, the prototype still has engineering limitations that must be addressed prior to wider implementation, namely: (1) relatively high vibration of the frame and casing, (2) insufficient input hopper height affecting feeding comfort, and (3) blade support holes that are too loose, increasing the risk of bolt–nut loosening and potential safety hazards such as blade detachment. These limitations indicate the need for improvements in structural reinforcement, hopper design optimization, and enhanced blade locking system safety to improve overall reliability and operational safety.

CONCLUSIONS

The design and development of an elephant grass chopping machine integrating a rotary blade mechanism and a pull roll system successfully addressed the main challenges in the feed chopping process, particularly those related to feeding stability, productivity, and uniformity of the chopped material. The prototype achieved a target capacity of approximately 1 ton/hour at a blade speed of 1,680 rpm, indicating that the pull roll effectively stabilized material feeding and enabled continuous operation, while higher blade speeds reduced processing time and increased the proportion of smaller chopped particles. Performance testing also showed that chopping quality is influenced not only by rotational speed (rpm) but also by the mechanical properties of the material and key design parameters such as blade geometry and clearance. From an operational perspective, the machine reduced labor requirements and improved work efficiency, with favorable economic indicators including relatively low investment cost and a short payback period, making it suitable for application at the farm scale. Nevertheless, several engineering limitations remain, including relatively high frame vibration, suboptimal hopper design, and safety concerns related to blade mounting, indicating the need for further design refinement and structural reinforcement before wider implementation.

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