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Design, Fabrication and Performance Evaluation of a Poultry Feed Pelleting Machine

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Abstract:

The poultry industry plays a crucial role in meeting the global demand for animal protein. To ensure optimal growth and productivity of poultry, the formulation and processing of high-quality feed are essential. Feed pelleting is a common method employed to enhance the nutritional value, digestibility, and handling characteristics of poultry feed. The machine which meant for the production of poultry feed pellets in good quantities, was designed, fabricated and its performance evaluation was carried out accordingly. The independent dual operated Poultry Feed Pelleting Machine permits constant production line since the prime mover (diesel engine) would be plunged into operation as at when due, that is, when electricity power supply failed. The materials used were locally sourced which included; mild steel, high carbon steel, aluminum, 3hp electric motor, prime mover and axle. The base materials are corn, soybean, wheat, rice bran, wheat bran, herbs, fish meal, groundnut cake etc. The machine functioned reliably at the throughput capacity of 95kg per hour and up to 800kg per day with 95% efficiency proved its high performing rate. Moreover, the study showed that useful information in designing pelleting machine that produced pellet optimally when the appropriate moisture condition for feed materials is considered ranging from 20% - 30% with temperature range of 500C-700C. The results indicate that the developed machine offers significant advantages in terms of pellet quality, production efficiency, and energy consumption compared to conventional pelleting methods. The developed machine is recommended to facilitate the production of poultry feed pellets for small scale and medium scale farmers.

Keywords:
design; fabrication; performance evaluation; poultry; feed pelleting

I. Introduction

The poultry industry's growth necessitates innovative approaches to feed processing to ensure cost-effective and nutritionally balanced diets for poultry (Alves, dos-Santos-Alves, Soares, Borges, Jalal, Jani, Abreu-Junior, Capra, & Nogueira, 2023). Feed pelleting has gained prominence due to its potential to improve feed quality, reduce feed wastage, and enhance nutrient utilization (You, Tulpan, Malpass & Ellis, 2022). This study focuses on the design, fabrication, and performance evaluation of a poultry feed pelleting machine to address the challenges associated with conventional pelleting techniques. A Poultry Feed Pelleting Machine is a system that performs the function of turning the mashed feed into pellets for easy pick (Olugboji, Abolarin, Owolewa & Ajani, 2015). In line with technological advancement, the process of transformation becomes paramount which is the part of this study.

Pelleting is the process by which materials such as corn, soybean meal, grass, rice, rice husk, wheat, wheat offal, fish meal etc. (mashed), are turned into small dry countable form. There are wide range of application of the machine and may be commonly utilized industrially for multiple purpose and poultry/agricultural application (Sharma, Panigrahi & Dubey, 2021). Meanwhile, this centered on production of poultry feed ranges from 02mm-08mm in sizes especially from day old to maturity age of above 4 months. This includes rabbit, and other animals. Pellets can be an answer to dusty feeds. Pelleted feed offers several advantages over granular feed materials, including increase bulk density and flowability because the altered physical form will change the angle of repose, the inter-particle friction, and thus typically produces less bridging between particles (Samedi & Charles, 2019; Ajayi & Osumune, 2013). Additionally, pellets generally produce increase nutrient density, palatability and nutrient availability in livestock rations. Pelleted feed often reduces feed waste, dust generation and ingredient segregation (Romallosa & Cabarles, 2011).

Numerous studies have emphasized the importance of feed pelleting and its impact on poultry performance. Researchers such as Gidenne, Garreau, Drouilhet, Aubert and Maertens (2017) demonstrated that pelleted feed improved feed conversion efficiency and overall growth rate in broiler chickens. A study by Abdollahi, Ravindran and Svihus (2013) highlighted the role of feed pelleting in enhancing nutrient availability and reducing feed wastage. Additionally, studies by Jagtap and Kalbande (2023) and Garcia-Maraver and Carpio (2015) underscored the need for efficient pelleting machines to optimize the pelletization process. Collectively, literature underscores the critical role of feed pelleting in modern poultry nutrition. Through enhancing pellet quality, nutrient availability, and overall feed utilization, pelleting technology has the potential to significantly impact poultry growth, feed efficiency, and economic sustainability (Orimaye et al, 2019; Okafor et al, 2017). The studies discussed emphasize the need for continued research and innovation in feed pelleting machinery and techniques to further optimize feed processing and poultry performance.

The study of poultry feed design and its impact on performance evaluation is of significant interest to farmers who raise chickens and chicks. Abdisa's research on wheat row planting's impact on farmer livelihoods (Abdisa, 2023) illustrates the importance of innovative approaches to agriculture. While not directly related to poultry feed, this study emphasizes the need for tailored design strategies to enhance agricultural outcomes. This concept extends to poultry farming, where feed design plays a pivotal role. Médard et al. (2023) examine the production testing of one-day chicks using untreated palm oil weever combustion. This research underlines the significance of feed composition and its influence on poultry growth. Additionally, Serge et al. (2023) explore the effects of Moringa oléifera fluor proportions on chicks' growth. This study demonstrates the potential of specific feed additives to enhance chick development. Letasara et al. (2020) provide insight into acute toxicity evaluation, indicating the importance of assessing potential risks associated with feed additives. This extends to poultry farming, where feed safety and composition are critical considerations.

The machine is a common machine that can be fabricated but with technical know-how without which the entire process will be marred as misalignment will cause malfunction. Due to reverse engineering principle and condition of power system the build-up/arrangement of the machine targeted the adoption of electric motor and prime mover (gasoline engine) for efficient operation and continues operation (Renjani & Wulandani, 2019). The machine is designed in such a way that they have little manual intervention required during the process. Also, the design is cost effective and would be marketed domestically having evaluated and found it functional (Pane et al, 2020; Okafor et al, 2020; Okonkwo et al, 2020). A small–scale animal producer seldom invests in those large-scale technologies since it would be expensive on their part opting them to depend on the high cost of commercial feeds (Chen et al., 2015). But if these producers could have access to a pellet mill technology that is low cost yet dependable, then problem on expensive operation cost may be reduced leading to lower prices of animal products.

This research is therefore part of academic purpose and way forward to empower farmers to be independent in feed production. The need to curtail wastage of feed necessitated the concept of the machine whereby no or lesser waste is achieved. Incorporation of medicinal leaves and roots as pellets into poultry food help farmers both in preservation of feed and reduction of modality rate. With the rise of the breeding industry, the automated machinery replaces the manual, and the feed processing equipment has become a useful assistant to the feed processing plant. Though, high efficiency and worry-free farming have become the needs of farmers.

II. Reserach Methods

The design of the poultry feed pelleting machine integrates principles of mechanical engineering, material science, and poultry nutrition. The machine comprises a feeder, conditioner, pellet die, and roller assembly. Special attention was given to material selection, roller geometry, die configuration, and motor power to ensure optimal pellet formation and energy efficiency. The fabrication process involved precision machining, welding, and assembly of components to create a robust and functional pelleting machine. The performance of the developed poultry feed pelleting machine was assessed through a series of experiments.

2.1 Design concept and consideration

1. The machine was designed to produce pellets of different sizes ranges from Ø2mm to Ø6mm to aid the farmers to be independent in poultry feed production.
2. The material selection became imperative since the surface contact generate frictions in order to minimize tears and wears.

2.2 Selection of Pulleys and Belt

The configuration comprises of two pulleys which the respected diameters of the driver and driven pulleys are 100mm and 170mm respectively. The speed of the driver (electric motor) is 1440 rpm while the speed of the driven pulley is 847 rpm according to relation by Khurmi and Gupta, (2005) as,

$$N_1 D_1 = N_2 D_2 \qquad (1)$$

Where N_1 and N_2 are the respective driving and driven pulley's speed while D_1 and D_2 are the corresponding diameters of the pulleys.

The centre distance, C between the driving and driven pulleys was determine from the equation 2 as 235mm. (Khurmi and Gupta, 2005)

$$C = \frac{D_1 + D_2}{2} + D_1 \qquad (2)$$

The belt Length, L was computed as 899mm considering equation 3. Sharma and Aggarwal, (2006)

$$L = 2c + 1.57\,(D_1 + D_2) + \frac{(D_2 - D_1)^2}{4c} \qquad (3)$$

The angle of lap Ө for the drive's small pulley was computed as 2.84 rad Using equation 4 given by Sharma and Aggarwal (2006)

$$\theta = 180 - 2\left(Sin^{-1}\left(\frac{D_2 - D_1}{2c}\right)\right) \quad (4)$$

Where D_1 and D_2 constitutes the respective diameters of small and large pulleys of each drive.

The belt speed, V of Electric motor and the axle were determined using equation 5 as 7.54m/s

$$V = \pi \frac{N_2 D_2}{60} \quad (5)$$

The area of the die holes causing shear of the material (A_D) was calculated as 0.004m^2 having total number of holes as 324 with Ø4mm.

$$\pi r^2 \, N \quad (6)$$

Where r is the radius of the diameter and N number of holes. Note also that the area of the shear roller A_R is equal to the total area of the Die holes A_D.

Shear stress acting at the roller die contact point of the machine covering the surface area of the rollers is 77,400 NM^{-2} when the equation 7. is applied.

$$\tau = \eta \times \gamma \quad (7)$$

Where η is the viscosity of the material Nsm^{-2} and γ is the shear rate of the feed material.

$$\gamma = \frac{VR}{H} \quad (8)$$

V_R = roller speed
H = Dept of teeth on the roller 2mm.

The pelleting force F_P was calculated with the stated formulars 309.6 Newton. Since there are two rollers, the force applied will be multiply by two. (Sharma And Aggarwal, 2006)

$$F_P = \tau \times A \quad (9)$$

F_p = 619.2 N is the total force needed for pelleting.

2.3 Power requirement for pelleting P_P.

The calculated power is 2.786 KW which necessitated the choice of 3KW of electric motor. Equation 3.10 was used in calculating it.

$$P_p = F_R \times V_R \quad (10)$$

2.4 Calculating number of belts required.

The angle of contact on big pulley was computed as 3.44 rad using equation 11 given by (Khurmi and Gupta, 2005)

$$Q_2 = 180 + 2a \quad (11)$$

The tight side tension T_1 and slack side tension of the drive belt were gotten as 798 N, 401 N using equation 3.12 & 3.13 (Khurmi and Gupta, 2005)

$$T_1 - T_2 = \frac{P}{V} \quad (12)$$

$$2.3\, Log\, \frac{T_1}{T_2} = \mu_2\theta_2 \quad (13)$$

Where μ is the co-efficient of friction, Θ_2 angle of Lap on the bigger pulley, P power transmitted by Electric motor and V velocity ratio.

The number of belts required is 1 as computed by equation 14;

$$P_p = (T_1 - T_2)n \times v \quad (14)$$

2.5 Transmission Shaft design

The diameter of the shaft was computed as 28mm from the equations 15 and 16 stated.

$$T = \frac{P \times 60}{2\pi N} \quad (15)$$

$$T = \frac{\pi \tau d^3}{16} \quad (16)$$

Where τ is the Torque, P is the power transmitted N number of revolution and τ, is the shear stress.

2.6 Description of poultry feed pelleting machine.

The concept of the design centered towards pelleting of strong and good texture pellets. The major components of the designed machine were captured fully in the design. The designed production drawing for this machine is shown below.

Figure 1. *The developed Poultry Feed Pelleting Machine during performance testing*

The buildup of the machine includes Electric motor and prime mover, Hopper, Pelleting Chamber, Corrugated rollers, die plate, shaft, discharge chamber, cutters vehicle axle and frame.

These parts are mounted on a structural frame of U channel mild steel as the base. The electric motor or the prime mover drives the shaft of the axle, inversely transferring the motion perpendicular to the pelleting shaft of 28mm. The shaft in turn propels the two corrugated rollers 50mm x 62mm each which is mounted directly on the pellet die of Ø175mm x 34mm that has 324 holes of Ø4mm each.

Beneath the die, a dual cutter is situated on the body of the shaft as well as a rotary conveyor. As the cutters cut off pellets, the conveyor directs pellets to the outlet tray.

To manage the revolution of shaft needed as to minimize burning of pellets, a speed ratio of 1.7:1 of electric motor to axle shaft is considered respectively while the ratio of the axle shaft to pelleting shaft is 4½:1 which resulted to 188 rpm for pelleting shaft. A hopper of a Trapezoid shape was designed with little manual intervention (though in view to mount geared motor) for the operation of Conveying Screw. The Screw which also serves as mixer directs the mashed feed into the chamber. It has a minor diameter of Ø36mm and major diameter of Ø76mm with Length of 180mm.

The design also has a casing which houses the axle in a rectangular shape was formed using 1.5mm sheet metal.

Preview

Motor Speed = 1440 rpm
Axle Speed = 847 rpm
Motor pulley = 100mm
Axle pulley = 170mm
Shaft Speed = 188 rpm

The rest of the values are captured in the drawing views.

The major components of the Poultry Feed Pelleting Machine, are the entrance path which is the hopper that contains the driving screw for easy conveying of material into the chamber. The pelleting chamber houses the dual rollers and the drilled plate for pelleting. A cutter is positioned responsible for cutting out pelleted feed while a rotary conveying disc directs the feed through the outlet for collection. A temperature control panel/cabinet dryer maybe incorporated dependently or independently for drying of the pellets especially during winter season. In other to control speed ratio, an axle is incorporated that reduces the speed of Electric motor or prime mover down to 150 rpm to 350 rpm which normalizes tears & wears as well as reduce heat generation. Theory of engineering has brought relief from difficulty in agro merchandising. This plate type is the most common type and the focus of the design and performance evaluation.

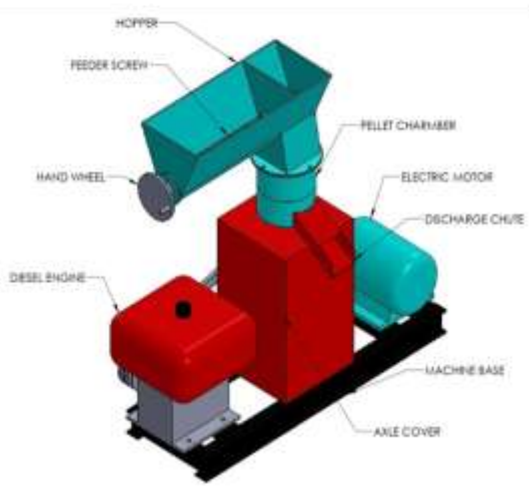

Figure 2. *Isometric View of the Poultry Feed Pelleting Machine*

2.7 Major Component of Poultry Feed Pelleting Machine

1. **Hopper:** This is the entrance path of the mashed feed after being moisturized. The shape can vary considering the choice of the designer. The compartment consists of a screw conveyor as shown in Appendix and can be driven by low motion electric motor or manually regulated wheel which carry's the feed into the chamber. The hopper is usually made by steel sheet of 2mm thickness or even 1.5mm. Some are also made up of stainless steel.
2. **Shaft:** The high carbon steel shaft links the roller, Die plate, cutter, Rotary Conveyor down to the crown wheel inside the axle. The quality is considered to avoid deflection while rotating.
3. **Rollers:** The rollers are made of high carbon steel and are corrugated for proper functioning. It is responsible for compressing the feed into the die holes and the rollers of Ø62mm x 50mm with two inserted bearings in each to allow for free rotation was used in this study
4. **Key:** Key is a circular key use to lock up (protect) the bearing inside the rollers.
5. **Die plate:** It is the part that converts the formulated feeds into cylindrical shapes. It can be made up of stainless steel or carbonized steel plate as to resist wears. The die plate consists of 324 holes of Ø175mm x 26mm.
6. **Chamber:** The chamber of cylindrical material of Ø185mm x100mm and a thickness of 10mm was used. This houses the rollers where pelleting is achieved.
7. **Axle:** The vehicle axle is considered due to it affordability and it serves as speed reducer.
8. **Electric motor/prime mover:** The purpose is to transmit an appropriate power to the machine for continues motion. A Single phase or 3 phase Electric motor of 3KW was considered for the purpose of this study. In case of house use, a single phase serves the purpose.
9. **Pulleys:** The pulleys of Ø100mm to electric motor and Ø170mm to axle respectively which in turn reduces the speed down to ratio of 4.5:1 for a required pelleting speed was used.
10. **Digital grain moisture metre:** The instrument is based on reading for accuracy of moisture content of feed before pelleting as well as after pelleting.

2.8 Performance evaluation of poultry feed pelleting machine

The Poultry Feed Pelleting Machine as shown above in **figure 1**was evaluated regarding the following; The input and output kg, moisture content (before and after pelleting) and time taken. The experiment was done in multiple times and average regarded for result. The tables below consist of all the experimented data. Thereafter, the through put (kg/h) and efficiency of the machine were determined.

Density of the formulated feed was determined using the formula

$$\text{Density (P)} = \frac{mass}{Volume} \qquad (17)$$

Mass = 136.964g

Volume = 150ml

$$P = \frac{136.964}{150} = 0.91 \text{ g/ml}$$

IV. Result and Discussion

The evaluation was carried out in different time range with respect to particular kilogram and the result tabulated as well as different kilograms. The operation was achieved in four phases/ steps.

1. Manual mixing of the formulated feeds with starch and water as binding material.
2. The formulated feed was raised in an enclosed chamber to a temperature of 60% or alternatively a steam can be introduced.
3. Pelleting of the feed was done and thereafter the pellets were sundried having an appropriate moisture of 12.5% which further drying by rotary/cabinet drier may retain the moisture at 11.0%.

Table 1. Values of different weight in kg with starch, pelleting time, throughput and efficiency (at 60^{o}c and moisture content of 28%)

S/N	Mashed (Kg)	Pelleted (Kg)	Non-Pelleted (kg)	Trapped (kg)	Time (S)	Throughput (kg/hr)	Efficiency %
1	5.3	5.00	0.1293	0.1626	190	94.74	94
2	7.5	7.134	0.1943	0.1680	282	91.00	95
3	9.0	8.632	0.200	0.1681	306	101.55	95
4	12.5	11.992	0.345	0.1626	461	93.64	95
Ave	**8.575**	**8.1895**	**0.2172**	**0.1653**	**309.75**	**95.233**	**94.75**

The feed which has density of 0.91g/ml was sourced from local market for the study. The water and starch were critical in the pelleting process. The presence of both at the 28% moisturized state and temperature range of 60 Degree Celsius was able to produce credibly at the percentage efficiency of 94.75% and through put of 95kg/hr after four trials. This is shown in table 1.

Table 2. Values of weight in kg without starch, pelleting time, throughput and efficiency

S/N	Mashed (Kg)	Pelleted (Kg)	Non-Pellet (kg)	Trapped (kg)	Time (S)	Throughput (kg/hr)	Efficiency %	Moisture content %
1	5	3.6	1.2	0.1626	154	84.15	72	15
2	5	4.3	0.6	0.1633	187	82.78	86	20
3	5	4.2	0.5	0.1654	200	75.00	84	25
4	5	4.3	0.5	0.1605	180	86.00	86	30
5	5	4.1	0.3	0.1636	154	97.00	82	30
Ave	**5**	**4.1**	**0.6**	**0.16308**	**175**	**84.986**	**82**	**24**

The Value of Table 2 which also indicated the weight in kg without starch, pelleting time, through put and efficiency varies when compared with the Table 1. The Variation proved non uniformity in reading due to difference state of the feed since it has variation of moisture percentage. Although absence of binding material and void of temperature increment constituted the reduction in throughput which is reduced to 84.9% and efficiency which is reduced to 82% as when compared with Table 1.

Moreover, the texture and strong look of pellets appeared good from the result of Table 1.

Table 3. Values of pellets in kg and moisture content lost before and after drying

S/N	Pellet before drying (kg) A	Pellet after drying (kg) B	Moisture lost (A-B) kg	Moisture retention %
1	3.6	3.4	0.2	12.5
2	3.7	3.5	0.2	12.5
3	4.3	4.0	0.3	12.5
4	5.1	4.7	0.4	12.5
Ave	**4.18**	**3.90**	**0.28**	**12.50**

$$Efficiency = \frac{Pelleted}{Mashed} \times 100 \quad (18)$$

$$Throughput = \frac{Pelleted}{Time\ (hr)} \quad (19)$$

$$Average\ Efficiency = \frac{\Sigma\eta}{no. of\ test} \quad (20)$$

3.1 Cost Analysis of the Research Project

Table 4. Bill of Engineering Measurement and Evaluation (BEME)

S/n	Material Description	Specification	Qty	Rate (unit Price)	Amount (#)
1	Back axle	Hummer Bus	1	30,000	30,000
2	Electrical motor	5Hp	1	80,000	80,000
3	Barrel (mild steel pipe)	Ø200 x 300 x 10 thickness (all in mm)	1	7,000	7,000
4	Bearings		6	500	3,000
5	Mild Steel Rod	Ø90mm x 100mm	1	5,000	5,000
6	U Channel iron	4" x 18ft	1	18,500	18,500
7	Mild Steel Sheet	1200 x 1200 x 2(mm)	1	12,500	12,500
8	Bults, Nuts & Washers	M12, M6, M14 & M25			6,000
9	Electrode	Guage 10 Guage 12	½ Pck ½Pck		1,500 1,500
10	Cutting disc	Ø225mm	2	1,000	2,000
11	Grinding disc	Ø150mm	1	700	700
12	Ø200mm x 15mm Flange	Ø200mm x 15mm	2	3,000	6,000
13	Mild Steel Plate	200mm x 500mm x 10mm	1	15,000	15,000
14	Mild Steel Rod	Ø200mm x 40mm	1	20,000	20,000
15	Mild Steel Rod	Ø70mm x 300mm	1	10,000	10,000
16	Nut	M 30	2	500	1,000
17	Drill bit (black)	Ø4mm	6		2,000
18	Rollers (Hinges)		4	500	2,000
19	Pulleys	Ø170mm Ø100mm Ø150mm	1 1 1	2,000 2,000 2,500	2000 2,000 2,500
20	Brass bearing	Ø100mm x 50mm	1	2,000	2,000
21	Driving belt	A 31 B	2 2	300 500	600 1,000
22	Electric Box		1	15,000	15,000
23	Angle iron	1" x 18FT	1	1,500	1,500
24	Surface Treatment	Sum		15,000	15,000
25	Prime mover (Gasoline Engine)			90,000	90,000
26	Miscellaneous	Sum		30,000	30,000
TOTAL =₦368,800.00					

V. Conclusion

The design and fabrication of the Poultry Feed Pelleting Machine was successfully carried out and performance evaluation done at the Scientific Equipment Development Institute (SEDI), Enugu. The machine which was locally fabricated performed credibly with percentage rate of 95% and a percentage loss of 5% due to some trapped materials and fewer that were not pelletized.

The moisture content of the pellets after sun dry (ready to package) is 12.5%. Indeed, the texture and appearance competed favourably with other feeds. The functionality of the machine is a function of moisture content for easy press and time related with a capacity through put of 95kg/h. The machine is recommended to facilitate the production of pellet feed for small scale and medium scale farmers. For reasons of reducing much expenses in purchasing feeds.

The study indicated optimization in view to scale up for mini-industrial purpose having discovered little or no variation of time with respect to kg when in operation.

An attachment of mini/ small regulated electric motor to replace the hand rotating wheel is recommend which will maximize functionality of the machine as ease effort in long operation.

References

Abdisa, L. M. (2023). The Impact of Wheat Row Planting on Farmer's Livelihoods, in Case of Wayu Tuka Woreda East Wollaga Zone, Oromia-Ethiopia. Budapest International Research in Exact Sciences (BirEx) Journal, 5(1), 1-18.

Abdollahi, M. R., Ravindran, V., & Svihus, B. (2013). Pelleting of broiler diets: An overview with emphasis on pellet quality and nutritional value. Animal feed science and technology, 179(1-4), 1-23.

Ajayi, A. B., & Osumune, J. I. (2013). Design of Sawdust Briquette Machine. Innovative Systems Design and Engineering, 4(10), 51-58.

Alves, E.C., dos Santos Alves, I.H., Soares, B.B., Borges, A.F., Jalal, A., Jani, A.D., Abreu-Junior, C.H., Capra, G.F. and Nogueira, T.A.R., 2023. Resource recovery of biological residues from the Brazilian poultry industry in mitigating environmental impacts: A life cycle assessment (LCA) approach. Journal of Cleaner Production, 416, p.137895.

Chen, Z., Yu, G., Yuan, X., Wang, Q., & Kan, J. (2015). Improving the conventional pelletization process to save energy during biomass densification. BioResources, 10(4), 6576-6585.

Garcia-Maraver, A., & Carpio, M. (2015). Biomass pelletization process. Biomass pelletization: Standards and production, 53-66.

Gidenne, T., Garreau, H., Drouilhet, L., Aubert, C., & Maertens, L. (2017). Improving feed efficiency in rabbit production, a review on nutritional, technico-economical, genetic and environmental aspects. Animal Feed Science and Technology, 225, 109-122.

Jagtap, A., & Kalbande, S. (2023). Statistical optimization, characterization and effect of process variables on cotton stalk pellets using tractor drive pelleting machine. Environmental Science and Pollution Research, 1-14.

Kamara, A., Kamai, N., Omoigui, L., Togola, A., Ekeleme, F., & Onyibe, J. E. (2020). Guide to maize production in Northern Nigeria. https://biblio1.iita.org/bitstream/handle/20.500.12478/6964/Guide%20to%20Maize%20Production%20%20in%20Northern%20Nigeria.pdf?sequence=1

Khurmi, R. S., & Gupta, J. K. (2005). A textbook of machine design. S. Chand publishing.

Letsara, R., Andrianantenaina, R., Ashande, C. M., Mawi, C. F., Saragih, M. Y., Ngbolua, K. T. N., & Rahelivololoniaina, B. R. (2020). Acute Toxicity Evaluation of the Malagasy

Endemic Aloe helenae and A. analavelonensis in Mice. Budapest International Research in Exact Sciences (BirEx) Journal, 2(4), 452-457.
Médard, M. M., Faustin, I. A., Junior, A. L., Héritier, N., Jean-Paul, N. K. T. N., Ridwan, M., & Gorges-Willy, B. (2023). Production Testing of One-Day Chikens by Untreated Palm Oil Weever Combustion in Gbadolite, the Democratic Republic of Congo. Britain International of Exact Sciences (BIoEx) Journal, 5(1), 34-40.
Okafor, C. E, Abdulrahman, J, Ihueze C.Cand Okoli N. C (2017). Optimal Design and Structural Analysis of Internally Pressurized Thin-Walled Shells. Scholars Journal of Engineering and Technology. 5(8):416-426. DOI: 10.21276/sjet.
Okafor, C. E., Oghenemaero, O. O., Chukwuebuka, M., & Isaac, O. O. (2020). Adaptive Design of a Universal Automotive Ball Joint Separating Device. Transportation Engineering, Elsevier. 2, 100010. https://doi.org/10.1016/j.treng.2020.100010
Okonkwo U. C, Okafor, C. E., and Ihueze C. C. (2020). Development and Performance Evaluation of a Double Barrel Cassava Grating Machine. Sumerianz Journal of Scientific Research, 3(11). 133-140. DOI: 10.47752/sjsr.311.133.140
Olugboji, O. A., Abolarin, M. S., Owolewa, M. O., & Ajani, K. C. (2015). Design, construction and testing of a poultry feed pellet machine. International Journal of Engineering Trends and Technology, 22(4), 168-172.
Orimaye, O. S., Ajewole, P. O., & Oni, I. O. (2019). Design, Fabrication and Performance Evaluation of Indigenous Fish Feed Pelletizing Machine for Low Income Farmers in Nigeria. Journal of Engineering Research and Reports, 4(3), 1-31.
Pane, I. F., Fachrudin, H. T., Fibriasari, H., & Lubis, A. S. (2020). Architectural Design by Considering Communication Systems with Observer (Case Study: KLIA Internasional Airport). Britain International of Exact Sciences (BIoEx) Journal, 2(1), 11-18.
Renjani, R. A., & Wulandani, D. (2019, June). Pellet Mill Fixed Dies Type for Production of Solid Fuel Pellets from Acacia mangium Bark. In IOP Conference Series: Materials Science and Engineering (Vol. 557, No. 1, p. 012057). IOP Publishing.
Romallosa, A. R. D., & Cabarles Jr, J. C. (2011). Design and evaluation of a pellet mill for animal feed production. Patubas, 6(1), 1-17.
Samedi, L., & Charles, A. L. (2019). Isolation and characterization of potential probiotic Lactobacilli from leaves of food plants for possible additives in pellet feeding. Annals of Agricultural Sciences, 64(1), 55-62.
Serge, M. K., Gaëtan, K., Joël, E., & Indila, C. L. (2023). Test of the Different Proportions of Moringa oléifera fluor on the Growth of COBB500 Chicks in Vivo in Kinshasa (DR Congo) Bay. Britain International of Exact Sciences (BIoEx) Journal, 5(1), 24-33.
Sharma, H. B., Panigrahi, S., & Dubey, B. K. (2021). Food waste hydrothermal carbonization: Study on the effects of reaction severities, pelletization and framework development using approaches of the circular economy. Bioresource Technology, 333, 125187.
You, J., Tulpan, D., Malpass, M. C., & Ellis, J. L. (2022). Using machine learning regression models to predict the pellet quality of pelleted feeds. Animal Feed Science and Technology, 293, 115443.