Development and Performance Evaluation of Sugarcane Bagasse Grinding and Pelletizing Machine for Livestock Feed Production

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Abstract –*This study endeavored to investigate the performance of the developed sugarcane bagasse grinding and pelletizing machine for livestock feed production. Bagasse is the residual fiber resulting from the extraction of sugarcane juice. In this study, sun dried bagasse collected from sugar industries were used as raw material in the testing of the fabricated prototype. Preliminary testing results revealed that grinder and pelletizer feed rates were 20 grams per 19 seconds feeding interval, 500 grams mixture per 125 seconds feeding interval, respectively. The grinding time was 76 seconds for every 100 grams of bagasse while pelletizing time was 500 seconds for every 1990 grams mixture containing 100 grams bagasse. The acceptable grinding discs clearance was obtained by making one-half turn in the knob or 180 degrees turn clockwise. Final performance evaluation results showed that the average grinding rate for 500-g raw bagasse was 1.12 g/s with a grinding efficiency of 85%, while the average pelletizing rate using the same amount of input was 4.99 g/s with a pelletizing efficiency of 97.52%. The pellet produced had an average length and diameter of 20 mm and 5 mm, respectively. Whereas, the average percentage mass yield of each pellet after undergoing tests to determine the resistance against friability was 99%.*

Keywords *–sun dried bagasse, grinding rate, pelletizing rate, grinding efficiency, pelletizing efficiency*

INTRODUCTION

Livestock feed or fodder is specifically used for feeding domestic animals such as goat, cattle, horse, hog, and chicken. Alternative ways of producing livestock feed are greatly supported in the Philippines. The country has an abundant source of raw materials that can produce fodder for livestock necessary for the improvement of agriculture and eventually help the economy. The processing of these raw materials should therefore be given high consideration for the benefit of the producer and the consumer. The safe keeping and proper maintenance of fodder greatly affects the quality of the livestock. It is necessary to have proper standards and procedures on how to process certain raw materials to maximize the possibilities of gaining desirable profit. Usually, the owners of livestock farms just purchase feeds that are available in the market. But now, others prefer some alternative materials to produce their own livestock feed. One of these alternatives is the use of agricultural by-product such as sugarcane bagasse.

Sugarcane is one of the most successful tropical crops, with many agronomic factors in its favour such as high yield, tolerance to a wide range of soils, resistance to pests, a perennial growth habit, and a sophisticated supportive technology providing improved varieties and cultural practices [1].

Bagasse is the fibrous matter that remains after sugarcane stalks are crushed to extract their juice. The dry pulpy residue left after the extraction of juice from sugarcane is used as alternative fuel for power generation for many years. Further, it is also utilized as raw material in the manufacture of pulp and paper; and building materials, and in the production of other bio-based materials. Specifically, the production of particle board from bagasse is a well-proven technology but it still faces some challenges due to high cost of imported synthetic resins, which serve as a binder to the bagasse fibers composing the board [2].

. A typical chemical analysis of bagasse based on a washed and dried basis consists mainly of cellulose ranging from 45 to 55 percent. Other compositions are hemicellulose (20-25 percent), lignin (18-24 percent), ash (1-4 percent) and less than one percent of waxes. It is an extremely inhomogeneous material comprising around 30-40 percent of pith fiber, which is derived from the core of the plant and is mainly parenchyma material, and bast, rind, or stem fiber, which comprises the balance and is largely derived from sclerenchyma material [3].

Sugarcane mills produce million metric tons of bagasse annually, accumulating more bagasse than can be utilized as a fuel resource for sugar processing. Though there are some commercial uses for the excess bagasse that have been identified and developed, its continuous accumulation presents a waste problem for the sugar industry. One potential use of bagasse is as a feedstuff for animals since the components of bagasse are in their natural, resistant conformation; and susceptibility to enzyme hydrolysis is extremely limited. Bagasse contains 40-50 percent moisture and around 30-40 percent fiber. This shows that the material can be a great source of fodder for fattening animals, especially beef cattle and goat [4].

Many research efforts have been explored to convert bagasse into valuable products. The experimental feeding using treated cane bagasse for animal feeding at the Bureau of Animal Industry Non-Conventional Feed Development Project in Quezon City was proved to be technically feasible. The use of chemicals for treating bagasse is expensive, but the use of enzyme or yeast has great promise. The scarcity of feedstuffs today may hasten the full use of fermented bagasse for feeding, both to monograstics and ruminants [5].

Conversion of dried bagasse into pellet forms is perceived a favourable way to store fodder in room temperature for the maximum duration of forty (40) days. At the same time, it can provide efficient feeding since livestock can consume pelletized feeds more rapidly than other kind of feeds. Also, these require lesser space for storage.

Office of the City Veterinarian and Agricultural Services (OCVAS) Livestock Division in Batangas City is an association that seeks alternative way of improving its livestock feed production. The Office is currently raising approximately 150 livestock including cattle and goat. This requires therefore a total amount of 50 kg of fodder per day to sustain the needs of all livestock. Hence, they are considering an economical source of fodder for the animals.

This study therefore attempted to develop a small-scale grinding and pelletizing machine for livestock feed production. This explored the optimum utilization of surplus bagasse from the sugar industries to address the solid waste disposal problem, thus, minimizing the degenerative effects to the environment. This covered the performance evaluation of the developed machine taking into consideration the grinding and pelletizing efficiency and the production of pelletized livestock feeds. The pelletized bagasse can be supplemented with other readily available concentrate mixtures.

MATERIALS AND METHODS

Thisis a developmental type of study and utilized engineering research design and process analysis to facilitate the completion of the project. A Conceive-Design-Implement-Operate (CDIO) model was employed starting from the conceptualization of the project, planning, designing until its implementation and operation. The following are the various phases of the study:

1. Design Phase

This phase established the design requirements and specifications of the sugarcane bagasse grinding and pelletizing machine. Schematic representation was drafted indicating the different system components and dimensions of the prototype. The 3D modelling was done using Solidworks to proportionately identify the best dimensions of the machine and simulate its intended functions.

2. Fabrication Phase

This phase covered the actual fabrication of the machine in accordance to its design specifications. Close monitoring of the fabrication processes was observed to ensure the proper assembly of the machine. Visual inspection was done as part of the quality monitoring process.

3. Preliminary Testing Phase

In order to establish the desired operating conditions of the fabricated machine, preliminary test runs were conducted. In this stage, appropriate settings of the machine were considered which include the grinder discs clearance, the operating speed, and the feed rates. Several modifications were implemented to attain the maximum efficiency of the operation.

4. Performance Evaluation Phase

The final tests were focused on the performance evaluation of the fabricated machine in terms of grinding rate, pelletizing rate, grinding efficiency and pelletizing efficiency using the established settings and operating conditions.

5. Experimental Testing Phase

The samples of the pellet products collected during the performance evaluation were tested to determine their resistance against friability.

Preparation of Raw Materials

The raw material used for various performance tests of the prototype was sugarcane bagasse collected from sugar industries located inBatangas province. These materials were sun dried for two to three days to achieve the acceptable moisture content of around 10 to 12 percent. The dried material was then fed to the grinder and pelletizer to produce the pelletized livestock feeds.

A mixture composed of ground bagasse with a maximum particle size of 3mm, starch as binder, and water was used as input for pelletizing process.

RESULTS AND DISCUSSION

System Components of the Machine

The fabricated sugarcane bagasse grinding and pelletizing machine is presented in Figure 1. This shows the arrangement and assembly of the machine indicating its system components. The design and materials of construction were carefully considered to ensure the optimum operation of the machine.

The major components include the grinding blades, grinding discs, agitator, rollers, pelletizing die, feeder, motor, gearbox and variable frequency drive.

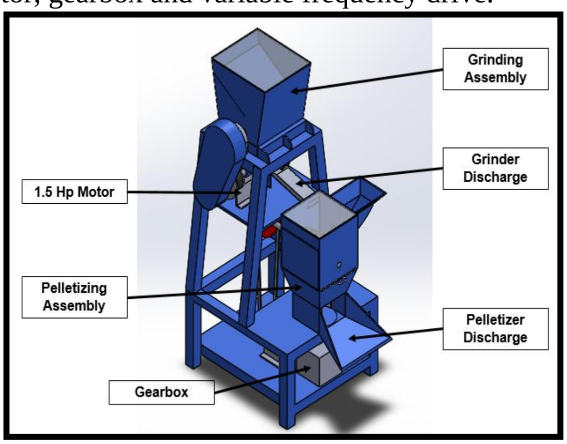

Fig. 1. The final set-up of the machine

The grinding blades made up of stainless steel are both rotating and stationary to cut the longer sizes of bagasse into smaller sizes. The grinding discs are used to reduce the raw materials into finer sizes suitable for pelletizing process. A turning knob was used to adjust the clearance between the grinding discs.

The agitator is made up of stainless steel which facilitates rotary motion and designed to avoid partial molding of feed amount of bagasse mixture before entering the pelletizer. This mixes evenly the raw material mixture thus, producing quality pellets.

The rollers are made up of stainless steel cylinder designed to press the bagasse mixture into the holes of the pelletizing die to produce pellets. Further, the pelletizing die has a diameter of 200 mm, plate thickness of 19 mm and composed of number of 5-mm diameter holes. The main function of the pelletizing die is to support the rollers from rotating while molding the pellets through its holes.

The feeder is installed in the machine which is made up of stainless steel where the raw bagasse is fed for grinding process. The machine uses two units of 1.5 hp at 1730 rpm electric motors. The first unit was installed directly to the shaft of the grinding blades by means of belt and pulley flexible transmitting elements. The other unit was connected to a gearbox that controls the speed of the rollers. A 1:2 ratio gearbox is used and is directly connected to the main shaft of the motor to reduce its output speed. A variable frequency drive was provided to adjust the operating speed of the agitator and the pelletizer.

Preliminary Testing Results

The results of the preliminary testing in determining the grinder and pelletizer feeding capacities, grinder feeding intervaland grinding time, pelletizer feeding interval and pelletizing time, and the bagasse-starch-water ratio were obtained after the modification stage.

Grinder Feed Rate and Grinding Time

To obtain the grinder feed rate, the grinder feeding capacity and the grinder feeding interval were needed.

For the grinder feeding capacity, the researchers conducted several tests of different amounts of sugarcane bagasse fed into the grinder. The best suitable amount of bagasse that can be fed at a time was 20g. Beyond this capacity, the grinder had longer time of grinding wherein grinding discs clogged several times.

To determine the grinding time, the best suitable grinder feeding interval was established first. A set of trials using three different mass inputs of sugarcane bagasse for the grinder were made during testing to establish the needed data. The first, second and third sets of trials, used a mass of 100, 300 and 500 grams of raw bagasse, respectively as feed for the grinder.

The average feeding interval and grinding time were recorded for each trial to get the mean feeding interval and grinding time for each mass input.

Table 1. Preliminary Testing Results for Determiningthe Grinder Feeding Interval and GrindingTime Using an Initial Feed of 20 grams

Mass of Raw Bagasse (g)	Grinder Feeding Interval (s)	Grinding Time (s)	Grinding Rate (g/s)
100	18.77	75.07	1.34
300	19.59	274.25	1.10
500	18.23	437.67	1.16

A mass of 20 grams was first fed into the grinder employing gradual feeding procedure to ensure unclogging of the grinder. Table 1 shows the recorded data for these test runs. It can be gleaned from the data that the appropriate feeding interval was 19 seconds while the grinding time was set at 76 seconds per 100 grams of raw bagasse.

Pelletizer Feed Rate

To obtain the pelletizer feed rate, the pelletizer feeding capacity and the pelletizer feeding interval were needed.For pelletizer feeding capacity, several tests of different amounts of sugarcane bagasse mixture fed into the pelletizer were conducted. The best suitable amount of bagasse fed at a time was 500g. Beyond this capacity, the rollers stopped from rotating.

To determine the pelletizing time, the best suitable pelletizer feeding interval was established first. A set of trials using three different mass inputs of sugarcane bagasse for the grinder were made during testing to establish the needed data. Corresponding to the mass of bagasse used were the amounts of starch, and water needed to produce good quality pellets.

Table 2 presents the results of determining the pelletizer feeding interval and pelletizing time for various amounts of bagasse. For 100-g raw bagasse, using 350 g of starch and 1540 g of water, the pelletizer feeding interval was 25 seconds for a pelletizing time of 500 seconds. Moreover, for 300-g raw bagasse, 1050 g and 4620 g of starch and water respectively were used. This mixture established a feeding interval of 125 seconds and pelletizing time of 1745 seconds. A feeding interval of 124 seconds was established for 500-g raw bagasse with 1750 g of starch and 7700 g of water yielding a pelletizing time of 2973 seconds

Table 2. Preliminary Testing Results for Determining the Pelletizer Feeding Interval and Pelletizing Time

Mass of Raw Bagasse (g)	Mass of Starch (g)	Mass of Water (g)	Pelletizer Feeding Interval (s)	Pelletizing Time (s)
100	350	1540	125	500
300	1050	4620	125	1745
500	1750	7700	124	2973

Analyzing the data presented in Table 2, it was concluded that the pelletizing time was set to 500 seconds per mixture containing 100 grams of bagasse.

Grinding Discs Clearance

The number of turns made in the knob was taken into consideration since the clearance between the grinding discs depended on it. The initial clearance of the grinding discs was 5mm and was reduced to 3mm to produce ground bagasse and avoid clogging in the grinder. The clearance of 3mm was achieved after making a one-half (1/2) turn in the knob or 180 degrees turn clockwise.

Final Performance Testing Results

The operating conditions established after the preliminary testing were evaluated and conducted for three (3) trials in order to verify the consistency of the obtained efficiency.

Table 3. Final Performance Testing Results for Determining Grinding Rate and Efficiency

Mass of Raw Bagasse (g)	Grinding Time (s)	Mass of Ground Bagasse (g)	Grinding Rate (g/s)	Grinding Efficiency (%)
100	76	83.33	1.12	83.33
300	228	256.67	1.13	85.56
500	380	423.33	1.12	84.67

Tables 3 shows the average data obtained from the performance testing using the established operating parameters of 20 grams, 19 seconds and 76 seconds for every 100 grams bagasse as grinder feeding capacity, grinder feeding interval and grinding time, respectively.

The 100-g raw bagasse had average grinding rate and efficiency of 1.12 g/s and 83.33%, respectively. The average grinding rate for 300-g raw bagasse was 1.13 g/s with an average grinding efficiency of 85.56%. Whereas for 500-g raw bagasse, the average grinding rate was 1.12 g/s with an average grinding efficiency of 84.67%.

Table 4. Final Performance Testing Results for Determining Pelletizing Rate and Efficiency

Mass of Raw Bagasse (g)	Pelletizing Rate (g/s)	Pelletizing Efficiency (%)
100	4.27	83.33
300	4.75	92.87
500	4.99	97.52

For 100-g raw bagasse, the average pelletizing rate and efficiency were 4.27 g/s and 83.33%, respectively. The average pelletizing rate for 300-g raw bagasse was 4.75 g/sec with an average pelletizing efficiency of 92.87%. For 500-g raw bagasse, the average pelletizing rate was 4.99 g/s with an average pelletizing efficiency of 97.52 %. The average length and diameter of the pellets produced during the process were 20 mm and 5 mm, respectively.

Table 5 shows the data obtained from the performance testing in determining the resistance to friability of the pellets. For each test, 20 samples of pellets were used by dropping each pellet from different heights such as 1, 2 and 3m.

Table 5. Results of the Performance Testing in Determining the Resistance to Friability at Various Heights

Height (m)	Average Initial Mass (g)	Average Final Mass (g)	Average Percentage Mass Yield (%)
1	0.318995	0.318995	100
2	0.318995	0.318945	99.98370
3	0.318995	0.316470	99.04978

After the conduct of friability tests, it revealed that almost all samples withstand the test without breaking and still comprise its original mass.The results indicate that pellet friability is influenced not only by pellet composition but also by the technique of its production such as the drying process and storage. There were some pellets produced during the trial testing, which are considered brittle or hard depending on the drying time employed in the process. Hard pellets therefore attained the acceptable friability requirements.

CONCLUSION AND RECOMMENDATION

The fabricated machine attained its maximum efficiency through establishing the appropriate operating conditions.These include the grinder feeding capacity of 20 grams, 19 seconds, and 76 seconds for every 100 grams bagasse as grinder feeding interval and grinding time, respectively.The acceptable grinding discs clearance was obtained by making one-half turn in the knob or 180 degrees turn clockwise. Significant findings of the study with respect to machine performance showed that the average grinding rate for 500-g raw bagasse was 1.12 g/s with a grinding efficiency of 85%, while the average pelletizing rate using the same amount of input was 4.99 g/s with a pelletizing efficiency of 97.52%. The pellet produced had an average length and diameter of 20 mm and 5 mm, respectively. Whereas, the average percentage mass yield of each pellet after undergoing tests to determine the resistance against friability was 99%. The performance test results showed that the machine is capable of producing good quality pelletized feeds which are valuable to meet the requirements of the end user

Further study may be conducted to improve the design of the machine and to accommodate larger capacity of raw materials. Sensors and other control devices can be integrated in the design of the prototype for exact and reliable measurement of the various operating conditions. Other type of agri-waste materials may be tested to determine the flexibility and usefulness of the machine. Comprehensive cost-benefit analysis can be done after testing the effectiveness of the pelletized feeds to the growth of the livestock. Intervention of experts is necessary to address some gaps and eventually attain its full scale operation and mass production.

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