







# An Approach for a Low-Cost and Enhanced Safety of An Animal Feed Pellet-Making Machine for Small-Scale Users

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**Abstract.** This project focuses on developing an improved animal feed pellet machine that is affordable, ergonomic, and safe for small-scale animal breeders and new-comers. It addresses the high cost and lack of safety features in existing machines. This project introduces a portable, electrically powered machine with enhanced safety measures, including an emergency stop button and aluminum pellet dies for better hygiene and cleaning. The project aims to enable breeders to produce their feed pellets, improving efficiency and reducing costs. Notable advancements encompass uncomplicated design for effortless operation and maintenance, the capability to produce variety of pellet sizes, and the incorporation of user safety elements. This enhanced pellet-making machine can produce 43.2 kg of pellets per hour with an efficiency of 72%, suggesting its capacity to substantially assist small-scale animal breeders by reducing feed production cost and enhancing access to high-quality feed, such as using their customized ingredients. This performance is a vital outcome that highlights the machine's efficacy in resolving issues related high cost, ergonomics, and safety associated with existing feed pelleting options. Recommendations for future improvements suggest using more resilient materials, incorporating a hopper lock, a detachable frame for simpler maintenance, an additional side handle for better handling, and a lighter electric motor to improve portability and user-friendliness.

**Keywords:** *small-scale, efficacy, portable, ergonomic, user-friendliness.*

## 1 Introduction

Feed is an essential need for animals, encompassing both poultry and livestock. This directly affects the quality of pellets produced. In contemporary agriculture, feed and machinery are essential for preparation, production, and processing of feed. In the pellet-making process, a pellet machine optimizes production, improves operational efficiency, and allows operators to expedite the process while ensuring superior output

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quality. Moreover, pelletized feed specifically improves digestibility, minimizes feed wastage, and prolongs shelf life by preserving nutrient stability (Abdollahi et al., 2013; Dhakal et al., 2024). Nonetheless, effective productivity depends on accessibility. In 2022, Nguyen determined that an optimal pellet machine must be safe, efficient, and capable of producing varied pellet-shapes. Notwithstanding these conditions, small-scale breeders face significant barriers in obtaining one.

The main challenge for breeders is cost, because high-quality pellet machines are usually imported from abroad and are quite expensive. As a result, breeders rely on making pellets for their animals manually, which requires significant labor. A recent study by Ukagwu et al. in 2024 underscores the necessity of creating a portable, electric-powered option for rural and small-scale breeders to circumvent these expenses. Secondly, in relation to lower-cost alternatives, safety and ergonomics are frequently neglected. Personal-use agricultural machinery often lacks critical fail-safe mechanisms, exposing operators to significant risks and injury. Furthermore, a 2019 study by Okolie et al. highlights that material selection in food processing equipment is vital for both longevity and ease of maintenance.

Thus, there is an essential requirement for a cost-effective, locally produced pelletizing solution that maintains safety and ergonomic standards. This project aims to design and develop a portable, cost-effective animal feed pellet machine with safety features. The study continues with a detailed evaluation of machine functionality and performance to verify these improvements.

## **2 Literature Review**

### **2.1 Animal Feed**

Food is vital for animal survival and mechanized feed reduces wastage, improves cost efficiency, and optimizes resources (Vlaicu et al., 2024). Compound feed, a homogeneous mixture of feed ingredients, facilitate mechanization, diminishes labor and enhances preservation. In 2022, Nguyen also emphasizes attributes such as safety, operational simplicity, and energy efficiency. Nonetheless, the gap remains. Although manual machines are economical, they require significant physical effort and proficient handling to avert accidents. This highlights that current market options do not adequately reconcile affordability with the essential safety measures required for inexperienced small-scale breeders.

### **2.2 Pellet Mills and Pelleted Feed Benefits**

Although pellet mills predominantly employ ring-die designs, flat-die configurations are often preferred for small-scale operations due to their inherent compactness and lower spatial requirements. Nonetheless, although previous studies note that efficiency relies on torque and alignment, many low-cost flat-die designs compromise on material quality, often using corrosive mild steel. To address this, the proposed design incorporates aluminum die plates for superior hygiene and maintenance. Furthermore, since

pelleting is proven to increase nutrient density, digestibility, and waste reduction (Payne & Wilson, 2017), precise particle sizing is essential for efficacy (Svihus, 2017).

### **2.3 Operational Safety and Cost Constraint**

Safe operation is crucial to avoid problems such as overheating and excessive vibration. In 2025, Gustav et al. emphasize that safety controls, including proper guarding and emergency stop mechanisms, are essential to avert operator injuries. Moreover, high machine costs limit adoption among small-scale breeders. The capital needed is often unaffordable for newcomers, hindering self-sufficiency in feed production. Cost-effective design and governmental subsidies are essential for facilitating wider accessibility. It is also recommended that the government mitigate financial obstacles, as dependence on external finance is not a viable engineering solution (Jena & Tanti, 2023).

### **2.4 Optimal Pellet Sizes**

Pellet sizes affect feed consumption and digestion. Sizes were customized according to species and development stage. Poultry derives benefit from 1-3 mm pellets early on, progressing to 4-5 mm (Abdollahi et al., 2013). Livestock calves, and mature goats thrive with 3-6 mm pellets (Kumar et al., 2020), whilst rabbits necessitate smaller pellets of approximately 2.5-4 mm (Buitrago et al., 2020).

### **2.5 Overview and Rationale for Design**

These research evaluations affirm that although pelleting provides enhanced nutritional advantages, current technology forces small-scale breeders to choose between expensive machines or low-cost machines that are inefficient and not safe. This study addresses the gap by demonstrating an improved design that uses an aluminum flat die to prevent corrosion, to cut costs but still maintaining hygiene and safety standards.

## **3 Methodology**

### **3.1 Development Process Workflow**

The development process of the pellet-making machine adhered to a methodical design framework. Fig. 1 below illustrates the workflow for the development of the pellet-making machine.

### Development Flow of Making A Pellet Machine

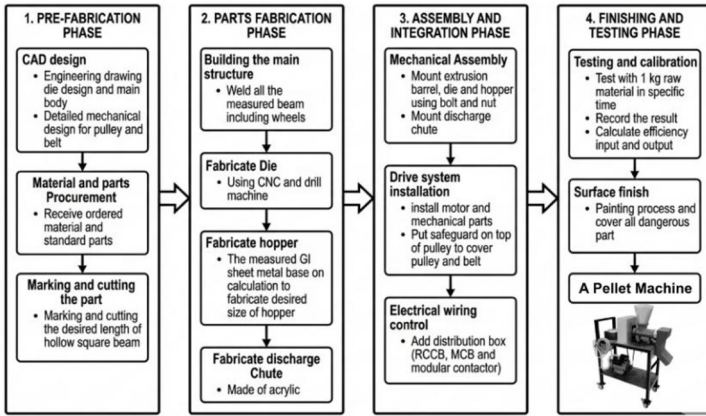


Fig. 1. Pellet machine development process. (Source: Authors)

### 3.2 Design Methodology

**Design sketch.** Conceptual designs are sketched to visualize the ideas, concepts, and structure of the project. The concept entails the integration of several functionalities and components that will form the final product. Key considerations include user friendly machines, adaptability to user needs, safety features and compatibility with existing machines. Fig. 2 below is the design sketch of the machine.

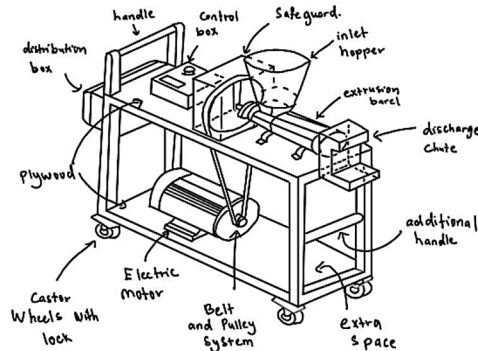
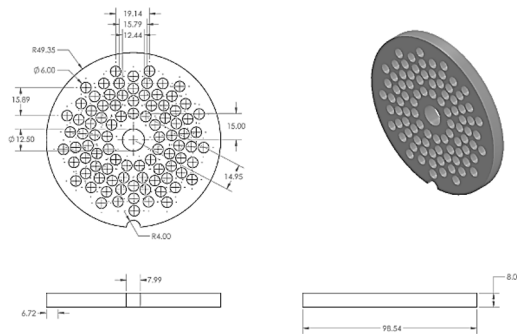


Fig. 2. Design sketch of the pellet machine. (Source: Authors)

**Computer-Aided Design (CAD).** SolidWorks 2021 to 2023 version were utilized to create the CAD drawing. The use of CAD software made the design and development process easier. Each part and component drawing was developed from the concepts derived from the sketch and morphological chart. These designs furnish exact measure-

ments and specifications required for product fabrication. The drawings are meticulously revised multiple times to incorporate all essential measurements for the components and the assembly. These detailed designs are crucial for the fabrication process. Notable features include an extra storage area for multipurpose use, castor wheels equipped with a lock for mobility and stability, and an additional handle for easier lifting and transportation. The base is made from wood planks, and the total anticipated weight of the machines is between 50 and 60 kg. The final assembly of the machine design is as in Fig. 9.

### Pellet dies discs



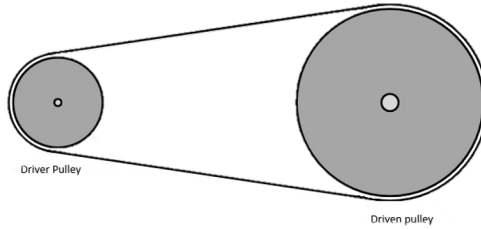
**Fig. 3.** A pellet die (available in 4, 5, and 6 mm. (Source: Authors))

Fig. 3 above shows the design of a pellet die. Pellet dies were what it took to form the cylindrical pellet shape. This die plate is made using an aluminum profile plate. The use of an aluminum plate for making this part is because aluminum will not rust and corrode like the mild steel ones that are commonly used, and it is cheaper than the copper version. Typically, aluminum plates have a density of approximately  $2700 \text{ kg/m}^3$  making it suitable for holding pressure in an extrusion part (Georgantzia et al., 2021). There are three different pellet size options included in the product design, which are 4, 5, and 6 mm. So, pellet dies can be chosen from any size, depending on the animal type, when it comes to pellet production. The overall diameter of the die plate is 98.7mm, and 8mm thick.

**Frame material.** Mild steel (A36) is the standard for structural frames because of its high stiffness and predictable failure modes. It has a Young's modulus of approximately 200 GPa, providing the necessary strength to maintain machine alignment under load (Georgantzia et al., 2021). Moreover, it is asserted that employing "hollow" sections provides an ideal combination of strength and material efficiency, effectively resisting bending and compression forces while reducing overall machine weight (Hibeler, 2022).

### 3.3 Calculation and Analysis for Design.

**Identification of belt.** The machine is equipped with a 3HP motor and belt, and a pulley mechanism (open belt drive) as shown in Fig. 4 below to run the screw during the pellet-making process.



**Fig. 4.** Open belt drive. (Source: Authors)

Length of the V-belt:  $L = \pi(r_1 + r_2) + 2x + \left(\frac{r_1 - r_2}{x}\right)^2$

$r_1$  = diameter of driver pulley

$r_2$  = diameter of driven pulley

$x$  = Center-to-center distance between pulleys

Calculation:

$$L = \pi(28.25 + 123.85) + 2(460.59) + \left(\frac{28.25 - 123.85}{460.59}\right)^2$$

$$L = 477.836 + 921.17 + 19.843$$

$$L = 1418.85 \text{ mm (Length of belt)}$$

$$r_1 = 28.25 \text{ mm}$$

$$r_2 = 123.85 \text{ mm}$$

$$x = 460.59 \text{ mm}$$

**Determination of Motor Performance.** The machine output was calculated based on the specification of the motor and the dimensions of the driver and driven pulleys.

The mechanism specification is as below:

Power of the motor, P: 2238 Watt / 3 HP

Rotational speed at the motor, N: 1400 rpm

Driver pulley diameter,  $d_1$ :  $\varnothing 1$  58.5 mm

Driven pulley diameter,  $d_2$ :  $\varnothing 2$  248.88 mm

Centre-to-center distance,  $x$ : 460.6 mm

The **rotational speed** at the driven pulley is found by using the formula,  $\frac{N_1}{N_2} = \frac{d_2}{d_1}$

$$\frac{1400}{N_2} = \frac{248.88}{58.5} \quad N_2 = 1400 \times \frac{58.5}{248.88}$$

$$N_2 = 329 \text{ rpm}$$

The rotational speed at the driven pulley is **329 rpm**.

Then, the **torque** of the motor is found by using the formula  $P = T\omega$  and  $\frac{T_2}{T_1} = \frac{\omega_1}{\omega_2}$

T1 is calculated:

$$P = T_1 \times \omega_1$$

$$2238 = T_1 \times 146.60$$

$$T_1 = \frac{2238}{146.60}$$

$$T_1 = 15.27 \text{ Nm}$$

T2 is calculated:

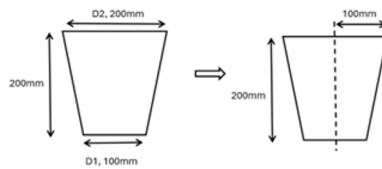
$$T_2 = \frac{146.6}{34.45} \times 15.27$$

$$T_2 = 65 \text{ Nm}$$

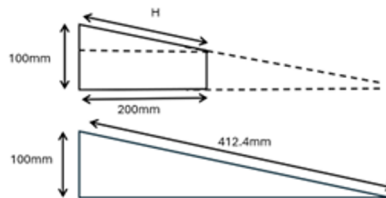
Therefore, the torque produced at the motor is **15.27 Nm**, and at the driven pulley, it is **65 Nm**.

**Making the Inlet Hopper.** The inlet hopper was in the shape of a conical frustum; the mathematical formula for a conical frustum was used to help with the hopper's fabrication. Fig. 5 and 6 both show the relation of the mathematical theorem towards its design fabrication. The calculations are as follows:

Desired size for the hopper:



**Fig. 5.** The dimensions desired for hopper. (Source: Authors)



**Fig. 6.** Applying Pythagorean theorem. (Source: Authors)

Find H,

Use Pythagoras' theorem:

$$H = \sqrt{a^2 + b^2} = \sqrt{50^2 + 200^2} = 206.2\text{mm}$$

Since 206.2mm is half the radius, 206.2mm times 2 equals **412.4 mm**, which will be drawn on the sheet metal as shown in Fig. 7 below.



**Fig. 7.** Hopper net. (Source: Authors)

$$S_1 = \pi D_1$$

$$S_1 = \pi \times 100 = 314.2 \text{ mm}$$

$$S_2 = \pi D_2$$

$$S_2 = \pi \times 200 = 628.3 \text{ mm}$$

$$r_1 + r_2 = 412.4 \text{ mm}$$

Find  $\theta$ ,

$$\theta = \frac{628.3}{412.4}$$

$$\theta = 1.523 \text{ rad}$$

$$\theta = 1.523 \times \frac{180}{\pi}$$

$$\theta = 87.3^\circ$$

## Operation Determination

*Efficiency.* Efficiency is the rate of how much raw material was used in pellet production by using this pellet machine:

$$\text{Efficiency} = \frac{\text{Weight of pellet produced (kg)}}{\text{Weight of raw materials used (kg)}} \times 100\%$$

$$\text{Efficiency} = \frac{0.72}{1} \times 100\% = 72\%$$

*Productivity*

$$\text{Productivity} = \frac{\text{Weight of pellet produced (kg)}}{\text{Time Consume (h)}}$$

$$\text{Productivity} = \frac{43}{1} = 43 \text{ kg/h}$$

*Determining of Operating Pressure (P)*

$$P = 0.7355 \times 1 \times \frac{Q}{D^2 L}$$

Capacity, Q in rev/s =  $329/60 = 5.5$  rev/s

Screw speed, L in m/s = Auger pitch in m  $\times$  Q =  $0.0435 \times 5.5 = 0.24$  m/s

Diameter of the barrel (Consider the barrel is cylindrical) in m = 0.07723 m

$$P = 0.7355 \times 1 \times \frac{5.5}{0.07723^2 \times 0.24} = \mathbf{2825 \text{ Pa}}$$

*Determination of Thrust Force (W)*

$$W = PA$$

Where A is the area of the barrel =  $\pi \frac{D^2 - d^2}{4}$  - Consider the barrel is cylindrical.

$$A = \pi \frac{0.09722^2 - 0.07723^2}{4} = 0.002739 \text{ m}^2 =$$

$$P = \text{Operating pressure} = 2825 \text{ Pa}$$

$$W = 2.825 \times 0.002739 = \mathbf{0.00774 \text{ kN}}$$

*Determination of the extrusion pressure at the pellet dies, PE.*

$$PE = \frac{W}{A} \quad A = \frac{N\pi D^2}{4}$$

W = thrust force = 0.00774kN

A = total area of die holes.

Where N is the number of holes on the die and D is the diameter of the hole.

<u>Pellet die 4mm:</u> D= 4mm N= 108	$A = 108 \times \frac{\pi(0.004^2)}{4}$ $= 0.00136\text{m}^2$	$PE = \frac{0.00774}{0.00136}$ $= \mathbf{5 \text{ Pa}}$
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Therefore, the extrusion pressure (P) for the die with **D = 4mm and N = 108** is **5 Pa**.

<u>Pellet die 5mm:</u> D= 5mm N= 96	$A = 96 \times \frac{\pi(0.005^2)}{4}$ $= 0.00189\text{m}^2$	$PE = \frac{0.000774}{0.00189}$ $= \mathbf{4.1 \text{ Pa}}$
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Therefore, the extrusion pressure (P) for the die with **D = 5mm and N = 96** is **4.1 Pa**.

<u>Pellet die 6mm:</u> D= 6mm N= 80	$A = 80 \times \frac{\pi(0.006^2)}{4}$ $= 0.00226\text{m}^2$	$PE = \frac{0.00774}{0.00226}$ $= \mathbf{3.4 \text{ Pa}}$
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Therefore, the extrusion pressure (P) for the die with **D = 6mm and N = 80** is **3.4 Pa**.

### 3.4 Pelleting technique

The method of pellet formation varies upon the sort of equipment used (Muley et al., 2016). This study employs the extrusion-spheronization technique to fabricate pellets with an axial-type screw extruder. This technique is the predominant method for pellet

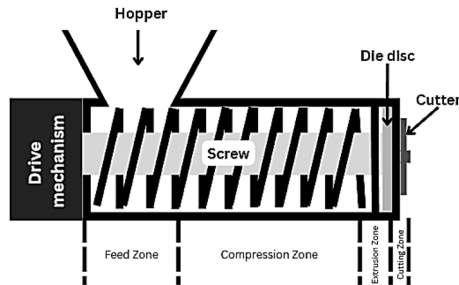
production. Vervaet et al. delineate a four-step method in their review article: (i) preparation of the wet mass (granulation); (ii) shaping the wet mass into cylinders (extrusion); (iii) fragmenting the extrudate and rounding the particles into spheres (spheronization); (iv) and drying the pellets (Vervaet et al., 1995).

#### i. Extrusion

The mixed ingredients mass undergoes extrusion in the extrusion zone, in which pressure is applied to the mass until it flows out through an orifice (pellet dies) to produce the extrudates (pellets).

#### ii. Spheronization

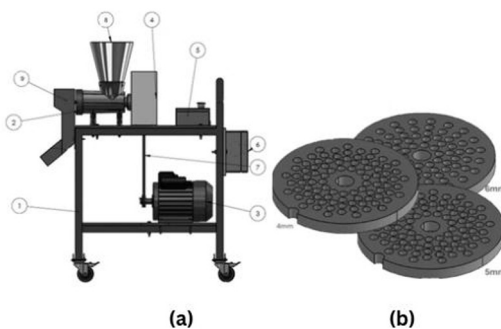
Throughout this procedure, the extruded, cylindrical-shaped pellets are broken (cut by the cutting blade) into uniform lengths. The shaping process is due to the plastic deformation of the mass that occurs in the extrusion zone when the mass is pushed out through the pellet die and cut by the cutter. Fig. 8 below show the schematic of a screw extruder.



**Fig. 8.** Schematic of a screw extruder. (Source: Authors)

### 3.5 Pellet Machine Specification

Fig. 9 below shows the final prototype of the pellet machine. The figure illustrates the components, and pellet die discs of the pellet machine. The detailed specifications of the machine components are provided below.



**Fig. 9.** (a) Machine parts; (b) Pellet die discs. (Source: Authors)

1. Body/Chassis - Made of hollow square steel with 1 mm thickness and 0.32 x 0.32 mm dimensions, the frame measured 687 x 340 x 907.8 mm. The frame has back and front handles for easier, more ergonomic lifting.
2. Extrusion barrel (body) - With dimensions of 246 x 135.62 x 203.26 mm, the body is used for pellet extruder.
3. Electric motor - 2.2kW single-phase AC motor drove the pulley.
4. Safeguard - The safety covers the driving pulley and enhances user safety during high-speed operation.
5. Control Unit - A 3D-printed box houses the primary switch, emergency stop button, and speed controller slots for upgrade. Control unit customization was straightforward using 3D printing.
6. Distribution box - The distribution box houses the system's fuse switch, RCCB, MCB, and modular contactor. We utilize 2.5-diameter wire where load distribution, overcurrent protection, and residual current protection are considered.
7. Belt and Pulley - A V-belt drive pulley was employed for efficient power delivery and maximum transfer during pelleting.
8. Inlet Hopper - Made from 0.3 mm GI sheet, inlet hopper feeds materials into the extrusion barrel.
9. Discharge Chute - Attached to the chassis, the chute directs pellets into a tray or container, reducing spillage. Detachable parts made cleaning and lifting easier.
10. Pellet dies discs (Fig. 10) - Pellet dies discs 4-, 5-, and 6-mm sizes are available and it sizes were designed for specific animals' requirements.

## 4 Results and Discussion

The pellet machine was developed and underwent testing and evaluation. The following sections present experimental outcomes supported by data and observations.

### 4.1 Ingredients for Pellets

The materials utilized for evaluating the pellet machine were obtained from local goat breeders in Kota Bharu, Kelantan, to accurately represent the feed compositions employed in small-scale agriculture. These materials are readily accessible and utilized in commercial feed manufacturing, including pulverized maize, bran, and several plant-derived constituents. The ingredients include maize, soybean meal, wheat, flour, wheat pollard, Distillers Dried Grains with Solubles (DDGS), molasses, palm kernel cake, leaf meal, dhal meal, soya hulls, limestone, salts, and dicalcium phosphate. The use of locally available and common ingredients ensured that the testing conditions closely matched actual usage scenarios, allowing for a more practical evaluation of the machine's performance in real-world applications, such as small-scale animal breeding.

A mixture of 1000g of dry feed ingredients and 1.3 liters of water was prepared for testing. The ingredients were initially quantified with a digital scale to guarantee precision. Upon preparation of the mixture, it was meticulously swirled to attain a consistent and homogeneous blend, hence assuring adequate moisture for the pelleting process. A

timer is established for one (1) minute to standardize the collecting duration during the testing process. The created pellets were gathered in a container and placed in a drying oven, where they were dehydrated at 70°C for three hours to di-minish moisture content and enhance durability. After drying, the pellets are stored in sealed plastic containers.

## 4.2 Production Capacity

A production capacity of approximately 0.717 kilograms per minute, equating to 43.02 kilograms per hour. This output is suitable for small-scale breeding operations.

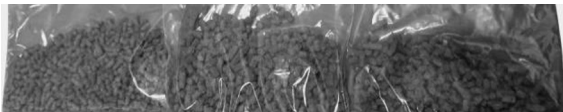
**Table 1.** Testing results.

Ingredients	Operation	Results as per 60 secs	1-hour production estimation
1 kg of raw materials + 1.3 liters of hot water	60 secs	0.717 kg	$0.717 \times 60 =$ 43.2 kg

Table 1. above shows that the machine's ability to produce approximately 0.717 kilograms of pellets in 1-minute operation. Extrapolating this rate over an hour, we can anticipate an estimated pellet production of around 43.3 kilograms ( $\approx 43\text{kg}$ ) for an hour operation.

## 4.3 Pellet Size Variety

The machine reliably generated pellets within the ideal size range specific to several animal species. Pellets for chicken, measuring between 2 and 4 mm, with some examples extending to 5 mm, are appropriate for broilers. Pellets for livestock, including goats and cows, regularly measure approximately 6 mm, facilitating improved growth and nutritional absorption. The pellet size for rabbits varied from 2.5 to 4 mm, corresponding to their dietary needs and eating habits. Ensuring uniform pellet sizes improves feed digestion, promotes superior animal health, and minimizes feed wastage. This accuracy guarantees that the pellet feed aligns with the physiological and nutritional requirements of the intended livestock. Fig. 10 below shows pellets produced.



**Fig. 10.** From left to right, 4-, 5-, and 6-mm pellets. (Source: Authors)

## 4.4 Ergonomic Enhancement

Significant attention was given to ergonomic design enhancements. The machine's height was optimized, the control panel repositioned for better accessibility, and mobility features such as wheels and handles were incorporated. The goal was to minimize

operator fatigue, highlighting improvements in operational ease and physical comfort during extended use. These modifications ensure that the machine remains user-friendly and accessible to operators with varying physical capabilities and technical expertise. Fig. 11 below shows the ergonomic focus on the pellet machine.

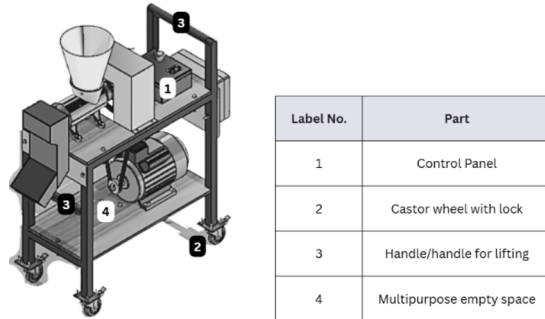


Fig. 11. Ergonomic focus on the pellet machine. (Source: Authors)

#### 4.5 Safety Features

The machine was designed with comprehensive safety features. It included an emergency stop button that allows for immediate shutdown in case of any operational anomaly. A lockable caster wheel can immobilize the equipment during operation, transfer, or storage when engaged. Protective barriers were implemented to safeguard users from moving components, while insulated electrical elements provided protection against electrical risks. MCB, RCCB, and a contactor are also incorporated for enhanced electrical wire system safety. Fig. 12 below shows the focus on safety for the pellet machine.

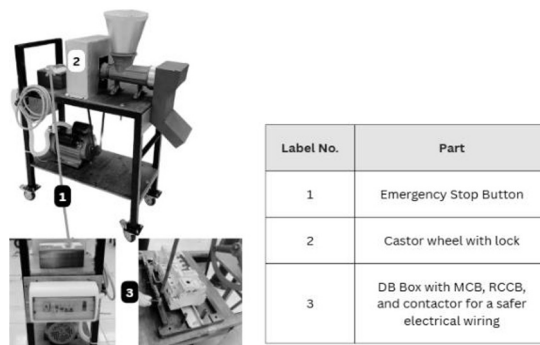


Fig. 12. Safety focuses on the pellet machine. (Source: Authors)

## 4.6 Performance Comparison

This section benchmarks the prototype against manual and commercial grade small pellet mill. The details of the comparison are summarized in Table 2.

Table 2. Comparative Performance.

Types	Production Capacity (Per hour)	Efficiency (%)	Pellet Quality	Energy/labor	Usability
<b>Manual</b>	0.9 - 4.2 kg (Abdollahi et al., 2013; Dhakal et al., 2024)	59 - 92 (Abdollahi et al., 2013; Nguyen, 2022)	More sensitive towards the operator's settings (Abdollahi et al., 2013; Dhakal et al., 2024; Ukagwu et al., 2024).	High manual labor energy is needed	Suitable for basic needs.
<b>Flat Die Pellet Mill</b>	<u>Small machine:</u> - 60 - 80 kg - 71 - 74 kg <u>3HP motor:</u> - 60 - 65 kg (Okolie et al., 2013)	84 - 87 (Okolie et al., 2013)	High-density durability (very high compressive force) with controlled settings (Vlaicu et al., 2024).	Higher energy use. $\approx 14000$ kWh/kg (Vlaicu et al., 2024). Low labor energy.	Suitable for continuous operations Small-medium scale.
<b>*Animal-feed pellet-making machine</b>	43 kg	72	Depending on the user's settings for its parameters. Suitable for small individual use.	Low labor energy Energy efficiency: <i>energy used</i> $\frac{\text{mass pellet produced}}{43.2 \text{ kg}} = 0.051 \text{ kWh/kg}$	Suitable for continuous operations for small-scale operations. (small-scale animal breeders)

## 5 Conclusion

Recent improvements in animal feed pellet machine designs show real progress in solving the problems found in older models. These projects focus on creating machines that are more affordable, easier to use, and safer, especially for small-scale animal breeders who often cannot afford expensive machines or rely on time-consuming manual feed preparation. The new designs bring practical benefits. With a production rate of 0.72 kg per minute (around 43.2 kg of pellets per hour), this would help small-scale breeders save time, reduce physical labor, and increase productivity. By using simpler and stronger parts, they are also more reliable, easier to maintain, and less likely to break down. Another big advantage is flexibility. These machines can produce feed for different kinds of animals using a single machine. This saves both money and effort. Looking to the future, these improvements give hope for more self-sufficient and cost-effective farming. As better machines become more available, they can help more small-

scale breeders produce their own high-quality feed, support animal health, and build a more sustainable and independent way of farming.

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**Disclosure of Interests.** The design of the pellet machine is filed under the Malaysian Copyright Act 1987 with copyright number CRAR2024P00874.

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