

Design and development of sugarcane crop waste pelletizer as animal feeds

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Abstract: This study was conducted to design and develop sugarcane crop waste pelletizer as animal feeds). The influence on the pelletizing capacity, chemical and quality of feeds/ pelleted feeds was examined such as the pellet diameter (5, 10 and 15 mm), speed (90, 105 and 120 rpm) and amount of sugarcane tops (5%, 10% and 15%) using Response Surface Methodology. The PhilMech developed pelletizer composed of 3 major components: barrel, die and a prime mover. It produces pelleted feeds of uniform quality in terms of shape, diameter and degree of compactness. The pelletizer die can be changed to different hole diameter such as 5 mm, 10 mm, and 15 mm. The optimum condition of sugarcane tops-based pelleted feeds to achieve the capacity (97.15 kg hr⁻¹), bulk density (1.03 kg m⁻³), pellet durability index (91.13%), hardness (61.19 kgf), crude protein (6.78 %w/w), crude fiber (10.73 %w/w), and ash content (28.69 %w/w feeds are 15 mm, linear speed of 0.87 m s⁻¹ and 8% sugarcane tops. Investment analysis showed that the break-even point of feed pellets is P96.23/ kg. Sugarcane tops-based pelleted feeds can be a viable option as animal feed. It can be an additional income to sugarcane farmers and at the same time eradicate the waste problem on sugarcane tops that are being burned in the field. Establishment of village-type sugarcane tops-based pelleted feeds plant in major producing areas is recommended.

Keywords: pelletizer, sugarcane crop waste, pelleted feeds, optimization, financial analysis

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1 Introduction

Globally, sugarcane is recognized as one of the most vital agricultural commodities, ranking second only to cereal production in total volume (Manrique et al., 2025). In the Philippines, it serves as a foundational pillar of agricultural development, driving rural economies and supporting the livelihoods of millions (Granada and Trondillo, 2025). For the fourth quarter of 2025, the country's sugarcane production reached approximately 6.64 million metric tons, with nearly 95% of this output originating from the Negros Island

Region, Western Visayas, and Northern Mindanao. While 99.3% of this production is utilized for centrifugal sugar, the harvesting process generates a massive volume of lignocellulosic waste (PSA, 2025).

Each ton of harvested sugarcane leaves behind between 270 and 280 kg of waste in the form of leaves and tops. These materials are complex lignocellulosic structures typically composed of 40% cellulose, 25% hemicellulose, and 18%–20% lignin (Ungureanu et al., 2022). Sugarcane tops, specifically, are characterized by high crude fiber (42.30%) and lignin (13.6%)

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content. This lignin acts as a significant physical and chemical barrier, preventing rumen microbes from effectively breaking down the cell walls, which limits the material's nutritional value and digestibility as animal forage (Yanti et al., 2021).

To facilitate manual harvesting and maximize sugar recovery, these residues are conventionally disposed of through open-field burning (Ungureanu et al., 2022; Manrique et al., 2025). This practice is a major contributor to severe air pollution, releasing particulate matter (PM_{2.5} and PM₁₀), carbon monoxide, and polycyclic aromatic hydrocarbons (PAHs) (Manrique et al., 2025). Exposure to these emissions has been linked to significant adverse health outcomes in workers and surrounding communities, including respiratory diseases like asthma and pneumonia, cardiovascular issues, and an emerging epidemic of chronic kidney disease of unknown etiology (CKDu) (Manrique et al., 2025). Furthermore, smoke exposure in the late stages of pregnancy has been associated with reduced birth weight and increased risks of fetal death (Rangel and Vogl, 2016, 2019; Manrique et al., 2025).

Addressing these challenges requires effective waste valorization strategies. Pelleting is a sophisticated manufacturing process that employs

moisture, heat, and mechanical pressure to transform bulky, unpalatable residues into homogenous and nutritionally balanced pellets (Buchanan et al., 2010; You et al., 2025).

Despite the abundant supply of sugarcane tops in the Philippines, there is currently no existing pelletizing equipment specifically designed for processing this type of biomass into pelleted animal feed. Moreover, limited research has been conducted on the mechanical requirements necessary for pelletizing sugarcane tops and the potential utilization of this residue as a feed resource. Therefore, this study aims to design and develop a sugarcane crop waste pelletizer to provide a sustainable pathway for animal feed production. The development of such equipment could enhance the utilization of sugarcane by-products while reducing the environmental and health impacts associated with open-field burning.

2 Materials and methods

2.1 Design and fabrication of feeds pelletizer

An AutoCAD-finished working drawing/ plan of pelletizer as animal feed was prepared to serve as a guide in the fabrication of the machine (Figure 1). The machine was fabricated using locally sourced materials available in the Philippines.

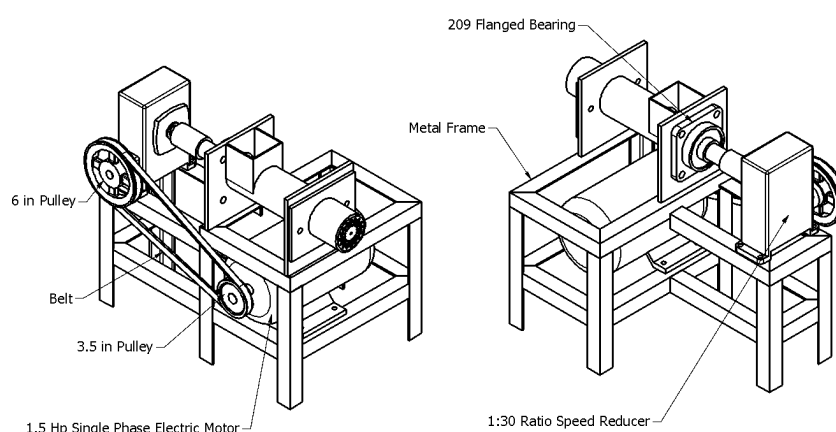


Figure 1 AutoCAD-finished working drawing/ plan of feeds pelletizer

2.2 Collection of experimental samples and analysis

The sugarcane tops with average maturity of 10 months were used in the study. The samples were obtained from Sugarcane Regulatory Administration (SRA,) Floridablanca, Pampanga, Philippines, located

at 15.014101° N, 120.524826° E. One kilogram of representative samples of fresh sugarcane tops was kept for analysis. The physicochemical analysis was performed by the Philippine Carabao Center (PCC), Science City of Munoz, Nueva Ecija, Philippines,

located at 15.7445° N, 120.9430° E, using standard methods.

2.3 Production of sugarcane tops pelleted feeds

Fresh sugarcane tops were manually chopped and dried using a cabinet dryer (Lassele, Daeyeong Industrial Co., Ltd, South Korea) (Figure 2a) at 50°C

until it reached moisture content of 17.65%–25% (db), equivalent to 80–85% dry matter as recommended by Orden et al. (2014). The dried sugarcane tops were then pulverized (IC-10B, Germany) to a particle size of less than 2 mm (Figure 2b).



(a) Pulverizer (IC-10B)



(b) Pulverized sugarcane tops

Figure 2 cabinet dryer and pulverized sugarcane tops



(a) Fabricated mechanical mixer



(b) PHilMech Pelletizer

Figure 3 Fabricated mechanical mixer and PHilMech Pelletizer

The pulverized sugarcane tops were mixed with JOVIMIN, a feed supplement developed by the Department of Agriculture–Pangasinan Research and Experiment Center (DA-PREC), Tebag, Sta. Barbara, Pangasinan, Philippines, located at 16.0699° N, 120.0854 °E. It is a feed supplement which contains highly digestible fermented protein, molasses, salt, mineral mixture, bran, macro and micro minerals and vitamins – all solidified by natural binder. It supplies fermentable readily available protein and energy. It is recommended for all physiological ages of goats (weanlings, growing, fattening, pregnant and lactating animals). JOVIMIN balls were developed due to poor quality roughages, e.g. cereal straws, poor quality hay, or dry-season forage that contains a lot of stem but not much leaf, can be deficient in crude protein (N). Insufficient N in the diet means that rumen

microorganisms cannot make enough microbial protein for the maintenance or growth of ruminants. This can become critical, resulting in loss of condition and increased disease risk (Datuin, 2019).

Pulverized sugarcane tops (5%, 10%, and 15% by weight) were mixed with one (1) kilogram of JOVIMIN and 200 grams molasses using a mechanical mixer to ensure the homogeneity of mixture (Figure 3a). The mixed ingredients were pelleted using the designed and fabricated PHilMech Pelletizer (Figure 3b). The pelletizer consists of a stationary long barrel with rotating screw inside, and a die at the end. It uses single-screw extrusion made of stainless steel. The pelletizer has a dimension of 0.60 meters x 0.44 meters x 0.53 meters. It is powered by a 1.5 hp single phase electric motor. The feed mix is forced through the die, and then cut into specific size. It can produce uniform

diameter of 5, 10 and 15 mm pellets.

The sugarcane pelleted feeds were dried using a cabinet dryer (Lassele, DY-330H) at 50°C (Figure 4). The initial and final weight of the pelleted feeds was

measured, and the moisture content was determined using standard oven method at 105°C for 24 hours, until no change in weight.



Figure 4 Cabinet dryer used during drying of sugarcane pelleted feeds



Figure 5 Fabricated pellet durability index (PDI) tester

2.4 Determination of physical properties of pelleted feeds

2.4.1 Bulk density

The density of the produced pelleted feeds was determined after drying by measuring the volume and weight of five samples. The weighing of samples was performed using an analytical balance (Shimadzu, AUW220D) while the dimensions were measured using a digital caliper. The density was determined by calculating the ratio of mass and volume of the pelleted feeds.

2.4.2 Pellet durability

Tumbling can method is used to estimate the pellet quality in terms of pellet durability index (PDI), or, simply percent durability. This test simulates the mechanical handling of pellets and predicts the possible fines produced due to mechanical handling. During tumbling, pellets disintegrate and produce fines

due to impact, and shearing of pellets over each other and over the wall of the tumbling can (Kaliyan and Morey, 2009). Durability or abrasive resistance test simulates either mechanical or pneumatic handling. These tests can help control the densification process and, thus, pellet quality in the feed manufacturing industry. According to Kaliyan and Morey (2009), the tumbling can method is the most often used method in feed manufacturing industries in the United States.

A fabricated pellet durability index (PDI) tester was used to determine the durability of the produced pelleted feeds to abrasion following the ASAE Standard S269.5-Pellet Durability Test (Figure 5). A pelleted feed with known weight was sieved to remove fines and placed inside a tumbler rotating at the speed of 0.8 m s^{-1} for ten minutes. After ten minutes of tumbling action the pelleted feed was taken out and was sieved. The weight was recorded, while the pellet

durability was calculated using the formula below (Stark and Fahrenholz, 2015):

$$\text{Pellet Durability Index} = \frac{W_2}{W_1} \times 100 \quad (1)$$

Where,

W_1 = weight of pellets or crumbles before tumbling, g;

W_2 = weight of pellets or crumbles after tumbling, g.

2.4.3 Hardness

The hardness of the produced pelleted feeds was evaluated using the 1/5 kg sensitivity hardness tester (Kija Seiskashuko, Ltd. No. 174886) (Figure 6). Five randomly picked represented pelleted samples were evaluated. Each sample was placed on the plate of the tester, then compressed until the material failed; the measurement recorded the failure value registered on the tester.



Figure 6 Hardness testing of produced sugarcane tops based pelleted feeds

2.5 Determination of chemical properties of pelleted feeds

A representative sugarcane tops pelleted feeds sample for each treatment were collected for chemical analysis. The analysis was undertaken at Animal Nutrition Analytical Services Laboratory in University of the Philippines Los Baños (UPLB), Los Baños, Laguna, Philippines, located at 14.1589° N, 121.2445° E. The samples were analyzed for proximate composition following standard AOAC (2005) procedures: moisture content by oven-drying method, crude protein by the Kjeldahl method, crude fiber by acid-alkali digestion, crude fat by Soxhlet extraction, and ash by muffle furnace incineration.

2.6 Statistical analysis

A three-factor, three-level Box-Behnken experimental design under Response Surface Methodology (RSM) was used to optimize the level percentage sugarcane tops (5%, 10% and 15%), speed

(90, 105 and 120 rpm) and pellet diameter (5, 10 and 15 mm) for pelleted feeds.

A total of 15 experimental runs were conducted in randomized order to minimize experimental bias. The response variables considered are capacity, bulk density, pellet durability index, hardness, crude protein, ash content, , crude fat and crude fiber.

Response surface methodology is a collection of mathematical and statistical techniques used to model and analyze data for process optimization. ANOVA table was utilized to determine the level of significance among treatments.

2.7 Financial evaluation

A simple partial budget analysis was carried out to determine the cost of production and income in processing of sugarcane crop waste based pelleted feeds.

3 Results and discussion

3.1 Description of the pelletizer

The PhilMech developed pelletizer composed of 3 major components: barrel, die and a prime mover (Figure 7). It produces pelleted feeds of uniform quality in terms of shape, diameter and degree of

compactness. An electric motor serves as prime mover of the machine connected to a speed reducer through a belt to regulate the speed. The pelletizer die can be changed to different hole diameter such as 5 mm, 10 mm, and 15 mm.



Figure 7 PhilMech developed feeds pelletizer

3.2 Production of sugarcane tops-based pelleted feeds mixed with JOVIMIN

Figure 8 shows the different sugarcane tops pelleted produced using the PHilMech developed pelletizer. Sugarcane tops pelleted increased the feed intake of beef cattle. It can be an alternative way to improve the quality of sugarcane tops for use as ruminant roughage source (Yuangklang et al., 2005).

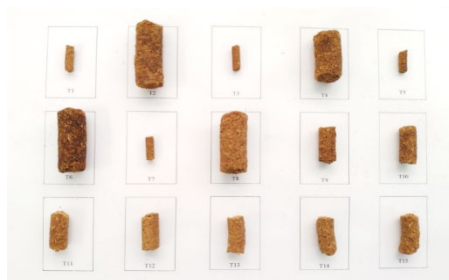


Figure 8 Sugarcane tops pelleted produced using the PHilMech developed pelletizer

3.2.1 Pelleting capacity

Pelleting capacity is the weight of pellets produced per unit of time of operation and is expressed in kilograms per hour (kg h^{-1}) (PNS/BAFS PABES-274: 2019). Figure 9 shows the effect of pellet diameter and sugarcane tops on capacity for the case when the speed is constant at 105 RPM. The highest pelletizing

capacity obtained is 123.4 kg hr^{-1} . The capacity decreases with the increment of pellet diameter. The bigger the diameter of the feeds, the higher the capacity of the pelletizer while capacity decreases as the decreases.

The mathematical model for capacity prediction as a function of pellet diameter screw speed and sugarcane tops were obtained as follows:

$$\text{Capacity} = 47.20 + 37.12 \cdot A + 10.19 \cdot B - 13.36 \cdot C + 19.83 \cdot A \cdot B \quad (2)$$

Where,

A = pellet diameter;

B = screw speed;

C = level (%) of sugarcane tops.

3.2.2 Physical properties of pelleted feeds

3.2.2.1 Bulk density

One of the advantages of manufacturing feed in pellet form includes increased in bulk density (Stark and Fahrenholz, 2015). Bulk density had a significant role viewed in transport and storage efficiency. In addition, bulk density provided a strong influence in the form of transport equipment, storage and conversion process (Zainuddin et al., 2014).

Figure 10 shows the effect of pellet diameter and sugarcane tops on bulk density of sugarcane tops-based pelleted feeds for the case when the speed is 105 RPM. There is decreased in final bulk density as the pellet diameter decreases. Likewise, as the diameter of the feeds increases, the bulk density decreases. Treatment 4 (pellet diameter: 15 mm, speed: 120 RPM, sugarcane tops: 10%) and 6 (pellet diameter: 15 mm, speed: 105 RPM, sugarcane tops: 5%) obtained the highest bulk density of $1.1 \pm 0.0 \text{ kg m}^{-3}$. The highest

bulk density will lead to reduced transportation costs and enabled easier handling with proper storage equipment (Zainuddin et al., 2014).

The mathematical model for final bulk density prediction as a function of pellet diameter, speed and sugarcane tops were obtained as follows:

$$\text{Bulk density} = 0.80 + 0.072 \cdot A + 3.750E-003 \cdot B + 6.250E-003 \cdot C + 0.020 \cdot A \cdot B - 0.050 \cdot A \cdot C + 0.018 \cdot B \cdot C + 0.13 \cdot A^2 + 0.029 \cdot B^2 + 0.044 \cdot C^2 \quad (3)$$

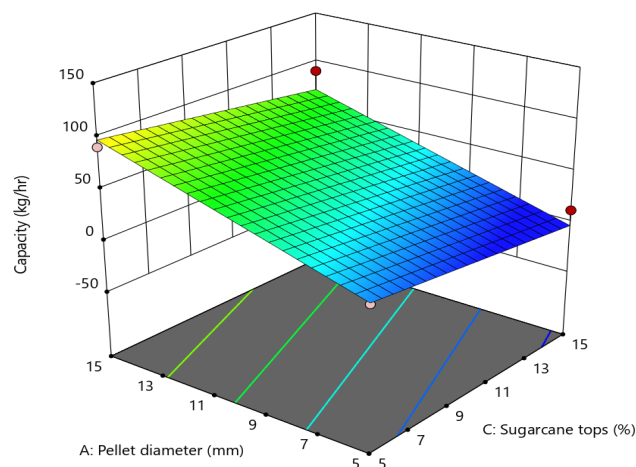


Figure 9 Capacity as the function of the pellet diameter and sugarcane tops

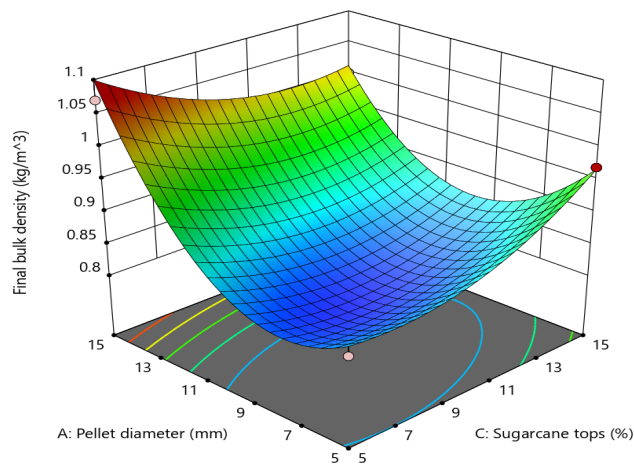


Figure 10 Bulk density as a function of the pellet diameter and sugarcane tops

3.2.2.2 Durability

Durability is the prevalent form of measurement and expression of pellet quality in the feed pelleting industry. In the feed industry, high durability means high quality pellets (Kaliyan and Morey, 2009). Durability is the amount of fines from the pellets after being subjected to mechanical or pneumatic agitation (Thomas and van der Poel, 1996). In addition, it is the ability to handle pellets without experiencing

unacceptable breakage or generating significant amount of fines. Pellet durability tests indicate the effectiveness of the pelleting process and the quality of the product delivered to the customer (Stark and Fahrenholz, 2015). Feed quality is often defined by physical characteristics and is based on the amount of fines present. Fines are major factor in determining consumer satisfaction with pelleted feed quality. Producing a tough pellet will eliminate most fines

complaints (California Pellet Mill Co, 2012). In the feed industry, high durability means high quality pellets.

Figure 11 shows the effect of pellet diameter and sugarcane tops on pellet durability index of sugarcane tops-based pelleted feeds for the case when the speed is 105 RPM. Treatment 7 (pellet diameter: 5 mm, speed: 105 RPM, sugarcane tops: 15%) obtained the highest percentage durability index of $97.9\% \pm 0.9\%$. In the feed industry, a maximum of 10-20% fines in pelleted feed are acceptable (California Pellet Mill Co, 2012). The fines' content in feed pellets affects animal

performance (Kaliyan and Morey, 2009). The pellet durability index decreases as the pellet diameter increases. This is in agreement with the study of Oduntan and Koya (2015) in cassava pellets. Pellets with large diameters are more likely to break compared to those of the smaller diameter pelleted feeds.

The mathematical model for pellet durability index prediction as a function of pellet diameter, and sugarcane tops were obtained as follows:

$$\text{Durability Index (\%)} = 85.71 - 4.50 \cdot A - 4.38 \cdot C - 5.00 \cdot A \cdot C + 6.79 \cdot A^2 \quad (4)$$

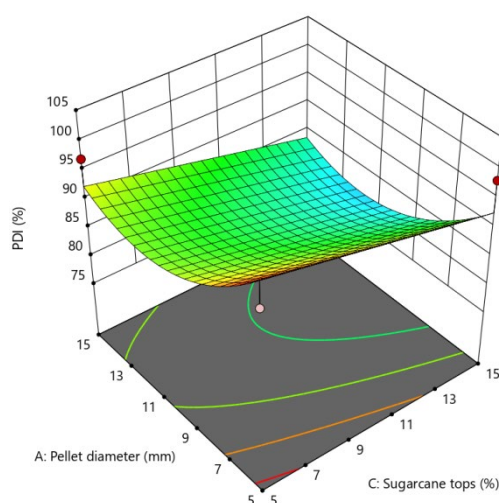


Figure 11 Pellet durability index as a function of the pellet diameter and sugarcane tops

3.2.2.3 Hardness

Hardness is the force necessary to crush a pellet or a series of pellets at a time (Thomas and van der Poel, 1996). Compressive resistance test simulates the compressive stress due to weight of the top pellets on the lower pellets during storage in bins or silos, crushing of pellets in a screw conveyor, and crushing (i.e., chewing) of feed pellets between animal teeth (Kaliyan and Morey, 2009). Hardness is a quantity which is important for the nutrition of animals since hardness may play a role with preference of animals (Skoch et al., 1983 as cited by Thomas and van der Poel, 1996)

Figure 12 shows the effect of pellet diameter and speed on the hardness of sugarcane tops-based pelleted feeds for the case when the amount of sugarcane tops is 10%. Treatment 4 (pellet diameter: 15 mm, speed: 120 RPM, sugarcane tops: 10%) obtained the highest

hardness of 61.2 ± 7.9 kgf. The hardness of pelleted feeds decreases as the pellet diameter decreases. According to Pfof (1963) as cited by Thomas and van der Poel (1996), hardness is used to evaluate the effect of die selection. Based on the result, as the pellet diameter decreases, the hardness of the pelleted feeds also decreases. According to Robohm and Apelt (1985) as cited by Thomas and van der Poel (1996), pellets with small diameters (3 mm) proved to be more susceptible to breakage than those with larger diameters (6 mm). On the other side, the hardness of the sugarcane tops based pelleted feeds increases as the speed increases.

The mathematical model for hardness prediction as a function of pellet diameter, speed and sugarcane tops were obtained as follows:

$$\text{Hardness (kgf)} = 48.92 + 12.93 \cdot A + 7.75 \cdot B + 2.27 \cdot C + 8.73 \cdot B \cdot C - 11.28 \cdot C^2 \quad (5)$$

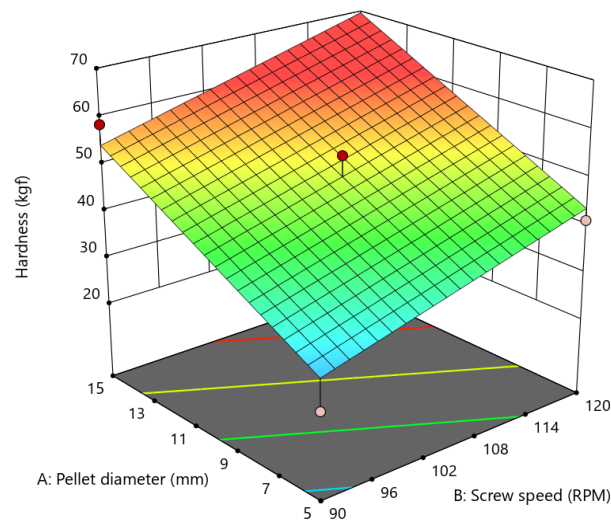


Figure 12 Hardness as a function of the pellet diameter and speed

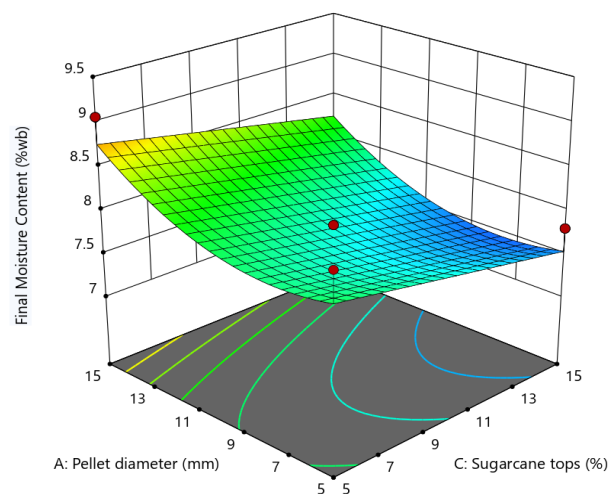


Figure 13 Final moisture content as a function of the pellet diameter and sugarcane tops

3.3 Chemical properties of pelleted feeds

3.3.1 Moisture content

Figure 13 shows the effect of pellet diameter and sugarcane tops on the hardness of sugarcane tops-based pelleted feeds for the case when the speed is 105 RPM. The final moisture content decreases as the pellet diameter decreases. On the other side of the graph, the final moisture content of pelleted feeds decreases as the sugarcane tops increases. Treatment 6 (pellet diameter: 15 mm, speed: 105 RPM, sugarcane tops: 5%) has the highest final moisture content of $9.1 \pm 0.3\%$. While Treatment 3 (pellet diameter: 5mm, speed: 120 RPM, sugarcane tops: 10%) has the lowest moisture content of $7.3 \pm 0.0\%$. The final moisture content of pelleted feeds should be less than 12% for proper storage and handling (California Pellet Mill Co., 2012). High moisture content promotes fungal and

bacterial growth (Cruz, 1996).

The mathematical model for final moisture content prediction as a function of pellet diameter and sugarcane tops were obtained as follows:

$$\text{Final moisture content} = 7.80 + 0.35 \cdot A - 0.26 \cdot C + 0.34 \cdot A^2 \quad (6)$$

3.3.2 Crude protein

Crude protein is the proteins and all other nitrogenous compounds in feeds and feed ingredients (PNS/BAFPS 84:2010). It is an estimate of the level of protein in the feed based on the amount of nitrogen present. Since some, but not all, of the nitrogen is in the form of true protein, it is termed “crude” protein. It also does not give individual amino acid profiles. Crude protein content of plants peaks at about 4–6 weeks of age, then begins to decline quickly. Legumes such as alfalfa, koa haole, and clovers are generally

higher in protein than grasses and other forages. Seed oil meals have higher crude protein values than whole grains. The protein quality of grasses declines more rapidly than that of legumes with plant age, and tropical forages decline more rapidly with plant age than temperate forages. Crude protein includes both true protein and non-protein nitrogen (which can be used most effectively by ruminant animals). Because feeds high in protein are generally more expensive, compare feed costs on the basis of cost per pound of crude protein rather than per pound of DM.

Figure 14 shows the effect of pellet diameter and sugarcane tops on the crude protein of sugarcane tops-

based pelleted feeds for the case when the speed is 105 RPM. Treatment 9 (pellet diameter: 10 mm, speed: 90 RPM, sugarcane tops: 5%) obtained has the highest crude protein content of $7\% \pm 0.1\%w/w$. While Treatment 11 (pellet diameter: 10 mm, speed: 90 RPM, sugarcane tops: 15%) has the lowest crude protein content of $6.5\% \pm 0.1\%w/w$. The crude protein decreases as the sugarcane tops increases due to low crude protein content of sugarcane tops.

The mathematical model for crude protein prediction as a function of sugarcane tops were obtained as follows:

$$\text{Crude protein (\%w/w)} = 6.74 - 0.13 \cdot C \quad (7)$$

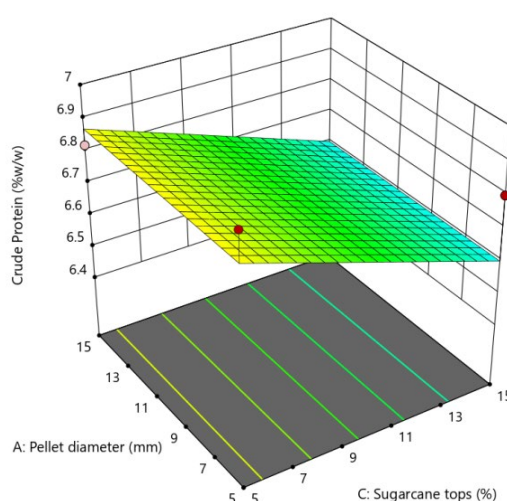


Figure 14 Crude protein as a function of the pellet diameter and sugarcane tops

3.3.3 Crude fat

Crude fat is the fats, oils, waxes and similar components found in feeds and feed ingredient, which are extracted with warm ether in chemical analysis (PNS/BAFPS 84:2010). Figure 15 shows the effect of pellet diameter and sugarcane tops on the crude fat of sugarcane tops-based pelleted feeds for the case when the screw speed is 105 RPM. Treatment 9 (pellet diameter: 10 mm, speed: 90 RPM, sugarcane tops: 5%) obtained the highest crude fat content of $5.5\% \pm 0.0\%w/w$. There is an increased in crude fat as the pellet diameter decreases (crude fat maximum is around pellet diameter 10 cm) and slightly decreases afterwards. While on the other side of the graph, the crude fat remains constant with respect to sugarcane tops.

The mathematical model for crude fat prediction as a function of pellet diameter were obtained as follows:

$$\text{Crude fat (\%w/w)} = 5.06 - 0.065 \cdot A - 0.45 \cdot A^2 \quad (8)$$

3.3.4 Crude fiber

Crude fiber is the coarse, fibrous and indigestible portion of feeds and feed ingredients, relatively low in digestibility and nutritive value such as cellulose, hemi-cellulose and lignin ((PNS/BAFPS 84:2010). It is the insoluble carbohydrate remaining in the feed analysis process after the sample is boiled in weak acid and alkali. Moreover, it is poorly digested component of a feed. Crude fiber analysis has been replaced by NDF and ADF analysis for ruminant feedstuffs, but it is still used by the feed industry as a measure of fiber content for monogastrics (DuPont, nd).

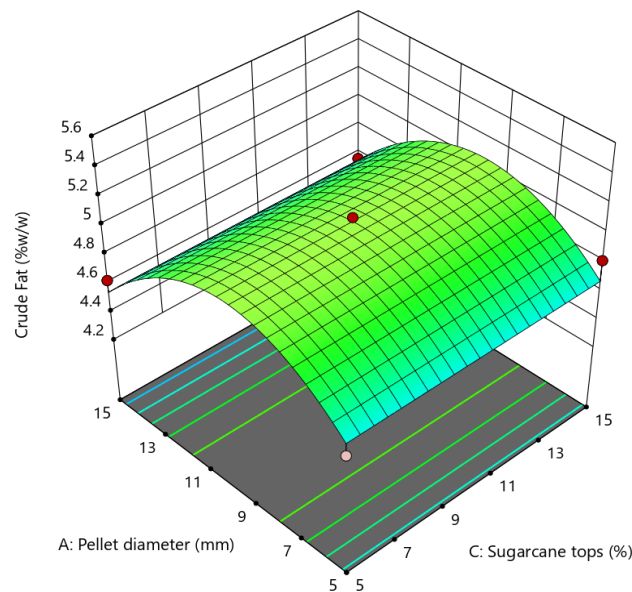


Figure 15 Crude fat as a function of the pellet diameter and sugarcane tops

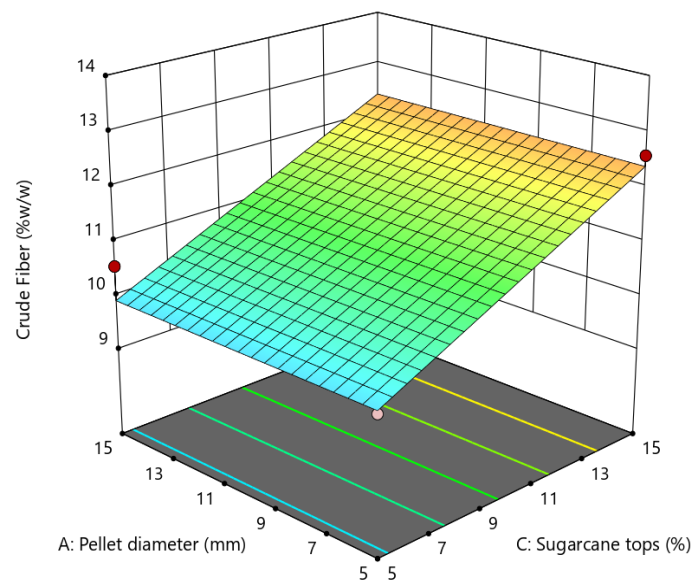


Figure 16 Crude fiber as a function of the pellet diameter and sugarcane tops

Figure 16 shows the effect of pellet diameter and sugarcane tops on the crude fiber of sugarcane tops-based pelleted feeds for the case when the speed is 105 RPM. Treatment 12 (pellet diameter: 10 mm, speed: 120 RPM, sugarcane tops: 15 %) obtained the highest crude fiber content of $12.9\% \pm 0.0\%w/w$. The crude fiber increases as the sugarcane tops increases due to high fiber content of sugarcane tops. Addition of fibrous materials increases the pellet quality (Yasothai, 2018). Sugarcane tops contain high neutral detergent fiber that increases the animals milk production. In addition, fiber is the major source of energy of ruminants, promotes rumen health and cud chewing

(Chamberlain et al., 2016).

The mathematical model for crude fiber prediction as a function of sugarcane tops were obtained as follows:

$$\text{Crude fiber (\%w/w)} = 11.15 - 1.24 \cdot C \quad (9)$$

3.3.5 Ash

Ash is a measure of the total mineral content of the feed, but it does not tell the quantity of each mineral present. Figure 17 shows the effect of pellet diameter and sugarcane tops on the crude fiber of sugarcane tops-based pelleted feeds for the case when the speed is 105 RPM. Treatment 13, 14 and 15 (pellet diameter: 10 mm, speed: 105 RPM, sugarcane tops: 10%)

obtained the lowest ash content of $25.6\% \pm 1.8\% \text{w/w}$. There is a decreased in ash content as the pellet diameter decreases. Likewise, the ash content decreases as the sugarcane tops increases. Ash is not digestible by animals. High ash content of feeds may dilute the amount of nutrients available to the animal. Bone content of feeds of animal origin can contribute to ash content. If a plant feed is high in ash content, it

may be due to soil contamination during harvest of the plant material. Although minerals are not digested by animals, some are essential to their health (DuPonte, nd).

The mathematical model for ash prediction as a function of sugarcane tops were obtained as follows:

$$\text{Ash Content} = 25.57 - 0.080 \cdot A + 0.47 \cdot B - 0.82 \cdot C + 2.31 \cdot A^2 + 2.48 \cdot B^2 + 2.65 \cdot C^2 \quad (10)$$

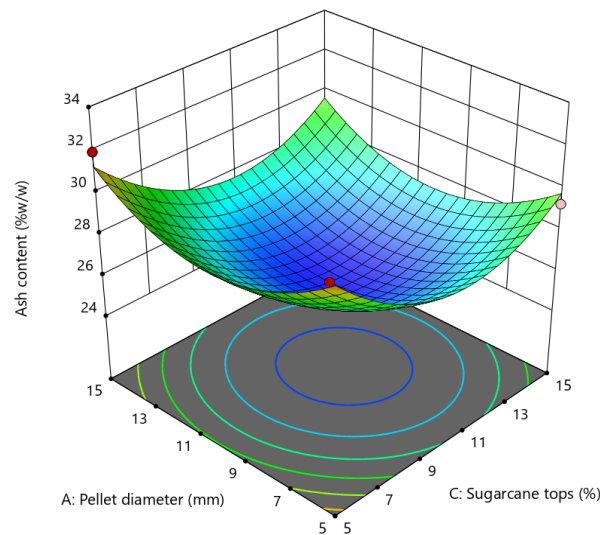


Figure 17 Ash content as a function of the pellet diameter and sugarcane tops

Table 1 Investment analysis of producing sugarcane tops pelleted feeds

Parameters	Values,
Investment Cost, \$	\$4,265.63
Chopper	853.13
Pulverizer	1,194.38
Mixer (2 units)	1,706.250
Pelletizer	511.88
Fixed Cost	\$1,706.25
Depreciation	768.28
Repair & Maintenance	511.88
Interest	426.56
Variable Cost	\$38,140.56
Salaries and wages	652.786
Power cost	36,462.02
Ingredients	1,025.77
Annual operating cost, \$	\$39,847.81
Annual production, Kg	23,232
Break-Even point, \$/ Kg	\$1.64/kg

3.3.6 Optimization of response variables

The optimum condition for the production is sugarcane top pellets are 15 mm, speed of 109 RPM and 8% sugarcane tops. The capacity, bulk density, pellet durability index, hardness, crude protein, crude fiber, and ash content obtained are 97.15 kg hr⁻¹, 1.03 kg m⁻³, 91.13%, hardness of 61.19 kgf, 6.78%w/w, 10.73%w/w, and 28.69%w/w, respectively.

3.4 Financial profitability

The estimated investment cost of sugarcane based pelleted feeds is P250,000 which includes pulverizer mechanical mixer, and pelletizer. Investment analysis showed that the break-even point of pelleted feeds is \$1.64/ kg (Table 1).

4 Conclusions

The PhilMech developed pelletizer composed of 3 major components: barrel, die and a prime mover. It produces pelleted feeds of uniform quality in terms of shape, diameter and degree of compactness. The pelletizer die can be changed to different hole diameter such as 5 mm, 10 mm, and 15 mm.

The capacity of the PHilMech pelletizer is significantly affected by the pellet diameter and the amount of sugarcane tops. The bigger the diameter, the higher the capacity of the pelletizer.

There is a decreased in sugarcane tops based pelleted feeds bulk density as the pellet diameter decreases. Likewise, pellet durability index decreases as the pellet diameter increases. The hardness of sugarcane tops pelleted feeds decreases as the pellet diameter decreases. On the other hand, the hardness of the sugarcane tops based pelleted feeds increases as the speed increases.

The crude protein, pellet durability index and ash content of sugarcane tops pelleted feeds decreases as the sugarcane tops increases. However, the crude fiber increases as the sugarcane tops increases due to high fiber content of sugarcane tops.

The optimum condition of sugarcane tops pelleted feeds to achieve the capacity (97.15 kg hr⁻¹), bulk density (1.03 kg m⁻³), pellet durability index (91.13%), hardness (61.19 kgf), crude protein (6.78%w/w), crude

fiber (10.73%w/w), and ash content (28.69%w/w feeds are 15 mm, speed of 0.87 m s⁻¹ and 8% sugarcane tops.

Investment analysis showed that the break-even point of feed pellets was \$1.64/kg.

Establishment of village-type sugarcane tops pelleted feeds plant in major producing areas is recommended.

Conduct study on the economic viability of sugarcane top pelleted feed processing plant through pilot testing to enhance income of farmers and at the same time address the problem on waste disposal and environmental pollution.

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