
**DESIGN AND EVALUATION OF A PELLET MILL
FOR ANIMAL FEED PRODUCTION**

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ABSTRACT

This study was conducted to design and evaluate the performance of an electric motor-driven pellet mill for animal feed production. The designed pellet mill is composed of major parts namely, feed hopper, pelleting chamber, pellet roll, die plate, discharge chute, and frame. It is driven by a 1.5 Hp electric motor. It operates using a roll-type extrusion press to force the formulated feeds out of the die plate. As the pellet rolls rotate, force is also 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 particles to break and malleable particles to deform forcing them to be fed in the die and come out as pellets. The pellets then fall naturally due to impact created by the rotating die plate. The machine has an over-all dimension of 35 cm (W) by 75 cm (L) and 102 cm (H). It can produce pellets of 4 mm diameter and 1 mm long each weighing 0.138 g. The pellets produced has a bulk density of 0.51 g/cc. The machine has a capacity of 57 kg pelletized feeds per hour of operation. An investor needs Php50,000.00 for the procurement of the pellet mill and for the construction of its housing. Considering that the CPU-CARES Formulated Starter Mash will be used to pelletize feeds, financial analysis indicated that it will be profitable to venture in this project. It will give a rate of return of 423% of the capital invested. The benefit derived is 16% of the cost incurred. The investment to this project including housing can be paid back in less than three months. Based on the aforementioned findings, the pellet mill was able to convert dusty mashed feeds into pellets and it can produce significant amount of pellets per day.

INTRODUCTION

Feed milling in the country is dominated by a few companies (PCARRD, 2006). The Panay Agribusiness Venture (LoveFeeds) and Philippine Foremost Milling Corporation (Excel Feeds) predominantly produce commercial feeds for local animal raisers in Iloilo. Purina, San Miguel, and Vitarich Feed Companies, which are Luzon-based are also penetrating the local markets.

The raw materials formulated in mixing these feeds were mostly imported (BAS, 2009) since most of these materials, 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.

This high cost of input has led some individuals to formulate their own home-mixed rations for feeds of their animals like native chickens (Cabales & Dusan, 2006). These individuals process these feeds using manual- or electric-operated corn mill and they just mix it manually. The dusty nature of the feeds was the common problem they encountered during the process. This also triggered the loss of nutrients in rations. Some moisten the feeds before feeding to minimize dustiness but in turn, the feeds easily spoil.

Pelleting can be an answer to dusty feeds. Pelleted feeds offer 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 feeds often result in reduced feed waste, dust generation and ingredient segregation (from http://distillersgrainsquarterly.com/article-print.jsp?article_id=1212). Pelleting of feeds, however, would need 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. The pellets are made by compacting the mash or meal into small holes in a die, which is usually round, and the pellets are pushed from the inside out (from http://en.wikipedia.org/wiki/Pellet_mill).

Presently, however, only giant feed millers have the financial capacity to use pellet mills. Some of these large-scale pelleting equipment developed have a capacity of 1 to 8 tons per hour with feed sizes that range from 1.5 mm to 8 mm (from <http://chemgroup.enalibaba.com>). Other units developed could produce 0.5 to 1.5 tons of pellets per hour. The pellets with die plate diameter of 250 mm had pellet sizes that range from 2 to 18 mm (from <http://www.zhengchang.com/eng/ProductShow.asp?Id=20>).

A small-scale animal producer seldom invests in these large-scale technologies since it would be expensive on their part leaving them no choice but to depend on the high cost of commercial feeds. But if these producers could have access to a pellet mill technology that is low cost yet dependable, then problems on expensive operational costs maybe reduced leading to lower prices of animal products.

With this, Cordero (2008) designed and evaluated a manually-operated pelleting machine that can pelletize an average of 25 kg of feeds per hour. The machine operates at an approximate speed of 80 rpm. The problem, however, that it is labor-intensive since it is manually-operated but it is ideal in areas with no electricity. One of the recommendations made to improve the operation of the machine was to maintain the speed in manipulating the handle in order to obtain uniform compaction of the pellets produced. This is difficult to attain if done manually, hence, the best way is to mechanize the operation using an electric motor.

Many factors have to be considered in the production of pelleted feeds. The major parameters that influence pelleting include feed conditioning and ingredients, and pellet mill die geometry. Conditioning goals include heating the feed particles, adding moisture and mixing. Moisture is also essential when conditioning feeds. Steam addition is usually sufficient, but direct injection of water may also be needed. When conditioning, the most common target moisture content at conditioner discharge is between 15 and 17%. Eighteen percent is often the highest recommended moisture. Too much moisture will clog the pellet mill. Thoroughly mixing the moisture into the feed particles and providing a consistent heat distribution throughout the feed mass is another major goal of conditioning. To achieve this mixing, retention times in conditioners between 30 seconds to five minutes are common. Longer times will lead to more starch gelatinization (starch is a key to binding particles together), and thus better binding. The particle size of the ingredients is also important when trying to produce pellets. In general, the finer the particle size, the better the resulting pellets, because moisture and heat have the ability to penetrate more thoroughly during conditioning. After discharge from the mill, pellets must be cooled in order to remove residual

heat and moisture. Otherwise, the risk of mold growth during storage is high. It is suggested that pellets should have a final moisture content of less than 13 % in order to be safe for storage (from http://distillersgrainsquarterly.com/article-print.jsp?article_id=1212).

Objectives of the Study

The general objective of the study was to design and evaluate the performance of a roll-type extrusion press pellet mill for animal feed production. Specifically, it aimed:

1. to evaluate the operating performance of the machine in terms of pelleting time, pelleting capacity, moisture loss of pellets produced and total solids, and physical parameters of pellets like particle size, shape and bulk density; and,
2. to analyze the cost and return of operating the roll-type extrusion press pellet mill.

Time and Place of the Study

Design and evaluation of the performance of the feed pellet mill was done at the Appropriate Technology Center, College of Agriculture, Resources, and Environmental Sciences (CARES) at Central Philippine University, Iloilo City. The canvass of construction materials followed. The fabrication of the machine was started on February 27, 2009 and was finished on May 18, 2009. Pre-fabrication of the pellet roll and die plate was done at Lopez Engineering and General Services at La Paz, Iloilo City while installation of the pre-fabricated parts and construction of the frame was done at Dennis Welding Shop in Pavia, Iloilo. Evaluation was done on May 18 to 21, 2009.

METHODOLOGY

Description of the Pellet Mill

The pellet mill as schematically shown in Figures 1 and 2 consisted of the following parts:

Feed hopper. This was where the CPUCARES formulated feeds were fed and extruded by the two pellet rolls to the die plate as pellets. It has outer and inner diameters of 36 cm and 21.5 cm, respectively, with a height of 29 cm. A gauge number 20 stainless steel was used to prevent sticking of feeds to the feed hopper and to allow easy cleaning. The outer diameter was welded with a 6 mm plain round bar to eliminate any sharp edges that may be caused by the stainless steel sheet.

Pelleting chamber. This was where mixing and extruding of feeds were performed prior to being pushed through by the pellet rolls into the holes of the die plate. This part was made from a 1/8 in. mild steel (MS) plate with dimensions of 21.5 cm diameter x 13 cm high in order to withstand the rigorous force created by the rotating die plate and pellet rolls.

Pellet roll. This part was responsible in compressing the formulated feeds before it was extruded in the die plate. The two corrugated pellet rolls were put in with two bearings each and were inserted in a 1 in. cold rolled steel (CRS) shafting to allow them to freely rotate once the die plate rotated also. The pellet rolls, each with a dimension of 7.5 cm diameter x 7.5 cm length, were also fixed flange bearing on both sides to minimize slippage during operation.

Die plate. It was the part that converted the formulated feeds into cylindrical-shaped solid materials or into pellets. The die plate was locked by a 1-in. diameter CRS shafting to allow it to rotate once the electric motor is turned on. It was made from a metal plate with 21 cm diameter with 3/4 in. thickness in order to bear the weight and force created by the rotating pellet rolls. It has 682 holes each with a diameter of 4 mm.

Discharge chute. This was where the pelletized feeds were discharged for collection. It was made from 1/8 in. thick MS plate with dimensions of 16 cm wide x 45 cm long x 5 cm deep.

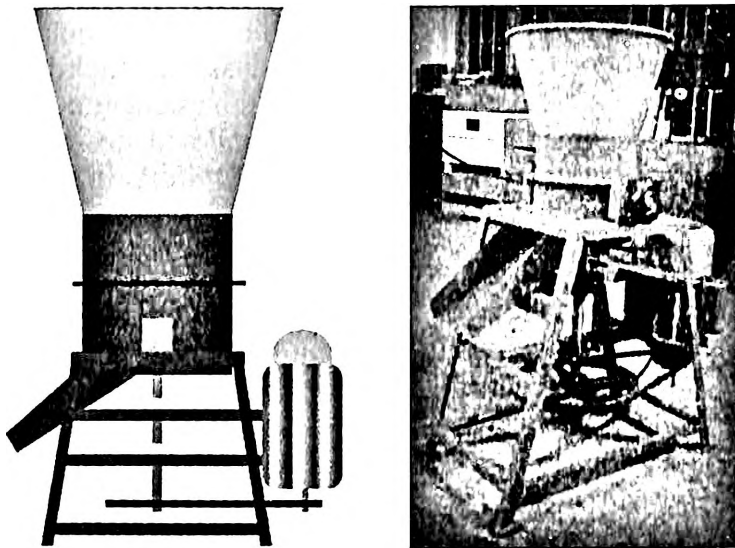


Figure 1. Schematic Drawing and Picture of the Electric Motor-Driven Pellet Mill

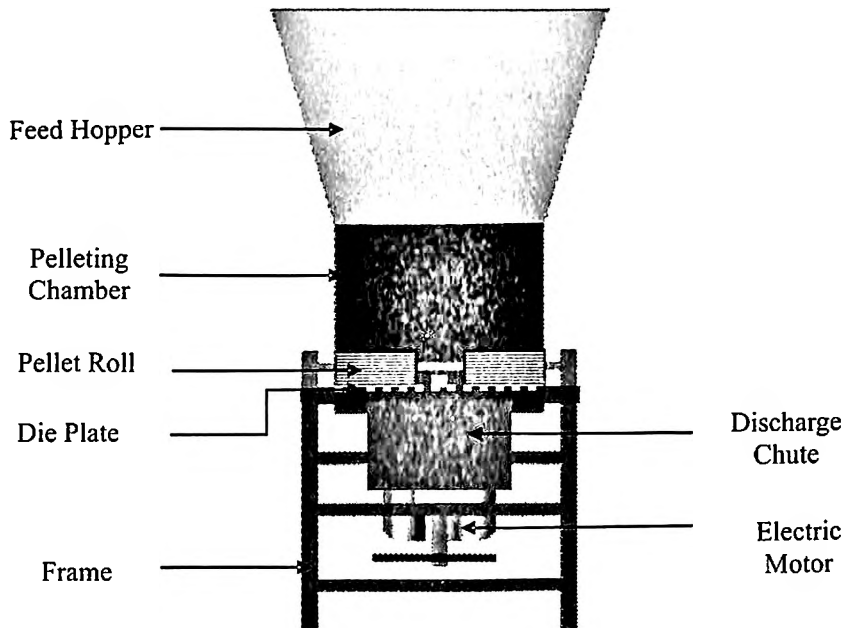


Figure 2. Detailed Parts of the Electric-Motor Driven Pellet Mill

Electric motor. This was responsible in driving the die plate to an appropriate speed that led to the conversion of mashed formulated feeds into pellets. A single-phase 1.5 Hp electric motor was used in order to drive the needed speed for operation of 1700 rpm and at the same time is able to bear overload should it happen. The motor was affixed with a 3 in. single-groove v-belt pulley where it was connected to the pellet mill affixed with a 12 in. single-groove v-belt pulley.

Frame. A 3/16 in. x 1 in. x 1 in. angle bar was used as material for the construction of the frame to make sure that the entire body of the pellet mill can be carried by the frame. It has a total dimension of 35 cm wide x 61 cm long x 62 cm high.

Principle of Operation of the Pellet Mill

The machine worked on a principle that it uses a roll-type extrusion press. The formulated feeds were fed into the pelleting chamber by the pellet rolls. As the pellet rolls rotated, force was also applied creating rearrangement of the particles in order to fill the voids or holes of the die plate. The pressure was increased in compression step, causing brittle particles to break and malleable particles to deform forcing them to be fed in the die and come out as pellets (University of Michigan-Multimedia Educational Laboratory, 1999; http://www.feedmachinery.com/glossary/pellet_mill.php). The pellets then fell naturally due to the impact created by the rotating die plate, hence, a cutter was no longer needed.

Performance Evaluation

Evaluation was done in five runs. The machine was operated in three major steps: manual mixing of the formulated feeds with the binding material and water was done first, followed by pelleting them, after which the pellets were sundried until the appropriate moisture for storage was attained.

Feeds for poultry formulated by the College of Agriculture, Resources and Environmental Sciences (CARES) were used as feed materials for this study. The formulated feeds which were a mixture of blood meal, fish meal, ipil-ipil leaves, bone meal, sweet potato, golden snail, corn bran, copra, peanut oil meal, malunggay, lemon, kakawate, molasses, powdered oyster shell, corn mix, rice, kangkong, wheatflour, and flavorings amounted to a total of 50 kg. Every kilogram of feeds, however, was mixed with 0.125 kg of corn starch as binding material and 800 ml of hot water. 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 Pandan Tsina; and Trial 3 Lemon Grass.

The mixture of formulated feeds, corn starch, and hot water was weighed first before it was loaded into the hopper of the pellet mill while the machine was already turned ON. This operation indicated the start of pelleting time. The pellets produced after each trial were then weighed and sundried for a few hours until the appropriate moisture content for storage was achieved. 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.

Instrumentation

The following instruments were used in testing the performance of the electric motor-driven pellet mill: 20-kg Spring-type balance, 2-kg compact scale, Analytic Mettler-Tole balance, standard-sized aluminum cooking pot, 2000-ml beaker, stop watch, steel tape, and vernier caliper.

RESULTS AND DISCUSSION

Pellet Mill Design and Specifications

Shown in Table 1 are the major parts and design specifications and dimensions of the pellet mill. As presented, the machine is mostly made of stainless sheet, mild steel, and angle bars. The feed hopper was made of stainless sheet number 20 to minimize the sticking of feeds to the feed hopper and to allow easy cleaning. The pelleting chamber, which is cylindrical, is made from a 1/8 in. thick MS plate, similar to that of the discharge chute. Two pellet rolls were used for this machine and they were from a CRS shafting having the same diameter and length of 7.5 cm. The die plate was made of 21.5 cm and 3/4 in. MS plate. It has 682 holes each having a diameter of 0.4 cm. The hole in the die plate served as molder of pellets. The discharge chute which was made of the same materials used for the pelleting chamber had a dimension of 16 cm wide by 45 cm high and 5 cm depth. The frame was made of 3/16 in. thick x 1 in. x 1 in. x 20 ft angle bar giving a total dimension of 35 cm wide by 75 cm long by 102 cm high. The pelleting machine was powered

Pelleting

The water and binding material are critical in the pelleting process. Too much or too little of both will not produce the desired quality of the product. In the three trials conducted using 68 kg (average weight of wet compounded ration), it produced 66.55 kg of pellets in 52.33 min. or an average pelleting capacity of 1.272 kg/min. These data are presented in Table 2.

Pellets Basic Parameters

The newly produced pellets contained high level of moisture and need to be dried before storage. It was observed that the average moisture content was 25.47%. From 66.55 kg wet pellets 49.19 kg dry pellets were produced (Table 3). This had percentage solids of 74.53% and a bulk density of 0.51 g/cc (Table 4). The pellets produced had a uniform diameter of 4 mm, length of 11 mm and weight of 0.138 gram per pellet (Table 5).

Table 1. Design and Specifications of the Pellet Mill.

Major Parts	Design Specifications and Dimensions
Feed hopper	Stainless sheet # 20
Outer diameter, cm	36
Inner diameter, cm	21.5
Height, cm	29
Pelleting chamber	1/8 in. thick MS plate
Diameter, cm	21.5
Height, cm	13
Pellet roll	2 pieces Corrugated CRS 1 in. shafting
Diameter, cm	7.5
Length, cm	7.5
Die plate	MS plate
Diameter, cm	21.5
Thickness, in.	3/4
No. of holes	682
Diameter of holes, cm	0.4
Discharge chute	1/8 in. thick MS plate
Width, cm	16
Depth, cm	5
Height, cm	45
Frame	3/16 in. x 1 in. x 1 in. x 20 ft. angle bar
Width and Length, cm	35 and 61
Height, cm	62
Electric motor	Matsumoto single-phase, 1.5 Hp
Total Dimension	
Width, cm	35
Length, cm	75
Height, cm	102

Table 2. Weight of Pellets Produced, Pelleting Time and Pelleting Capacity of the Machine.

Trial	Weight of Wet Materials	Wt. of Pellets Produced (A)	Pelleting Time (B)	Pelleting Capacity*
	kg	kg	min	kg/min
1	66	63.50	50	1.270
2	71	71.70	57	1.258
3	67	64.45	50	1.289
Ave	68	66.55	52.33	1.272

* Computed as, Pelleting Capacity = [A/B]

Table 3. Moisture Content and Total Solids of Pellets Produced.

Trial	Wt. of Pellets		Moisture* Content	% Total Solids**
	Before Sundrying (A)	After Sundrying (B)		
	kg	kg	%	%
1	63.50	59.08	6.97	93.03
2	71.70	43.00	40.03	59.97
3	64.45	45.50	29.40	70.60
Ave	66.55	49.19	25.47	74.53

* Computed as, Moisture Content = [(A-B)/A] x 100

** Computed as, % Total Solids = [B/A] x 100

Table 4. Bulk Density of the Pellets Produced.

Trial	Wt. of Pellets After Sundrying Using Container (A)	Total Volume of Pellets Using Container (B)	Bulk Density*
	g	cc	g/cc
1	121.20	223.52	0.54
2	110.80	223.52	0.50
3	108.98	223.52	0.49
Ave	113.66	223.52	0.51

* Computed as, Bulk Density = [A/B]

Table 5. Physical Properties of Sundried Pellets Produced.

Trial	Diameter	Average Length	Average Weight
	mm	mm	g
1	4	12	0.147
2	4	10	0.132
3	4	10	0.135
Ave	4	11	0.138

Financial Analysis

Financial analysis considered was for a community or a small-scale producer that would consider venturing into feed milling production; hence, the marketing price was used since this would be the amount that would be invested by the producer for the machine. Housing cost was included since this would be needed for storage of equipment and materials for production. An investor needs Php35,000.00 for the pellet mill and Php15,000.00 for the housing of the equipment. In the three- year projected income statement (Table 6), the total fixed cost amounted to Php23,450.00. The operations were assumed to pelletize the CPU-CARES Formulated Starter Mash, which would cost only Php11.05 per kilo. This is much economical compared to that of commercial feeds at Php26.00 (Table 7). If the equipment will operate at 269 days per year, it would produce 121,319 kg of pellet feeds costing Php1,236,240.00. Given the electric power requirements, the labor at Php200.00 per man-day and miscellaneous costs, the total variable cost for the 1st year was Php1,336,991.92. If the pelletized starter feeds will be sold at Php13.00 per kilo, it will give an income of Php1,577,147.00. In the first year of operations, the project can give a net income before tax of Php211,705.08.

It is assumed that yearly increase in income and variable cost is 2%. The internal rate of return (IRR) which is the financial indicator for the three-year projections was 423%. This means that the return on the investment made is more than 400 times. This is further supported by a benefit cost ratio (BCR) of 16% which is more than the operational cost incurred. Investing on this pellet mill is profitable. It only needs 0.23 year or less than three months of operations to recover the initial investment on equipment and housing.

DISCUSSION

Feeding native chicken does not necessarily require imported feedstuffs which may cost billions of dollars (BAS, 2009). The CPU-CARES formulation (Table 7) can help solve the dilemma (Lotilla, 2009) by reducing the operating expenses of the animal growers due to lower cost of feeds. Furthermore, the problem on the dusty home mixed rations (Cabarles & Dusaran, 2006) was overcome by pelleting the feeds. The newly developed machine was also found to be more efficient than the one developed by Cordero (2008). The new design can produce pellets at 1.272 kg/min, whereas that of Cordero (2008) which is manually operated can only generate 0.53 kg/min. Electric-operated pelleting machine can produce nearly half a ton of feeds in an 8-hour operation per day.

Problems encountered during the operation of the machine were also documented. There was spillage every time the feed materials were fed into the hopper and pellets would uncontrollably come out of the discharge chute. Fines or unprocessed feed materials would also come out of the discharge chute. The machine cannot easily be transferred to another location because of its weight and spilled feeds from the hopper would sometimes drop to the rotor of the electric motor causing more problems later on its operation if not properly cleaned and maintained.

Table 6. Three-Year Projected Income Statement for Pelleting Machine Operations

Income	Year of Operations ⁵			
	0	1	2	3
Starter Pellets Sales ¹		1,577,147.00	1,608,689.94	1,640,863.74
Total		1,577,147.00	1,608,689.94	1,640,863.74
Initial investment				
Pelleting machine	35,000.00			
Housing	15,000.00			
Variable cost				
Starter mash ²		1,236,240.61 ³	1,260,965.42	1,286,184.73
Electricity ⁶		33,713.77	34,388.05	35,075.81
Labor ⁷		53,800.00	54,876.00	55,973.52
Miscellaneous ⁴		13,237.54	13,502.29	13,772.34
Subtotal		1,336,991.92	1,363,731.76	1,391,006.40
Fixed cost				
Depreciation (machine) ⁸		10,500.00	10,500.00	10,500.00
Depreciation (housing) ¹²		5,000.00	5,000.00	5,000.00
Interest on investment ⁹		8,400.00	8,400.00	8,400.00
Repair and maintenance ¹⁰		3,500.00	3,500.00	3,500.00
Insurance ¹¹		1,050.00	1,050.00	1,050.00
Subtotal		23,450.00	23,450.00	23,450.00
Total Cost	50,000.00	1,365,441.92	1,392,181.76	1,419,456.40
Return above variable cost		240,155.08	244,958.18	249,857.34
Net income before tax	(50,000.00)	211,705.08	216,508.18	221,407.34
Beg. return of earning	(50,000.00)	161,705.08	378,213.25	599,620.60
IRR	423%			
BCR	1.16			
Payback period (in years)	0.23			

¹ Produced 121,319 kg of pelletized starter feeds per year @ Php13.00/kilo

² 269 days of operation/year @ 451 kg/day

³ Php11.05 per kilo of CPU-CARES formulated starter feeds

⁴ 1% of the total variable cost

⁵ 2% increase in sales and variable cost per year of operations

⁶ P1.12 kW/hr @ 8 hrs operation x P14.00/kW-hr

⁷ Php200 per man-day

⁸ Straight line method at 10% salvage value and 3 years life span

⁹ 24% of IC

¹⁰ 10% of IC

¹¹ 3% of IC

¹² Zero salvage value @ Php5000/year

Table 7. CPU-CARES Formulated Base-mix Ration and Compounded Starter Feed with Corresponding Volume Used and Cost per Unit Volume

Feedstuffs Used for Base-mix	Cost of Feedstuffs	Base-mix	Final Cost of Feedstuffs
	Php/kg	kg	Php/kg
Blood meal	17.50	0.50	8.75
Fishmeal	7.00	4.00	28.00
Ipil-ipil leaf meal	3.00	2.00	6.00
Bone meal	2.50	1.00	2.50
Sweet potato top meal	3.00	3.00	9.00
Golden snail meal	4.00	2.00	8.00
Corn bran	12.50	3.00	37.50
Copra meal	15.00	2.00	30.00
Peanut meal	50.00	1.00	50.00
Malunggay leaf meal	5.00	2.00	10.00
Lemon grass meal	4.00	1.00	4.00
Kakawati leaf meal	3.00	1.00	3.00
Molasses	10.00	2.00	20.00
Powder oyster shell	25.00	0.50	12.50
Total		25.00	229.25
Compounded Starter Pellets Using Base-mix and its Final Cost per Kilo			
Base-mix	9.17	25.00	229.25
Corn bran	12.50	3.89	48.63
Kangkong meal	3.85	11.66	44.85
Rice bran	12.00	3.89	46.68
Corn starch	25.20	5.56	140.11
Total		50.00	509.51
Pelleting and drying cost per 50 kg feeds			43.19
Final cost per bag			552.70
Cost per kg of native chicken starter pellets			11.05
Retail price of commercial chicken starter pellets			26.00
Savings of using the CPU-CARES formulated ration			14.95

CONCLUSIONS AND RECOMMENDATIONS

Based on the aforementioned findings, it can be concluded that the machine developed was able to convert mashed feeds into pellets having 4 mm diameter, an average length of 10 mm and an average weight of 0.138 g. It operated using a roll-type extrusion press forcing the formulated feeds out of the die plate through the two pellet rolls. The pellet mill can produce pellets at an average of 1.272 kg/min making it more efficient than the previously designed manually-driven pelleting machine. With this rate, the pelleting machine can produce daily nearly half a ton of feeds for an 8-hour operation making it more ideal for community feed milling or for even just a small-scale feed miller. Considering that the CPU-CARES Formulated Starter Mash will be pelletized, financial analysis indicated that it will be profitable to venture in this project.

The following are recommended to further improve the design and operation of the pellet mill:

1. The feed hopper should be modified to minimize the spillage of mixed feeds due to the force created by the rotating pellet rolls.
2. A stopper or vertical lid should be provided on the opening of the discharge chute to better manage the pellets that come out of it.
3. A pellet screener that would separate pellets from fines that come out of the die plate and a separate discharge chute for these fines to allow them to be pelletized again should be provided.
4. Rollers should be installed on each leg of the frame to allow easy transfer every time the machine is used.
5. A cover on the electric motor should be provided to minimize spillage of feeds that might clog the rotor part of the machine causing interference in its operation.

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