STUDIA UNIVERSITATIS BABEȘ-BOLYAI
Engineering 69(1) 2024 DOI: 10.24193/subbeng.2024.1.18

Development and Evaluation of a COOI24m Pelletizer

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Abstract. *It is essential to formulate appropriate feeding pellets with the required nutrient compositions for poultry animals to meet the growing demand for protein through the provision of eggs and meat. Forming the required feed concentrates into pellet-mash requires a pelletizing machine, which is, in most cases, very expensive for the local farmers due to the high foreign exchange rate. Based on this, the study focuses on the development of a simple and affordable pelletizing machine from locally sourced materials. The machine consists of a frame, hopper, die roller, pelletizer, and internal combustion (5.5 hp), and it was run at 950, 600, and 450 revolutions per minute. The formation and discharge of pellets from the machine increased with the pelletizing efficiency (Pe) of 70.3% to 84.6% at a moisture content (MC) of 15.8% to 27.1%, and the Pe decreased at a moisture content above 29.0%. Also, the drying temperature (DT) has a significant effect on the pellet moisture content (MC) and bulk density at P > 0.05. The effects of weather conditions on pellets produced using the COOI24m pelletizer were assessed in this study. The analysis showed that changes in weather conditions had an insignificant effect on the quality and properties of the pellets. The machine is highly recommended for use by small-scale livestock farmers for the local production of pellet-mash of different compositions because of its affordability, ease of use, and high working efficiency.*

Keywords: *Machine, pellets, pelletizing, moisture content, compositions, pellet-mash, local, farmers.*

1. Introduction

A range of basic ingredients are used in the production of compound meals for animals. The feeds are defined in accordance with precise guidelines for physical, sanitary, and nutritional quality, as well as guidelines on their nutritive composition.

In order to optimise processing while preserving or regulating nutritional quality for a particular feed form, these requirements collectively necessitate understanding of a wide range of distinct constituent qualities. Thus, it may now be necessary for the fields of "feed science and technology" and "nutritional science" to work together in order to advance cattle production. It has been observed that animals fed pelleted feeds perform better than those fed mash feeds in terms of average daily gain and feed conversion [1,2] in both the case of pigs and poultry [3]. Feed processing affects how quickly feed components break down and move through ruminants [4]. For example, pelleting decreases starch's resistance to ruminai degradation by around 15% [5]. Pellets must also possess a fundamental physical property, such as durability and hardness, in order to endure the rigours of transportation. Durability is the amount of particles that return from pellets following mechanical or pneumatic agitation, whereas hardness is the force required to smash a pellet or a batch of pellets at once. The impacts of feed composition, conditioning, expander treatment, pellet binders, die selection, etc., can also be assessed using these quality parameters [6].

A pelletizer, also called a pellet machine, is specialised equipment used to create feeds (feed pellets and feed mash) for animals like sheep, pigs, cattle, pets, fish, birds, chickens, poultry, and other livestock. A roller and a flat die are the machine's essential components. The feed stock enters the pelleting chamber directly and uniformly, and the feeding of flat-die tiny feed machinery is dependent on material weight. The raw materials will be forced through the pellet die's perforations during the pelletizing process by the pressure created between the dies and rollers. Additionally, the mash components will be compressed into uniform pellet particles.

Specific machinery for making feeds (feed pellets & feed mash) for animals such as sheep, pig, cattle,pet, fish, hourse, chicken, poultry and other livestock is known as pelletizer or pellet machine. The key parts of the machine are flat die and roller. The feeding of flat die small feed machinery relies on materials weight and the feed stock enters into the pelleting room directly and evenly. While pelletizing, the pressure generated between the dies and rollers will force the raw materials through the holes in the pellet die. And mash materials will be pressed into regular pellet particles. It is known for the features of easy operation, greater mobility, low noise, low price, low energy consumption and relatively low productivity when compared with ring die feed mills. Some of the materials usually used for pelleting are wheat, rice, corn, soya expeller, maize, sorghum, broomcorn, e.t.c. It is well-known for having simple operation, increased mobility, little noise, low cost, low energy usage, and, in comparison to ring die feed mills, comparatively low productivity. Typically, pelleting involves the use of wheat, rice, corn, soy extract, maize, sorghum, broomcorn, and other materials.

Nutritionists specify objective parameters for animal feed, which include certain moisture needs. In addition to being necessary for diets, moisture is also necessary for the pelleting of animal feed. Particle binding, gelatinization, pellet quality, mill energy consumption, and profitability are all facilitated by enough moisture. Elevated moisture levels may result in "plug-ups" and decreased mill throughput, which can drive up energy costs and accelerate microbial development. Low feed moisture, on the other hand, causes brittle pellets, which raise fines and result in inefficient use of feed on farms. Controlling moisture is essential to the financial success of producers. Even moisture distribution and absorption inhibit unchecked microbial load growth, promoting feed utilisation and pellet quality while lowering shrink and loss in the production process. One important criterion for selecting premium pellets is moisture content. Producers must guarantee uniform moisture absorption in order to protect feed shape.

Additionally, as feed pelleting progresses, temperature changes. In order to encourage moisture absorption into the feed, high temperatures are employed during conditioning. Temperatures between 50°C and 90°C have been shown to improve pellet quality and increase the digestibility of crude protein, dry matter, and starch. Although this varies by kind of feed, such as high starch, fibre, or protein, heat-sensitive, and more, most manufacturers condition feed around 78–80 °C. This temperature range allows feed to absorb steam moisture sufficiently, which promotes particle binding, starch gelatinization, and improved digestibility. When feed is pushed into the die, pressure is created. The friction that results flashes off any water that hasn't been fully absorbed, affecting the feed's moisture content. The thermal energy produced by this friction can occasionally surpass the heat applied during conditioning. However, by lowering or raising the processed pellet's weight excessively, relative humidity and ambient temperature have a substantial impact on its quality and can lead to contamination and blockage. The rising reliance on exogenous enzymes in animal nutrition has led to a greater body of research on the impact of pelleting on enzyme stability in recent years [7,8]. There hasn't been much research done on how ambient temperature and relative humidity affect pellet quality, though. This brings up the main goal of the study, which is to evaluate how weather impacts the quality of pellet mash.

2. Materials and Methods

2.1. Design consideration

The following factors were taken into considerations in designing, fabrication and testing of the pellet machine: weight of the machine, physical characteristics of the feed materials (rolling resistance, friction), screw auger speed, prime mover power output and the selection of fabrication materials in line with the approaches of [9] and [10].

2.2. Description of the component parts of the pellet milling machine

COOI24 pellet machine is composed of the following component parts as shown in Figure 1: 1. Frame, 2. Hopper, 3. Die roller, 4. Pelletizer plate, 5.Bearing, 6. Bolt and nut, 7. Internal combustion(5.5hp)

2.2.1. Design for pelletizer hopper

The hopper of the pelletizer was designed as indicated as follows:

$$W = f\left(\frac{D}{B}\right)^{t_{B^{2.5}}} \tag{1}$$

T = time in minute for the flow
B = Orifice diameter
W = bulk density of the concentrate
D = Average diameter of the concentrate [11].

2.2.2. Design for pelletizer extrusion pressure

The pelletizer extrusion pressure is the pressure that force concentrate through a die at a high pressure. The pelletizer extrusion pressure was designed as expressed in equation (2):

$$P = \frac{W}{A} \tag{2}$$

where:
W = Thrust force
A = Area of the extruder = $A = (N\ \frac{\pi D^2}{4})$
N = Number of holes
D = Hole diameter

2.2.3. Design for propeller shaft

The pelletizer shaft was designed using the expression as follows:

$$T = N\frac{60}{2\pi N} \tag{3}$$

where:
T = Transmitting force (N)
P = Power (Watts)
N = Number of holes [12].

2.2.4. Design for volume of barrel (Extrusion Chamber)

The volume of the extrusion barrel was computed using the relationship given as:

$$V = \pi r^2 h \tag{4}$$

where:
V = volume of extrusion barrel
r = radius of barrel, and
h= height of barrel [13]

2.2.5. Design for tangential force

Tangential force of the pellet machine was designed using equation

$$F = W\tan\Phi \tag{5}$$

where:
F = Tangential force
W = Thrust force
Φ = Helix angle [14].

2.2.6. Die plate

It is the process that turns the prepared feeds into solids with a cylinder shape, or pellets. When the internal combustion engine is turned on, the die plate can rotate because it is bolted perpendicular to a vertically positioned diameter shaft. It has 400 holes with a 6 mm diameter, all of which are evenly spaced.

2.2.7. Discharge chute

The pelletized feeds are released for collection at this point. Gauge number 2 mm stainless steel sheet is used to construct the inclined discharge chute. To reduce the amount of pelleted feed that spills unintentionally, a flapper is hinged close to the chute opening as described by [15].

2.3 Concentrates formulation

Rice and maize husks were mixed with maize grain and eggs at different mixing ratios. Water was added to reach a moisture content level of 15%. Five (5) levels of concentrate formulation of 2, 4, 6, 8, and 10 kg were used for the testing of the machine, as follows:

i. $\frac{1}{2}\ kg$ of rice husk, $\frac{1}{2}\ kg$ of maize husk, 1 kg of maize grain and two (2) eggs;
ii. $1\ kg$ of rice husk, $1\ kg$ of maize husk, 2 kg of maize grain and (4) eggs;

iii. $1\frac{1}{2}\ kg$ of rice husk, $1\frac{1}{2}\ kg$ of maize husk, 2 kg of maize grain and (6) eggs;
iv. $2\ kg$ of rice husk, $2\ kg$ of maize husk, 2 kg of maize grain and (8) eggs; and
v. $2\frac{1}{2}\ kg$ of rice husk, $2\ \frac{1}{2}\ kg$ of maize husk, 5 kg of maize grain and 10 eggs.

The chicken and bird feed pelletizing machine was evaluated in terms of pelleting efficiency, as described by [16] and [17]. The pelleting efficiency of the machine was calculated and expressed as follows:

$$\mathrm{P_e} = \frac{\mathrm{W_{fp}}}{\mathrm{W_{fc}}} * 100 \tag{6}$$

$\mathrm{P_e}$ = Pelletizing efficiency (%);
$\mathrm{W_{fp}}$ = Weight of formed pellets (Kg); and
$\mathrm{W_{fc}}$ = Weight of feed concentrates (Kg)

The pellet moisture content (PMC) at each 5-minute interval was computed to achieve a relative safe moisture content of 10% for storage as recommended by [18] and [17]. Pellet Drying Time (PDT): This is the time taken in drying the pellets for each treatment combination to the desired safe storage moisture content. The oven was set at a drying temperature of 105 °C and the drying was monitored at intervals of 10 minutes to ascertain the changes in their weights as follows

i. $$\mathrm{PMC_{5min}} = \frac{\mathrm{IWP_{5min}} - \mathrm{FWP_{5min}}}{\mathrm{IWP_{5min}}} * 100 \tag{7}$$

ii. $$\mathrm{PMC_{10\ min}} = \frac{\mathrm{IWP_{10min}} - \mathrm{FWP_{10min}}}{\mathrm{IWP_{10min}}} * 100 \tag{8}$$

iii. $$\mathrm{PMC_{15\ min}} = \frac{\mathrm{IWP_{15min}} - \mathrm{FWP_{15min}}}{\mathrm{IWP_{15min}}} * 100 \tag{9}$$

iv. $$\mathrm{PMC_{n\ min}} = \frac{\mathrm{IWP_{\ n\ min}} - \mathrm{FWP_{n\ min}}}{\mathrm{IWP_{n\ min}}} * 100 \tag{10}$$

where:

IWP is the initial moisture content of the pellet;
FWP is the final moisture content of the pellet;
Time interval: 5 minutes, 10 minutes, 15 minutes …………….. *n* minutes.

2.3.1. Bulk density

The produced pellet was loosely poured in a 250 ml beaker till was full, so as to get the bulk volume, then the feed inside the beaker was weighed to get the mass. The bulk density be calculated as follows:

$$\mathrm{BD} = \frac{\mathrm{BMP}}{\mathrm{BVP}} \tag{11}$$

where:

BD = Bulk density;

BMP = Bulk Mass of the pellet;

BVP = Bulk volume of the pellet

The MC differential in response to the temperature and relative humidity of the storage environment was used to assess the quality of the pellet at 10% moisture content (MC).

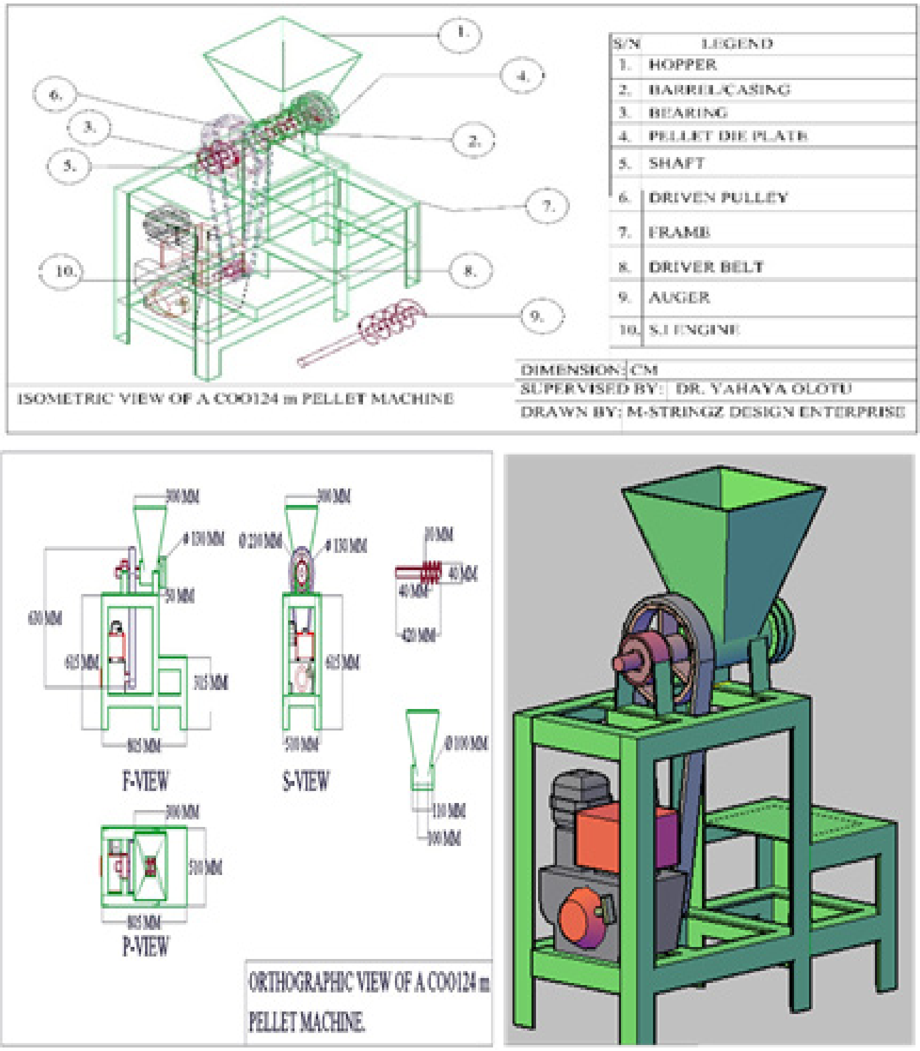

Figure 1. Isometric view and section drawing of a COOI24m pellet machine

3. Results and Discussion

3.1. Pelletizing efficiency and moisture content

Pellet moisture content (MC) varied from 15.8% to 27.1%, with an increase in pelletizing efficiency (Pe) from 70.3% to 84.6%. Figure 2 an illustrates the directional proportional relationship that was found between the pelletizing functional efficiency and the pellet's moisture content. Raising the pelletizing moisture reduced the specific energy consumption while increasing the capacity for pellet production. The physical quality of the pellet improved with the decrease in moisture content. Heat is produced while the raw materials are being ground because of the impact and friction between the material and the fast-moving hammer. The temperature inside the crushing chamber is typically between 45 and 50 ºC, which is higher than the outside temperature. In that process, moisture loss typically ranges from 0.5% to 1.5%. The temperature, type of hammer mill, and particle size all affect the degree of loss. Feed conditioning and tempering is the process of hydrothermally treating the materials by adding steam prior to their entry into the granulator, which enhances the material's chemical and physical characteristics. After conditioning, the material's moisture content is reasonable, ranging from 14% to 15.5%. The finding is line with the studies of [19] and [20]. This is because the pellet feed produced and processed under these conditions has good processing quality, making it easy for the finished product's moisture content to meet standards. It is challenging to maintain 14% moisture content after conditioner during dry and hot seasons. The limited moisture content of the feed concentrates at low moisture content (15.3%) was insufficient to bind the feed constituents together for appropriate pellet production and discharge. Pellet formation was moderate, ranging from 18.0% to 28.0% MC in moisture content. However, when the machine was run at 950, 600, and 450 revolutions per minute, the formation and discharge of pellets from the machine decreased at a moisture content above 29.0%.

3.2. Formation of pellet mash

Figure 3 presents the relationship between the feed concentrates and pellets produced by the pelletizing machine. The modelling expression revealed that the coefficient of determination (R^2) value of 0.999 showed that a strong and positive relationship existed between *PP* (pellet produced) and *FC* (feed concentrates). The results demonstrate that, as a result of the feed concentrates' moisture content and the operating machine speed, the majority of the formulated concentrates were converted to pelletized mash in every experimental trial with very little loss.

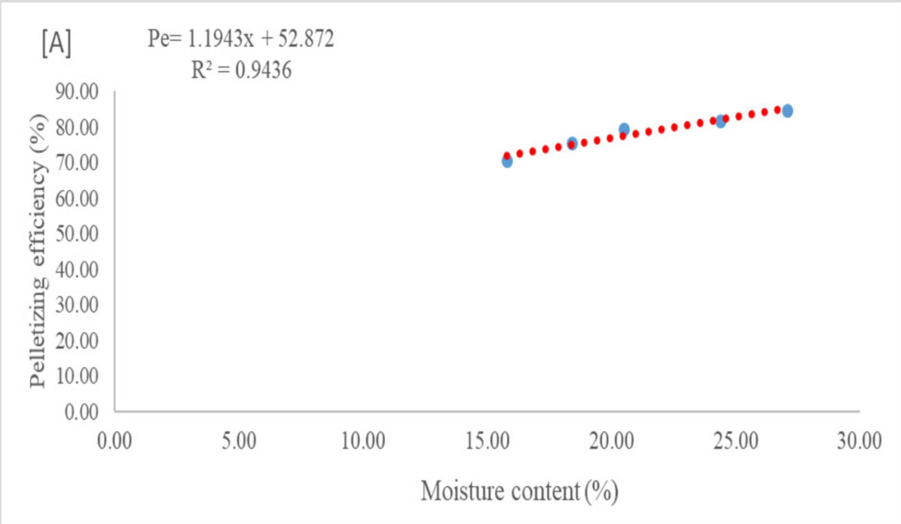

Figure 2. Moisture content and pelletizing efficiency

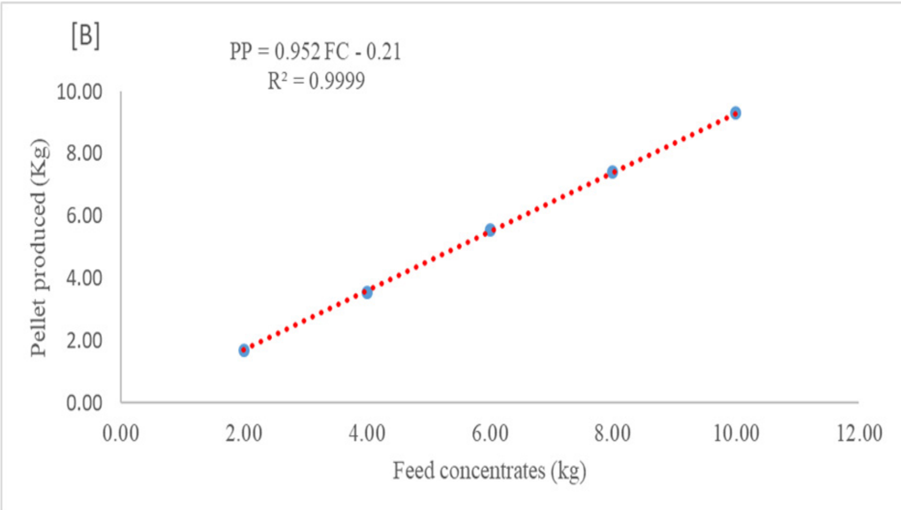

Figure 3. Moisture content and pelletizing efficiency

3.3. Pellet machine arrangement and loading

The COOI24m pelletizing machine developed from locally-sourced is used to convert formulated feed concentrates into mash pellets for chicken. The pellet machine adopts a large modulus hard toothed helical gearbox, strengthened spindle, strong power output, equipment stable operation, low failure rate, low production cost as shown in plate 1 a-b. Pellet machine was applied to a wide variety of many different applications, and the drive loading was varied from an easy, uniform load to severe shock loading. The power transmission was developed for more severe conditions, safety, reliability and overall longevity. Generally, the gearing used in a typical gear-driven pellet machine is life and durability limited, not shock load limited. Therefore, the tooth design is more than adequate to handle any shock loading. In the case of belt drives, the shock resistance of the belts is limited by a combination of heat dissipation capacity, the tensile strength of the reinforced strands and the durability of the friction surfaces in contact with the sheaves. The average pellet size of 8 mm was formed with operational capacity of 188 kg/hr or 7.5 bags of pelletized feed mash per hour as shown in Figure 4 and plate 1 a-b. Plate 2a-b shows the freshly produced pellet-mash at 27.1% moisture content and oven-dried pellet-mash at 15.1% moisture content.

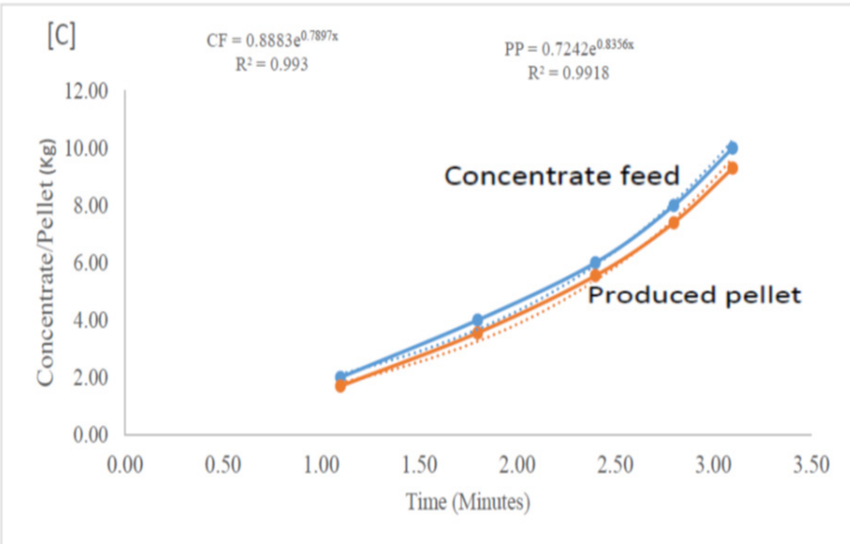

Figure 4. Pellet machine arrangement, loading and milling time

Plate 1. The developed COOI24m pellet machine before operation (a) and the pelletizing machine during operation (b).

Plate 2. Freshly produced pellet-mash at 27.1% moisture content (a) and oven-dried pellet-mash at 15.1% moisture content (b).

The relationship between pellet moisture content (MC) and drying temperature (DT) is demonstrated by the results shown in Figures 5 and 6. At the drying temperature (DT) of 30°C, the pellet-mash moisture content decreased to 27.1°C; at the DT of 40°C, it decreased to 24.4%. At 70 °C DT, the moisture content steadily decreased to 15.8%. If the drying temperature is kept at 70°C for an extra five minutes after the pre-set fifteen minutes of drying time, it is anticipated that the pellet moisture content could be lowered to 10.0%. The variation in moisture loss is depicted in Figure 5 following the production of a pellet that was dried at different temperatures. The relationship between the DT and MC is inverse, as demonstrated by the modelling expression shown in Figure 5.

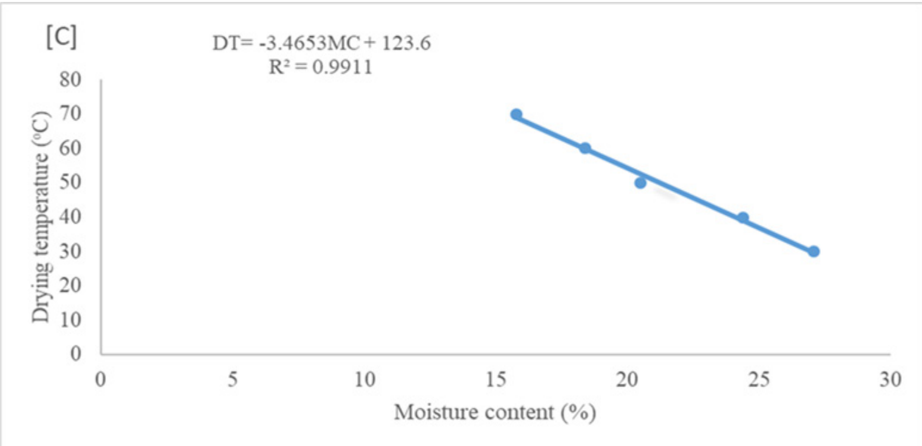

Figure 5. Pellet moisture content and drying temperature

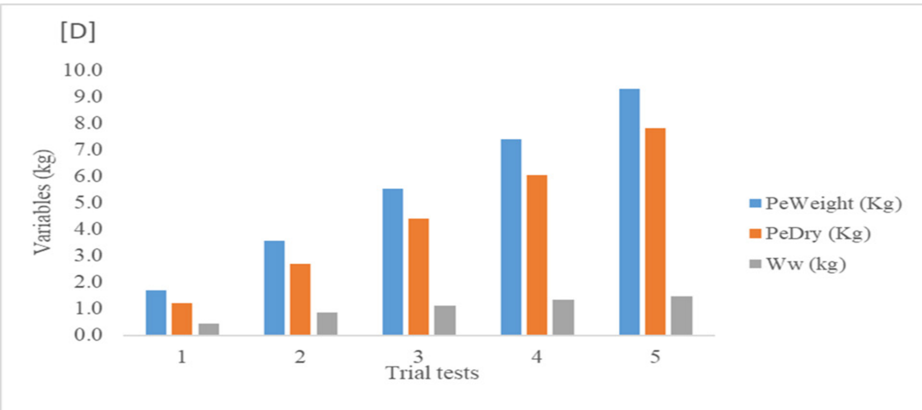

Figure 6. Variation of pellet-mash moisture loss in response to drying temperature

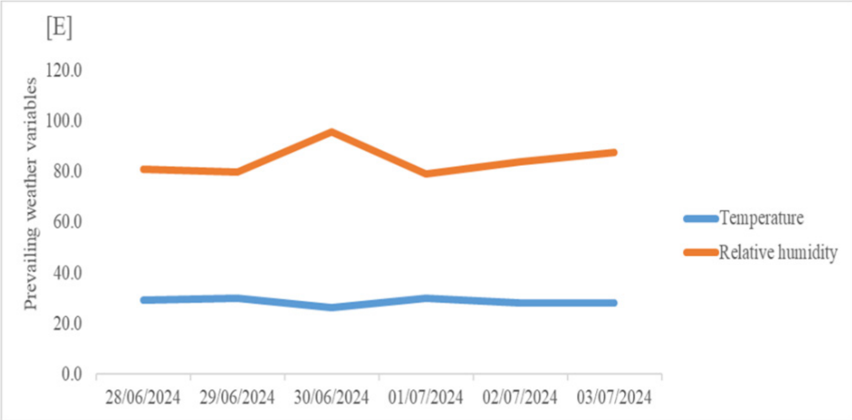

Figure 7. Prevailing weather variables of the storage facility

The outcome in Figure 7 depicts the six (6) days of average weather in the pellet-mash storage facility. The air temperature was 28.1°C on 02/07/2024 and 30.2°C on 01/07/2024, respectively, and the greatest and lowest relative humidity readings, of roughly 79.5% and 97.0%, were recorded on 01/06/2024. Climate variability, however, has no appreciable impact on variations in the product's volume, weight, size, or general quality.

3.4. Effect of drying temperature on the pellet bulk density and moisture content

The effects of the drying temperature (DT) on the pellet moisture content (mc) and bulk density (BD) as presented in Table 1-3. The highest bulk density of the formed pellets was recorded as 244.2 kg/m^3 at a moisture content of 27.1 % (db) and drying temperature of 30°C while the lowest bulk density was recorded as 200.1 kg/m^3 at a moisture content of 15.8 %(db) and 70°C DT as shown in Table 1. It is generally observed that increase in drying temperature led to decreases in bulk density and pellet moisture content which is significant at $P > 0.05$. This led to reduction in weight, size, and volume of the formed pellet-mash.

Table 1. Effects of drying temperature on pellet

Drying temp (°C)	Moisture content (%)	Bulk density (kg/m^3)
30	27.1	244.2
40	24.4	230.6
50	20.5	220.2
60	18.4	210.6
70	15.8	200.1

Table 2. Summary data

Treatments				
	Drying temp	**Moisture content**	**Bulk density**	**Total**
N	5	5	5	15
$\sum x$	250.0	106.2	1105.7	1461.9
Mean	50.0	21.2	221.4	97.5
$\sum X^2$	13500.0	2338.2	245690.4	261528.6
Std. Dev	15.8	4.5	17.1	92.2

Table 3. Result Details

Source	**SS**	**df**	**MS**	**F**
Between treatment	116793.4	2	58396.71	310.28
Within treatment	2258.4	12	188.2	
Total	119051.9	14		

4. Conclusions

The pelletizing machine COOI24m was developed for the production of poultry pellet mash using locally sourced materials. The machine has a milling and production capacity of 188.5 kg/hr of pellet-mash equivalent of 7.5 bags/hour on the basis of 25 kg per bag. The highest pelletizing efficiency of 84.4% was at 27.1%, while the lowest *Pe* at 70.3% was obtained at the *MC* value of 15.8%. It is estimated that the functional efficiency of the machine increases with the increased moisture of the feed concentrates used to form the pellet-mash. Thus, the bulk density decreased with the increase in drying temperature of the pellet-mash. This demonstrates that the drying temperature has a significant effect on moisture content and bulk density at $P > 0.05$. To enhance the formation of pelletized feeds, binding materials ought to be incorporated into feed concentrates. Small- and medium-sized fish farmers would benefit greatly from the adoption of the pelletizing machine as it would enable them to generate their own feed and reduce the issues related to obtaining imported feeds. Engineers can use the information in this study to enhance the efficiency of pelletizing machines.

Acknowledgment. I would like to express my sincere gratitude Engr. Ibrahim and all the project students for their invaluable guidance and support throughout this research project. I also thank the research team members for their collaborative efforts and insightful feedback that greatly enhanced the quality of this article. Lastly, I appreciate my family for their unwavering encouragement during this challenging journey.

Author contributions: Conceptualization, Y. Olotu, methodology, A.A. Rodiya, writing-review, V.N. Haruna and editing, B.C. Ikwuebene .All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

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