Technical Evaluation of a Roll-Type Extrusion Pellet Mill for Animal Feed Production

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Abstract

The study dealt with the design and technical evaluation of a pellet mill developed in the Philippines that utilizes the roll-type extrusion method of producing powder materials of different mixtures into pelleted feeds and driven by a 2 Hp electric motor. It is comprised of a feed hopper, pelleting chamber, pellet roll, die plate, discharge chute and frame. As the pellet rolls rotated, force is also applied creating rearrangement of the particles in order to fill the voids or holes of the die plate. The machine can produce 1.272±0.009 kg/min or about 76.32±0.54 kg/hr of pelletized feeds. It is an efficient, portable and user-friendly machine that can convert a kilo of mash feeds by 97.87±0.596%. The pellets produced have a 4-mm diameter with a length and weight of 10.667±0.667 mm and 0.138±0.005 g, respectively, while the moisture content after sundrying was 25.467±9.744% and the total solids was 74.533±9.744%. In addition, the pellets produced had a bulk density of 0.510±0.015 g/cc, pellet durability index of 95.77±0.596% and a percent fine of 1.8±0.115.

Keywords: pellet mill, pelleting machine, animal feeds, pellets, feed production, extruded feeds, roll-type extrusion

1. Introduction

Production of commercial feeds for local animal raisers in the province of Iloilo is dominated by few feed milling companies like Panay Agribusiness Venture (LoveFeeds) and Philippine Foremost Milling Corporation (Excel Feeds) (PCARRD, 2006). Companies mostly based near Manila like San Miguel, Purina and Vitarich Feed Companies have also gradually penetrated the local markets.

According to the Philippines' Bureau of Agricultural Statistics (BAS, 2009)the raw materials formulated in mixing these feeds aremostly imported since most of them like corn, cannot be sufficiently produced to meet the demand of the animal production industry. This high demand for feedstuffs on a commercial scale gave rise to billions of dollars spent in their importation. The Philippine Association of Feed Millers, Inc. (PAFMI) together with other stakeholders petitioned to the government for the removal of tariffs on imported feedstuffs to lessen the price increase of finished products (Phil. Daily Inquirer, 2008). This is the reason why commercial feeds in the country are very expensive. At the international level, the feed industry is also facing shortage of quality feeds creating variable supply and high prices. These constraints have therefore allowed for the need and exploration of substitute resources (Dhillon et al, 2013).

Pelleting is the answer to dusty mashed feeds. Pelletized feeds are easier to handle (Moritz et al, 2002) and animals fed with it had higher feed efficiency (Moritz et al, 2001). It offers several advantages over granular feed materials, including increased bulk density and flowability because the altered physical form will change the angle of repose, the inter-particle friction, and thus typically produce less bridging between particles. Additionally, pelleting generally produces increased nutrient density, palatability and nutrient availability in livestock rations. Pelleted feed often reduces feed waste, dust generation and ingredient segregation.

Pelleting of feeds, however, would require a pellet mill, a machine used to create cylindrical pellets from a mixture of dry powdered feedstock, such as flour, sawdust, or grass, and a wet ingredient, such as molasses or steam. During the process, the pellets are made by compacting and forcing the feeds through die openings by a mechanical process (Adapa et al, 2004).For countries like the Philippines, only giant feed millers have the financial capacity to invest on such technology. Most of the available pellet mills in the market can produce more than a ton/hour with feed sizes that range from 1.5 to 8.0 mm (Cutlip et al, 2008; Adapa et al, 2004; Parsons et al, 2006). Other units developed have a die plate diameter of 250 mm producing pellets with diameter ranging from 2 to 18 mm. These units could produce from 0.5 – 1.5 tons of pellets/hour (KEMPC, 2006). Other units developed like in China have die plate diameter of 250 mm producing pellets with diameter that ranges from 2 to 18 mm. These units could produce from 0.5 to 1.5 tons of pellets per hour pellets.

In pelleting, which employs the extruding process, binders and lubricants are considered necessary in order to hold the pellets formed together and also to improve the machine's production rate. Binders are increasingly used by feed millers to produce good quality pellets that do not crumble upon handling, thereby, improving its role in the animal feed industry to be significant (Nweke et al, 2002; Dufour et al, 2002). A study conducted by Kosoko et al (2011) has clearly established the suitability and effectivity of cassava as a binder for their micro-livestock (grasscutter) feed.

In the Philippines, a small-scale animal producer seldom invests in these large-scale technologies because of the expenses involved, thus, they settle for the costly commercial feeds. The aim, therefore, of the study was to develop a technology for stakeholders to have access to a low cost yet dependable machinery that would help them convert their own feeds.

2. Materials and Methods

2.1 Study Area

The Philippines has a land area of 300,000 km^2 with a total population of 92 million based on the 2010 Philippine Census of Population and Housing. It is an archipelago of 7,107 islands located in Southeast Asia. Iloilo City, where the study was conducted, is the capital of the Province of Iloilo which belongs to the Western Visayas region of the country. Technical evaluation of the machine was conducted at the Appropriate Technology Center inside the campus of Central Philippine University (CPU) located in Jaro, Iloilo City. The study was an output of a continued search for the enhancement of designed pelleting machines.

2.2 Description of the Pellet Mill

The pellet mill seen in Figure 1 is composed of major parts like feed hopper, pelleting chamber, pellet roll, die plate, discharge chute, and frame.

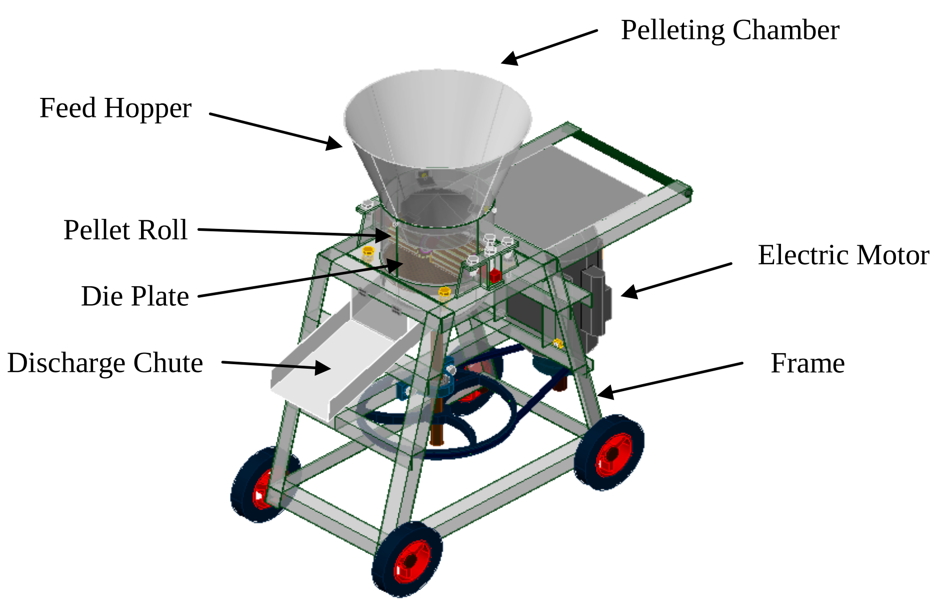

Figure 1. Detailed parts of the pellet mill

It is driven by a 2 Hp electric motor. It operates using a roll-type extrusion press to vertically force down the formulated feeds out of the die plate (Figure 2).

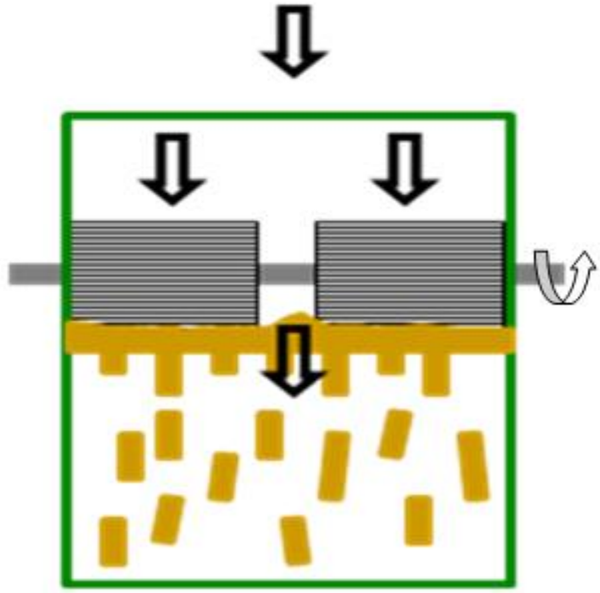

Figure 2. Roll-type extrusion operation of the pellet mill

As the two pellet rolls revolved due to the rotational movement of the vertically positioned shafting, force is applied creating rearrangement of the particles in order to fill the voids or holes of the die plate. The pressure is increased in compression step, causing brittle materials to break and malleable particles to deform forcing them to be fed into the die and come out as pellets. The pellets then fell down naturally due to impact created by the rotating die plate. The machine has an over-all dimension of 44 cm width by 90 cm length by 95 cm height. Compared to prior arts, the device is simple and compact in design, has a mechanism for adjusting the gap of pellet rolls to die plate, low cost and requires less electric energy requirement.

Feed hopper. This is where the formulated feeds are fed and eventually extruded by the two cylindrical pellet rolls to the die plate as pellets. The upper diameter is welded with a stainless steel plain round bar to eliminate any sharp edges that may be caused by the stainless steel sheet. An inner conical cover is bolted near the bottom part of the hopper to regulate the flow in of powdered materials and control spillage during the pelleting operation. This part is detachable from the pelleting chamber.

Pelleting chamber. This is where mixing and extruding of feeds is performed prior to being pushed through by the pellet rolls into the holes of the die plate. This part is also detachable from the main frame.

Pellet roll. This is responsible in compressing the formulated feeds before it is extruded to the die plate. Two ball bearings are implanted on both ends of the two pellet rolls. These bearings would allow the rotational movement of the pellet rolls to the inserted 1 in. cold rolled steel (CRS) shafting which is in turn locked both sides by a single bolt placed above a spring. This locking mechanism allows gap adjustment between the pellet rolls and the die plate depending on the mixtures utilized by the user later on. The locks also prevent the set-up of the pellet rolls to slide sideways towards the perimeter of the pelleting chamber during operation; allowing only the pellet rolls to rotate to the shaft. This specific part of the machine can also be detached but only after the unbolting of the pelleting chamber from the main frame.

Die plate. It is the part that converts the formulated feeds into cylindrical-shaped solid materials or pellets. The die plate is bolted perpendicular to a vertically positioned 1 in. diameter CRS shafting allowing it to rotate once the electric motor is turned on. It has 682 equally spaced holes each with a diameter of 4 mm.

Discharge chute. This is where the pelletized feeds are discharged for collection. The inclined discharge chute is made from gauge number 20 stainless steel sheet. A flapper is hinged near the opening of the chute in order to minimize uncontrolled spillage of pelleted feeds produced.

Electric motor. This is the mechanical device responsible in driving the die plate to a recommended speed of 400 – 450 rpm that led to the steady conversion of mash-formulated feeds into pellets. A single-phase 2 Hp capacitor-start electric motor is used.

Frame. A 3/16 in. x 1-1/2 in. x 1-1/2 in. angle bar is used as material for the construction of the frame of the pellet mill. A gauge number 20 stainless steel sheet is fixed on the upper opposite side of the discharge chute. This part serves as placement of container of formulated feeds during operation while protecting also the electric motor from unnecessary powdery materials. The legs of the frame are also supported by 16 cm diameter rubber wheels to allow easy movement of the machine. The frame has a total dimension of 34 cm wide x 61 cm long x 60 cm high.

2.3Performance Evaluation

Evaluation was done in three runs. The machine was operated in three major steps: 1) manual mixing of the formulated feeds with the binding material and water; 2) pelleting and 3) sundrying of the pelleted feeds until the appropriate moisture level for storage was attained.The formulated feeds developed at the College of Agriculture, Resources and Environmental Sciences of Central Philippine University for poultry use were utilized in evaluating the technical performance of the machine. The mash feeds were a mixture of blood meal, fish meal, “ipil-ipil” or lead tree leaf meal, bone meal, sweet potato leaf meal, golden snail, corn bran, copra meal, peanut meal, “malunggay”or *Moringa*leaf meal, lemon grass leaf meal, “kakawate” or Gliricidia leaf meal, molasses, powdered oyster shell, corn mix, rice, “kangkong” or water spinach leaf meal, wheat flour, and flavorings amounting to a total of 50 kg. The formulated feeds were then mixed withhot water and with starch serving as binding material. Each run for the machine had similar combinations of materials except for the flavorings added. The following were the flavorings used for this study: Trial 1 – Strawberry; Trial 2 – PandanTsina; and Trial 3 – Lemon Grass.The mixture of formulated feeds, starch and hot water was first weighed before being loaded into the hopper while the electric motor was turned on. The pellets produced after each trial was then weighed and sundried for 8 hours starting from around 7 in the morning. After sundrying, the weight of the pellets produced was again measured while the quality of the pellets in terms of the size and bulk density were also analyzed.

2.4Parameters Analyzed

After all the data were collected, the following were analyzed. Pelleting capacity, which referred to the weight of pellets produced per unit time was computed using the Philippine Agricultural Engineering Standards formula(PAES, 2003). Moisture content affects the ingredient’s nutritional content and quality during handling, storage, and processing. Moisture content is the mass of water in the sample while total solids content is a measure of the amount of material remaining after all the water has evaporated (ASAE, 1997). Bulk density represented the mass per unit volume of the material. This parameter of a feed ingredient is important for inventory control purposes and determines how the ingredient performs during batching and blending (ASAE, 1997). Quality of pellets referred to the ability of a pellet to withstand repeated handling without excessive breakage. This is measured using the pellet durability index (PDI) and by calculating the fine particles (% fines) present after pelleting. These data were obtained by subjecting the three samples of pellets produced for laboratory analysis which was performed by the Quality Control Laboratory of San Miguel Foods, Inc. located in Pavia, Iloilo. The other parameter was the pelleting efficiency which referred to the total weight of pellets recovered from the total volume of mash feed fed in pelleting machine (Nwaokocha et al, 2008).

3. Results

3.1 Machine Performance

The performance of the roll-type extrusion pellet mill developed was able to produce 1.272±0.009 kg/min or about 76.32±0.54 kg/hr of pelletized feeds (Table 1).

Table 1. Mean performance of the roll-type extrusion pellet mill and pellet physical properties in comparison with other pellet mills.

Parameters	Performanceof the Pellet Mill	Performance ofPellet Mills from other Studies	
Pelleting Capacity (kg/min)	1.272 ± 0.009	3.33	KEMPC, 2006
Pelleting Efficiency(%)	97.870 ± 0.596	92.60	Nwaokocha et al, 2008
Diameter (mm)	4.000 ± 0.000		
Length (mm)	10.667 ± 0.667		
Weight (g)	0.138 ± 0.005		
Moisture Content (%)	25.467 ± 9.744		
Total Solids (%)	74.533 + 9.744		
Bulk Density (g/cc)	0.510 ± 0.015	1.197± 0.07 0.678	Adapa et al, 2004 Parsons et al, 2006
Fines (%)	1.800 ± 0.115		
Pellet Durability Index (%)	95.770 ± 0.596	92.00 87.29 86.20	Valadez et al, 2008 Moritz et al, 2001 Parsons et al, 2006

Out of one kilo of mash feed, the machine was able to produce 97.87±0.596% of pelletized feeds. About 2.13% were un-pelletized and were returned to the machine to be pelletized again.

3.2 Pellet Quality

The pellet mill produced pelletized feeds with a diameter of 4 mm, a length of 10.667±0.667 mm, and a weight of 0.138±0.005 g each. It had a moisture content of 25.467±9.744% and total solids of 74.533±9.744%. The compactness of the pellets produced was 0.510±0.015 g/cc. Recovered fines in the packed pellet feeds were 1.8±0.115% of the total volume and had a pellet durability index of 95.77±0.596%. Results are presented in Table 1 while the diameter and length of the pellets are seen in Figure 3.

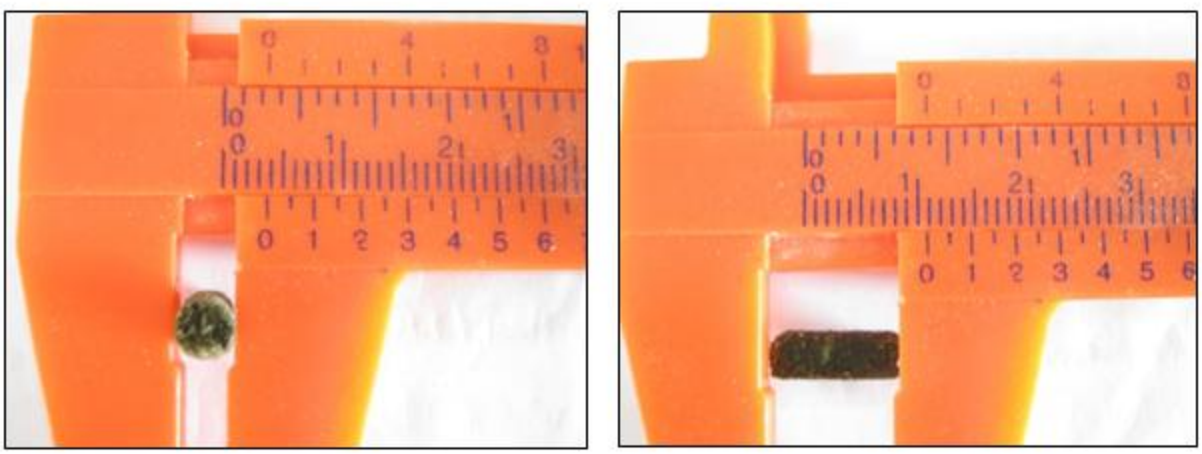

Figure 3. Pellets produced showing, from left to right, its diameter and length

4. Discussions

The pelletized feeds produced were of the same size as that of the chicken grower pellets available in the Philippine market. The machine had lesser pelleting capacity per hour than the smallest model manufactured by KEMPC (2006). Although the size of the machine is smaller, it was more efficient by 5.27% compared to that of the dual type cork-screw laboratory size pellet mill (Nwaokocha& Akinyemi, 2008) and have a higher pellet durability index than that of a larger extrusion or pelleting machine (Valadez et al, 2008; Moritz et al, 2001; Parsons et al, 2006). However, the pellets produced were less dense/compact compared to the final products of other pellet mills used by several studies which also produced the same type of processed feeds (Adapa et al, 2004; Parsons et al, 2006).

The bulk density of the pellets was affected by the type, moisture content, particle size, and pre-conditioning of feedstuffs used; binders used, and by the pressing or densification equipment (e.g. roller press) (Kaliyan & Morey, 2008; Adapa et al, 2004). The interaction of these factors will generate a certain degree of pellet quality which can be desirable or not (Amerah et al, 2008). The pellets produced by larger pelleting machines are done through the auger-pressing of the mash towards the die plate and by employing greater pressure (Aarseth et al, 2006) at a temperature of 65 to 80 C (Skoch et al, 1981) or even higher at 115 C (Aarseth & Prestlokken, 2003). The developed pellet mill's flow of operation was done in a vertical manner. Thus, the pellet rolls that press the mixed ingredients toward the die plate also served as molders. These results conformed with the observations of Kaliyan & Morey (2008) and Adapa et al (2004).

The size and weight of the pellet rolls were not enough to produce compact pellets like that of other commercial-scale pellet mills. However, the main advantage of this machine was the production of pellets at lower energy and temperature consumption. Conversely, the intense heat employed in the production of pellets among commercial scale pelleting machines may reduce the pellet durability index and the nutrient content of the feeds especially those nutrients which are heat sensitive (Aarseth et al, 2006). Findings of other studies revealed that there was a correlation between the durability index and moisture content of the raw materials (Larsson et al, 2008). In this study, the pellet durability index was not affected by the moisture content. It was even higher by 0.79 to 4.00% than the pellets produced on a commercial scale (Cutlip et al, 2008; Lundblad et al, 2008; Dozier et al, 2006; Boac et al, 2006). This means that these types of pellets can withstand breakage or product loss from various distribution procedures from the processing plant to the final consumer. This result agreed with the findings of Aarseth et al (2006). The presence of minimal fines can manifest the above claims.

5. Conclusions

This machine is composed of a feed hopper, pelleting chamber, pellet roll, die plate, discharge chute and frame. It is driven by a 2 Hp electric motor and is operated using the roll-type extrusion press to force the formulated feeds out of the die plate. The pellet mill can produce pellets resembling those available in the market and with qualities competitive with those produced by larger extrusion machine. This efficient, portable and user-friendly pellet mill can produce 76.32±0.54 kg/hr of pellets which is ideal for backyard animal production or community-based feed milling.

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Conflicts of Interest

The authors declare no conflict of interest.

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