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Development and Fabrication of Animal Feed Blocking Machine

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ABSTRACT

The use of a hydraulic system (piston and cylinder) to block straw and molasses-based multi-nutrient animal feed helps to feed animals with little or no waste, preserving nutrients for a long period, and simplifying transport and storage conditions. Straws are regarded as one of the most essential elements in Ethiopia, particularly tef, wheat, and barley straw. As a result, the motorized animal feed block-making machine was designed and tested for throughput capacity, real capacity, efficiency, durability, and shelf life. The average actual capacity of the machine was 117, 128.5, and 133.3 kg/hr on different feed ingredients at the duration of time after mixing was 30 minutes, 45 minutes, and 1 hour. The durability of the blocks ranged from 87 to 98 % and 94 to 99 % as duration of time after mixing the ingredients increases from 30 min to 1 hr on both urea and straw-based feed blocks respectively. The post-compression expansion decreases from 8 to 5 % and 10 to 6 % as duration of time increases from 30 min to 1 hr on urea and straw-based ingredients respectively.

Keywords: Throughput Capacity; Actual Capacity; Blocking Efficiency; Durability; Post Compression and Expansion; Shelf Life; Moisture Content

1. Introduction

The livestock business is vital and has enormous potential for growth in the country's economy. Inadequate nutrition is one of the primary causes of animals' sub-optimal productivity [1]. Another issue contributing to low ruminant livestock productivity in the tropics is ineffective management of animal feed supplies, notably crop waste. The use of these locally available feed supplements has the potential to drastically lower animal production costs. Appropriate feeding strategies and processing technology would enable livestock farmers to make better use of these resources, resulting in higher animal performance. The idea of giving animals entire meals made up of fiber crop leftovers has gained favor in recent years.

Complete feed blocks have solidified into high-density blocks containing feed, concentrate, and additional supplemental nutrients in the appropriate quantities to suit the nutritional needs of animals [2]. The equipment can provide complete nourishment to animals in natural catastrophe situations. The manufacture of these feeds is crucial for enhancing animal output while utilizing low-cost feed material. Another advantage of total rationing is that it allows the animal to consume a variety of feed components, including roughages, without allowing the animal to select a single ingredient [3]. Blocking technology was quite popular in the world, ranging from simple to sophisticated, but it was not adopted in Ethiopia, but urea molasses feed block was practiced manually at the Debrezeit Agricultural Research Center and Bahirdar University. As a result, this research will be carried out to tackle the aforementioned concerns by creating a complete feed block machine, with the goal of developing and evaluating the performance of a complete feed blocking machine.

2. Materials and Methods

The project would be done in collaboration with Adami Tullu Agricultural Research Center.

2.1. Development ideas and manufacturing considerations

The following concepts guided development, material selection, and fabrication:

(1) Careful consideration has been given to the arrangements for adjustments, such as pouring the material into the hopper and conveniently removing the prepared block out.

(2) The system of hydraulics (piston and cylinder, hose, and oil pump) was designed to function with an electric motor.

(3) To guarantee easier maintenance and repairs, locally available materials were chosen; suitability and cost of materials were important factors considered when developing prototypes [4].

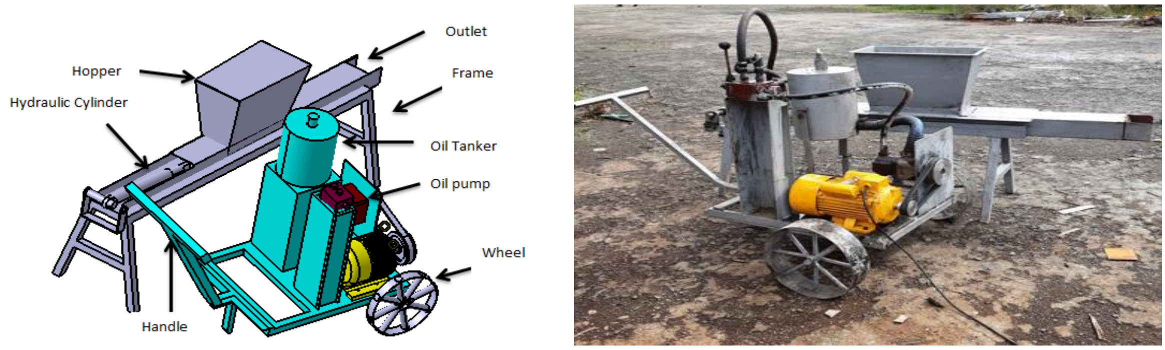
(4) As a result, several criteria were considered while determining components for the feed block manufacturing machine, and the materials used and the requirements used to select them are stated in Table 1.

Table 1. Materials specification and criteria of selection of the machine components

Main parts	Material used and specification	Selection criteria
Hopper	Sheet metal 2 mm	Workability, formability, and cost.
Pressing unit /molding chamber	Sheet metal 2 mm	Workability, formability, and cost.
Frame	Square pipe (4*40) mm	Strength and stability.
Power unit	(Oil pump, motor, pulley, oil tank, belt and direction controller)	Cost, lightness.

2.2. Description of machine

Power-driven feed block manufacturing machines can compress various types of feed material into rectangular shapes with appropriate length, width, thickness (10*15*L), and weight. The machine's overall dimensions were 2000mm*980*1050mm. The machine would be powered by a 5 hp electric motor. Figure 1 depicts the developed machine used in the experiment. Table 1 details the material specifications and dimensions for machine parts. Different materials would be picked for different parts based on their strength, availability, and cost and it would consist of the following basic components:



(a) Isometric view and its parts (Cad mod) (b) Pictorial view

Figure 1. Animal feed block-making machine Hopper

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The hopper feeds the mixed materials to be pressed into the pressing unit. The material used for the construction was sheet metal of 1.5mm thickness. The hopper is trapezoidal shaped and extended upwards, with the side tilted 10 degrees to the horizontal. The materials to be pressed fall into the pressing unit by gravity and are arranged manually in the pressing chamber and controlled by visual observation.

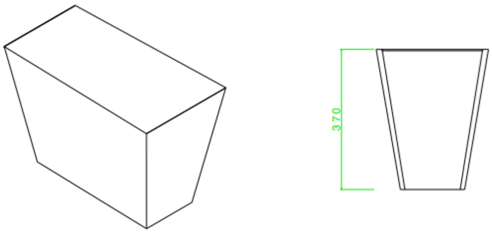

Figure 2. Hopper

The structure (frame): served as the holding component that held everything together and was strong enough to survive any working conditions while also providing movement and modifying routes. It was a square-shaped pipe. The machine's frame was constructed using mild steel bars (4 x 40 x 40) mm in compliance with the standard minimum ratio of frame lengths. This was done to improve stability and portability. It would be a stiff structure that could sustain dynamic stresses**.**

Power Transmission Assembly: power transmission assembly is carried out mechanically. This consists of an electric motor, a hydraulic piston and cylinder, a belt and pulley, and an oil pump. The pulley diameter was 120 on the oil pump and 90 mm on the motor with double lines. The power transmission system had two wheels and was easily moveable by guiding of handle.

Hydraulic Cylinder and piston: for pressing the feed to the required shape.

Direction control: used to order the piston by pressing/pushing and pulling mechanism.

2.3. Block feed preparation

To address the animal's daily nutrient requirements, two separate full feed blocks were developed. All raw materials were visually verified and weighed in accordance with the specified ratio. The ratio of the ingredients of the testing sample was prepared based on the guidance and recommendation of Adami Tullu Agricultural Research Center and based on [5].

Figure 3. Pictorial view and its output at farm

The test materials used were Wheat bran, nuge cake, tef straw, salt, cement, molasses, urea, and water. To make the complete feed blocks, the roughages and concentrate/micronutrient mixture were thoroughly mixed with the molasses and cement binding agent. Following the mixing of the feed mixes, the entire mixture is maintained for the appropriate time (duration time after mix) to allow each particle of feed ingredients to absorb moisture and become homogenized. A hopper then feeds this material into the feed block manufacturing machine. The blocks' height and width were 100 mm and 150 mm, respectively, while the length varied correspondingly and was changeable at the appropriate length, as seen in Figure 3.

2.4. Working principles

The feed block-producing machine was powered by a 5-horsepower electric motor, which rotated the oil pump via a coupling joint pulley and belt. The material is manually fed into the machine through the hopper and evenly distributed in the pressing chamber. The ingredients would be pushed into the pressing chamber by a hydraulic piston. With the force of the hydraulic cylinder, the hydraulic piston compacted the feeding ingredients and was attached to the pressing chamber at one end. A rectangle sheet metal with dimensions of (100 x 150) mm and a thickness of 3 mm was constructed and attached to the piston's extremity. The piston pressed ingredients and pushed blocks out as it traveled horizontally along the frame.

3. Performance Evaluation

3.1. Performance of physical attributes

To compute durability and post-compression expansion, the mean weight, thickness, and length of produced feed blocks would be determined.

3.2. Duration of storage

The moisture content will be utilized to assess keeping quality. In addition, visual inspection was performed to detect any changes in the look, color, or odor of the blocks over time.

3.3. Machine capacity performance

3.3.1. Durability Calculating

Durability testing has been carried out by falling three feed blocks from a height of 2 m onto a concrete floor at random. The weight of the blocks was measured prior to and after falling, and the amount of weight maintained after every drop was subsequently calculated to estimate durability (Du), it is provided in the equation below [6].

$$Durability = \frac{M_A}{M_B} X100\% \quad (1)$$

MB - The mass of the block prior to the drop test (in kilograms), MA - After-drop test mass of the block (Kg).

Post-compression-expansion (PCE) is the other machine parameter which is a technique used to increase the size of a compressed object after it has been compressed.

At the start, the height, width, and length of each feed block were measured and saved for a few days. The results of these measurements were carried out daily until the values approached an equilibrium level, and the PCE value was then determined using the equation below.

$$PCE(\%) = \frac{T_i - T_1}{T_1} X100\% \qquad (2)$$

Where T_1 is the height of the blocks immediately after compaction (1st day) (mm).

T_i- Block height on the i[th] day (mm)

3.3.2. Throughput capacity

Throughput is defined herein as the amount of feed block weight produced per hour when the machine is operating at optimal capacity. This was assessed by producing a known amount of blocks in a given time period. The quantity of blocks was measured by a digital weighing balance while the time taken was measured using a stopwatch.

$$TC = \frac{W_t}{T} \qquad (3)$$

Where, TC = Theoretical Capacity, W_t= weight of Feed block Ingredients, T = Blocking time in seconds.

3.3.3. Actual Capacity

The weight of the feed blocks prepared was calculated by taking into account the time required for loading, unloading, adjustments, worker tiredness, and so on.

AC = Actual block weight accomplished in one hour

4. Result and Discussion

Table 2. The performance result of the machine at different durations of time after mixing of ingredients

Time duration after mixing ingredients (min)	UMMB					SMMB				
	PCE	Durability	TC (Kg/hr)	AC (Kg/hr)	Efficiency (%)	PCE	Durability	TC (Kg/h)	AC (Kg/hr)	Efficiency (%)
30	8^a	87^a	130^a	117^a	90^a	10^a	94^a	123^a	111.5^a	91^a
45	6.1^b	95^b	140^b	128.5^b	91.8^a	8.7^b	97^b	129^b	121.3^b	94^a
60	5^c	98^b	145^b	133.9^b	92.3^a	6^c	99^b	132^b	128^c	97^a

[a,b] the same letter superscripts within the row are insignificant**.**

4.1. Physical performance

4.1.1. Durability

As indicated in Table 2, the durability of feed blocks was increased over time after combining the ingredients on both urea and straw-based feed blocks. In this investigation, the durability of the blocks ranged from 87 to 98% and

94 to 99% as the time after mixing the components increased from 30 min to 1 hr on both urea and straw-based feed blocks, respectively. Authors in [7] and [8] reported similar results for completed-feed blocks prepared for dairy animals. The durability of wheat and rice straw-based whole feed blocks ranged between 70.52 and 78.83%, according to [9], with rice straw-based blocks having significantly greater durability.

Durability is a product's capacity to last a long time without significantly deteriorating in quality. The greater the endurance of feed blocks, the greater the stability of their dimensions (form) and physical appearance, which has been described as a favorable quality parameter [7]. Except for blocking efficiency, the duration of time after mixing was important for both physical and mechanical performance evaluation factors.

4.1.2. Post-compression expansion

Duration of time after mixing was significant on the post–compression expansion on both UMMB and SMMB as could be seen in table 2. The post-compression expansion decreases from 8 to 5 % and 10 to 6 % as duration of time increases from 30 min to 1 hr on both UMMB and SMMB respectively. The findings of this study were consistent with that of [9], who discovered that higher PCE causes components to return to their normal shape after pressure is removed. As a result, the higher the quality of feed blocks, the smaller the PCE. Considering the improved durability and decreased PCE of both UMMB and SMMB components, the time after 1 hour is more suited for preparing feed blocks.

4.1.3. Shelf-life of Feed Blocks

According to Graph 4, the SMMB had the lowest percentage of moisture content and the UMMB had the highest. When the moisture content of the feed is high, the keeping quality falls [10]. The drawback of growing moisture levels is that unrestricted and 'unprotected' water threatens to feed quality by generating ideal conditions for rapid mould growth and the production of mycotoxins [11].

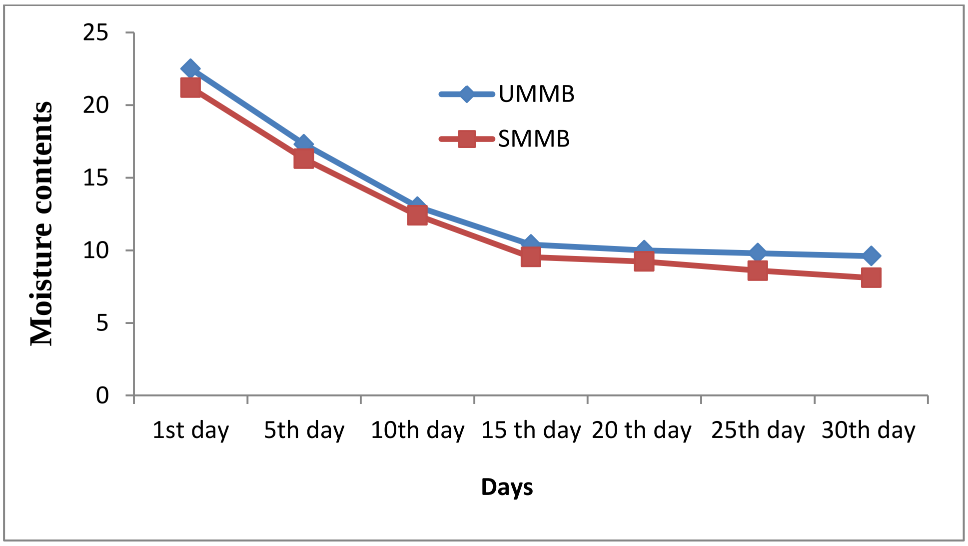

Figure 4. Moisture contents of feed ingredients in 30 days

Figure 4 shows that no obvious changes in color or texture, as well as no fungal development, were seen in feed blocks throughout a 30-day period. According to [12], prepared feed blocks had a higher shelf life when stored in polythene than when unpacked. Furthermore, he reported that entire feed blocks can be stored for 30 days in polythene-packed or unpacked settings without loss in quality.

4.1.4. Mechanical performance

The machine's performance is vital in determining how well the machine executes the work for which it was built and whether or not it is profitable. Determining the capacity is part of evaluating a machine's performance. The term capacity refers to the amount of work that can be done. The capacity of the machine was calculated in two methods, according to [7], theoretical capacity and actual capacity. Table 2 displays the throughput capacity, actual capacity, and blocking efficiency of both UMMB and SMMB Ingredients at different time intervals after mixing. Despite a numerical difference in theoretical capacities between the two feed blocks, the findings show that the time after mixing varies significantly at 45 minutes and 1 hour, as shown in Table 2. The feed components for UMMB and SMMB were essentially identical. This confirmed that the machine's throughput capacity is unaffected by increasing the time after mixing beyond 1 hour. As shown in Table 2, the average real capacity of the machine was 117, 128.5, and 133. 3 kg/hr on UMMB and 111.5, 121.3, and 128 kg/hr on SMMB feed components when the time after mixing was 30 minutes, 45 minutes, and 1 hour, respectively. In another world, the machine would produce 58.5 to 67 blocks/hr and 56 to 64 blocks/hr on UMMB and SMMB feed ingredients, respectively, as the duration of time after mix increases from 30 minutes to 1 hour with 2kg of weight on an efficiency of 90 to 92.3% and 91 to 97% on UMMB and SMMB feed ingredients, respectively. The acquired results follow a similar pattern to the findings of [7] and [10]. Apart from minor numerical variances, there were no substantial discrepancies in machine efficiency.

5. Conclusion

A performance evaluation was carried out in order to evaluate the effects of the feed ingredients and the period of time after mixing on throughput capacity, Actual Capacity, Blocking Efficiency, durability, and Post-compression expansion. To determine the best combination of the factors in question, two levels of feed block ingredients and three levels of time length after the mix were tested. Based on the performance evaluation and results collected, the following conclusions may be drawn:

(i) The machine's performance was significantly affected by the period of time after mixing rather than the types of feed ingredients.

(ii) Throughput and Actual Capacity, blocking efficiency, and durability increased with the increasing duration of time after mix, while Post-Compression Expansion decreased with the increasing Duration of time after mix on both feed ingredients.

(iii) The blocking efficiency slightly increases as the duration of time after the mix increases from 91 to 97 and 90 to 92.3 % on SMMB and UMMB as the duration of time after the mix increases from 30 to 1 hour respectively but no significant difference observed on UMMB.

(iv) The Post-Compression Expansion decreased from 8 to 5 % and 10 to 6 % on UMMB and SMMB respectively as the Duration of time after the mix increased from 30 to 1 hour, and durability increased from 87 to 98 and 94 to 99 % as the duration of time after mix increased from 30 minutes to 1 hour on UMMB and SMMB respectively.

(v) The study clearly indicated the optimum result was obtained at the duration of time after the mix was more than 30 minutes for the prototype machine developed.

6. Recommendations

Based on the findings, the following recommendations are made:

(i) Because the tef straw used in the test was not threshed, so it took a high percentage in volume and made difficulty on the uniformity of mixing feed block ingredients; hence the straw must be crushed and used.

(ii) Based on the result obtained, by developed machine animal feed block-making operation is possible, so highly recommended that the service provider can also use this machine which could generate income source by providing animal feed block.

Declarations

Source of Funding

This study has not received any funds from any organization.

Conflict of Interest

The authors declare that they have no conflict of interest.

Consent for Publication

The authors declare that they consented to the publication of this study.

Authors' Contribution

Abayineh Awgichew participated in the idea or design of the scheme, data gathering, analysis, interpretation, article drafting, article revision, and final approval of the manuscript. Rabira Nuguse helped with data gathering, article drafting, article revision, and final approval of the manuscript.

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