DEVELOPMENT AND PERFORMANCE EVALUATION OF POULTRY FEED MIXING AND PELLETING MACHINE

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ABSTRACT

Poultry feed mixing and pelleting machine was designed, fabricated and tested. The machine consists of two chambers (mixing and pelleting) horizontally assembled together as a single machine. It consists of single hoper, single electric motor and a stand frame. The components of mixing chamber are mixer auger, single pulley and bearing, whereas, the pelleting chamber consists of pelletizer auger, die plate and discharge chute. It was observed that the mixing and pelletizing efficiency, through put capacity and the percentage. Error recovery of the machine increased with increase in moisture content and the speed of the machine. The results, obtained from experiments were compared with that of locally made existing poultry feed mixing and pelleting machine. From the result of newly designed machine, the average machine capacity of 68.04kg/h was obtained on using 2litres of water and 70.37kg/h on using 3litres of water in feed formulation I while from the existing machine, the average machine capacity of 61.24kg/h was obtained on using 2liters of water and 63.34kg/h on using 3litres of water in feed formation I .The new designed machine shows higher throughput capacity of 166.67 kg/hr with maximum pelletizing and mixing efficiency of 97.24% while the existing machine throughput capacity of 150kg/hr with maximum pelletizing and mixing efficiency of 87.52% was obtained. The material hold up in both machines occurs at higher feed rate than the lower feed rate. The material recovery rate in newly designed machine was highest at 35minutes (68.06 Kg) and lowest at 25minutes (65.13 Kg) in formulation II. The ANOVA for the effect of liquid quantity in moisturizing the feed, feed formulation and feed rate and their interactions on the capacity of the mixing and pelleting confirms that these factors are significant processing parameters that affect the performance and capacity of the machine.

Keywords: *Poultry Feed, Mixing, Pelleting, Machines.*

1.0 INTRODUCTION

Feed production for livestock, poultry or aquatic life involves a range of activities, which include grinding, mixing, pelleting and drying operations. Kwari, and Igwebuike (2001), gave a summary of the different types of machinery needed for the production of various types of feeds to include grinders, mixers, elevators and conveyors, mixer, extruders, cooker, driers, fat sprayers and steam boilers. The mixing and pelleting operations in particular, is of great importance, since mixing is the means through which two or more ingredients that form the feed are interspersed in space with one another for the purpose of achieving a homogenous mixture capable of meeting the nutritional requirements of the target livestock, poultry or aquatic life being raised (Akpobi J. (2008). Pelleting is an extrusion type thermoplastic molding operation in which the finely reduced particles of the feed ration are formed into a compact, easily handled, pellets. Essentially, feed mixing can be done either manually or mechanically. The manual method of mixing feed entails the use of shovel to intersperse the feed's constituents into one another on open concrete floors. The manual method of mixing feed ingredients is generally characterized by low output, less efficient, labor intensive and may prove unsafe, hence, hazardous to the health of the animals. The mechanical method of mixing is achieved by using mechanical mixers developed over the years to alleviate the shortcomings associated with the manual method. A wide variety of mixers are available for use in mixing components, the selection of which depends mainly on the phase or phases the components exists such as solid, liquid or gaseous phases Diarra S. (2001). Some commonly used solid mixers received by Brennan *et al*. (2008) includes, tumbler mixers**,** horizontal trough mixers, vertical screw mixers etc. These are quite quick and efficient particularly in mixing small quantities of additives into large masses of materials. New, (2007) observed that regardless of the type of mixer, the ultimate aim of using a mixing device is to achieve a uniform distribution of the components by means of flow, which is generated by mechanical means.

In most developing countries including Nigeria, a major common problem facing farmers raising livestock, poultry and/ or aquatic life is the lack of access to proper feeds that can meet the nutritional requirements of their flocks at the right time and in the right quality and price. Dogo (2001) observed that the rate of poultry production in Nigeria is not commensurate with human population growth and demand. He therefore, opined that the major constraint is the high cost of feeds in the market. A holistic review of poultry pelleting machines revealed that only a handful of pelleters are available for the poultry industry worldwide as compared to other animal pelleters. This is as a result of the limited number of industries involved in the manufacture of poultry feed equipment. The main objective of this work is to design and fabricate a machine capable of mixing and pelleting poultry feed and also carry out its performance evaluation.

2.0 MATERIALS AND METHODS

There are several methods of designing machines for factory use. One of the disadvantages of the present day machine efficiency is poor design technique. In this research work, a detailed design of poultry feed mixing and pelleting machine consists of two sections. The first consist of electrical model equations and the second was mechanical model equations. Some sections of the machine high performance of the machine. Figure (1) shows the electrical model equations are given by

$$\frac{dI_a}{dt} = \frac{I}{L} V_a - RI_a + K_M - W \sin(No) \qquad (1)$$

$$\frac{dI_a}{dt} = \frac{I}{L} V_a - RI_b + K_M - W \cos(No) \qquad (2)$$

The mechanical model equation for the machine is

$$\frac{dI_a}{dt} = \frac{I}{J} = (-KM - Ia \sin\ (NO) + KaIb \qquad (3)$$

$$\frac{dw}{dt} = w \qquad (4)$$

Where V_a and V_b are the voltage on phases A and B respectively (volt), I_a and I_b are the currents in phases A and B respectively (Amp) ω is the angular speed (rad/sec), θ is rotor position (rad), R is the resistance of the phase winding (Ohms) and L is the self inductance of the phase winding (h) L is assumed to be constant (by neglecting magnetic saturations). $K_m$is the motor torque constant (N_m/A), K_v is the viscous friction coefficient (K_g/M^2/s) and J and Ti are the rotor inerhtia (kgm^2) and load torque (Nm) respectively.

The model can be represented by the following general form,

X = f(x,u) (5)

Y = h(x) (6)

Where x= $[I_{a,} I_{b,} \omega, \theta]T$ and Y = $[I_a I_b]$

Therefore by using equation (5) and (6) the non-linear continuous operation of the machine which also represents the model of molar machine can be expressed as

$$\begin{pmatrix} I_a \\ I_b \\ \omega \\ \theta \end{pmatrix} + \begin{pmatrix} \frac{I}{L} & 0 \\ 0 & L \\ 0 & 0 \\ 0 & 0 \end{pmatrix} \begin{pmatrix} V_a \\ V_b \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ \frac{-T_i}{J} \\ \theta \end{pmatrix} \quad (7)$$

$$+ \begin{pmatrix} I_a \\ I_b \\ \omega \\ \theta \end{pmatrix} = \begin{pmatrix} \frac{-K}{L} & 0 & \frac{-Km^1}{L}\sin(N) & 0 \\ 0 & \frac{-K}{L} & \frac{K_m}{L}\mathrm{Cos}(N\theta) & 0 \\ \frac{-K}{L}\mathrm{Sin}(N\theta) & \frac{K_m}{L}\mathrm{Cos}(N) & \frac{-kt}{L}(\cos) & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} I_a \\ I_b \\ \omega \\ \theta \end{pmatrix}$$

$$\begin{pmatrix} y_1 \\ y_2 \end{pmatrix} + \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \times \begin{pmatrix} I_a \\ I_b \\ \omega \\ \theta \end{pmatrix} \quad (8)$$

In order to test the dynamic performance of the machine with the proposed control algorithm, it is preferred to utilize the discrete model of the electric motor in discreet state space vector form instead of continuous form. This procedure can be obtained using the first order Eiler approximation Ahmed Rubaai, (2011) as

$$x_{k+1} = x_k + \mathrm{Tf}[x_{k,} U_{k,}] \quad (9)$$

$$Y_{k,} = \mathrm{h}[x_k] \quad (10)$$

Where $x_k = I_{a+(K),} \omega k\ \theta k],^T Y_k = I_{a+(K),} I_b k],^T$

and T is the samphine period (sec) which must be small compared to the electrical time constant of the motor. By using equation 9 and 10 the motor model can be expressed as

$$\begin{pmatrix} I_a(k+1) \\ I_b(k+1) \\ w(k+1) \\ \theta(k+1) \end{pmatrix} = \begin{pmatrix} I_a(k) \\ I_b(k) \\ w(k) \\ \theta(k) \end{pmatrix} +$$

$$\begin{pmatrix} \frac{-R}{L} & 0 & \frac{-K_m R}{L}\,\text{Sin}(N\theta k) & 0 \\ 0 & \frac{-R}{L} & \frac{K_m}{L}\,\text{Cos}(N\theta) & 0 \\ \frac{-K_m}{L}\,\text{Sin}(N\theta k) & \frac{K_m}{L}\,\text{Cos}(N\theta k) & \frac{-kv}{L}\,\text{Cos}(N\theta) & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} \begin{pmatrix} I_a(k) \\ I_b(k) \\ wk \\ \theta k \end{pmatrix} +$$

$$\begin{pmatrix} \frac{I\_1a}{L} & 0 \\ 0 & \\ 0 & \frac{1}{L}\ 0 \\ 0 & 0 \end{pmatrix} \begin{pmatrix} V_a \\ V_b \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ \frac{-T_i}{J} \\ \theta \end{pmatrix} \tag{11}$$

$$\begin{pmatrix} y_1(k) \\ y_2(k) \end{pmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \text{x} \begin{pmatrix} I_a(k) \\ I_b(k) \\ wk \\ \theta k \end{pmatrix} \tag{12}$$

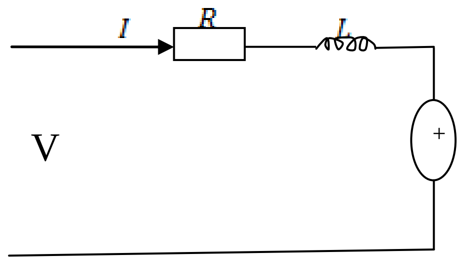

Figure 1: *Electrical circuit equivalent of DC motor.*

Parameter of the motor drive is:

Rated phase current I = 15 Amp
Rated phase voltage V = 90 volt
Self-inductance of Phase winding L = 22mH
Resistance of the phase Winding R = 2.202
Number of rotor teeth N = 50
Motor torque constant K_m= 0.252 Nm/A
Viscous- friction coefficient K_v= 0.0123 kg. M^2/s
DC motor and load inertia J= 6.9849 x 10^{-4} $Kg.m^2$
Load torque constant Ji = 0.01 N_m

Shafts design consideration.

The shaft is a cylindrical solid rod for transmitting motion through a set of load carried on it. The shaft uses for the pelleting is loaded by a press screw auger, bearings, pulley, and belt tension. All these forces act on the shaft. The design is based on Fluctuating torque, bending moment and shearing force. These called for knowing the combined shock and fatigue on the shaft. To determine the shaft diameter, we adopt the formula; (Fagbeuro O.A,(2008).

$$d^3 = \frac{16}{\pi\delta_{sy}}\left[(K_bM_b)^2 + (K_tM_t)^2\right]^{\frac{1}{2}} \qquad (13)$$

Where;
d = diameter of shaft (mm)
K_b = combined shock and fatigue factor for bending moment.
K_t = combined shock and fatigue factor for torsional moment.
M_b = Resultant bending moment (Nm)
M_t = Resultant torsional moment (Nm)
δ_{sy} = Allowable shear stress (MN/m^2)
π = constant, 3.142

Determining the Capacity of the Conveyor

A horizontal mixing auger conveyor (Fig.2) which operates inside a close fitted tube to effect blending of feed components was designed. The auger is designed with helices of uniform diameter of 145 mm and a pitch 16 mm.

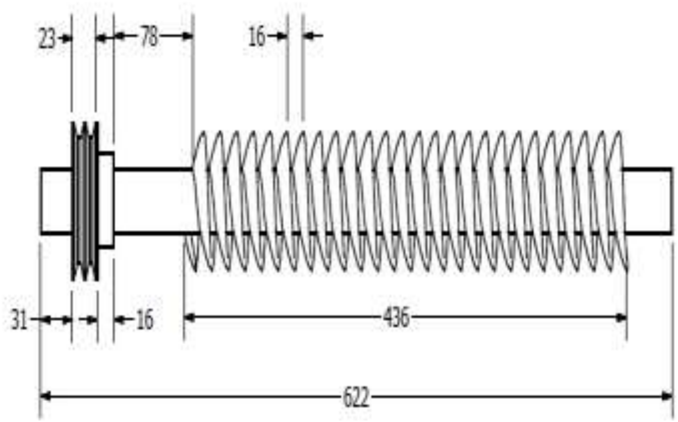

Fig 2: *Feed Mixer Auger*

For mixing auger, the capacity was determined using the formula below; figure 3 shows feed pelletizer screw Auger

$$Q = 60\, n\Phi\, \gamma\, p\, (D - d)\, \frac{\pi}{4} \qquad (14)$$

Where :
Q = capacity of conveyor, t/h;
γ = bulk density of conveyed material, 800 kg/m3;
n = number of screw rotations, 800 rpm;
p = conveyor pitch, 0.16 m;
D = pitch diameter of conveyor, 0.145 m;
d = diameter of shaft, 17.62 m,
π = constant, 3.142,
Φ = factor introduced for inclined conveyor, 0.33
(Okojie, 2011).

The capacity of the pelletizer auger was computed using equation given by Kubota (1995) as:

$$Q = 60\, n\, p\, \gamma\, (D_2 - d_2)^{\frac{\pi}{4}} \tag{15}$$

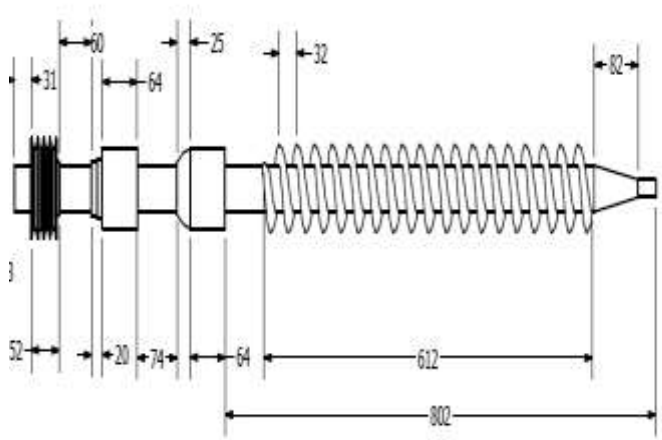

Fig 3: *Feed Pelletizer Screw Auger*

Where:
Q = capacity of conveyor, t/h;
γ = bulk density of conveyed material, 800 kg/m3;
n = number of screw rotations, 800 rpm;
p = conveyor pitch, 0.32 m;
D = pitch diameter of conveyor, 0.145 m;
d = diameter of shaft, 18.06 m,
π = constant, 3.142,

Principles of Operation of the Machines.
During operation with the switch of the mixer's electric motor set at the "ON" position, the feed ingredients are introduced into the mixer via a trapezoidal shaped hopper located at the upper part of the mixing compartment. Material introduction into the mixer is in order of quantity, with the bulkier among the components introduced into the machine first. With the material inside the mixing chamber, the rotating action of the centrally based vertical acting auger, lifts it up from the lower cylinder through the close fitting tube and drops it high up at the end of the tube. After thorough mixing is achieved as assessed through a look-in window located at the side of the mixing chamber, the flap of the discharge channel is open to allow the mixed components out of the mixer where the need for using the machine is only to blend feed constituents. Complete evacuation of the material is facilitated by the rotating action of the stirrer, which work close to the surface of the frustum section of the mixing chamber.

Fabrication of the machine parts
Figure 5 shows how the machine parts were fabricated. The items used to build the machine; the quantity of the items and their names is shown in Figure 5. The complete functional poultry feed mixing and pelleting machine is shown in figure 4.

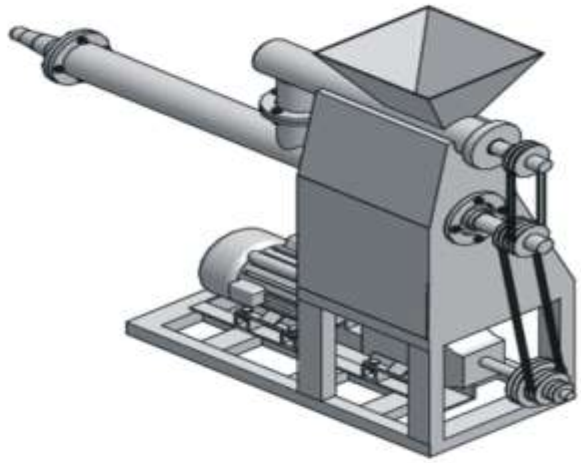

Fig 4: *Isometric Drawing of the poultry feed Mixing and Pelleting Machine*

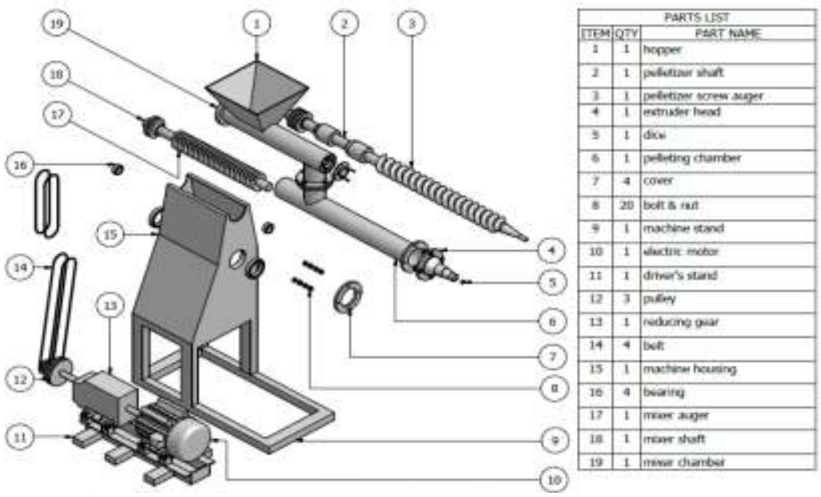

Figure 5: *Exploded View Drawing of the poultry Feed Mixing and pelleting Machine.*

Performance evaluation procedure.

The machine was first run under no-load condition using an electric motor of 3 hp to ascertain the smoothness of operation for the machines rotating parts. The actual test was conducted using two different feeds formulation. Two different feed rates were used on both formulations to get the mixing and pelleting capacity of the machine. Testing of the machine was targeted at evaluating its mixing and pelleting efficiency, through put capacity and percentage recovery rate. The results obtained were analyzed using analysis of variance (ANOVA).

3.0 RESULTS AND DISCUSSION

The performance results of newly designed machine and that of existing poultry feed mixing and pelleting machine was compared. The performance test carried out was to determine the machine's mixing and pelleting efficiency, through put capacity and percentage recovery rate on two different feed formulations and feed rates. The results obtained are presented in tables 1 and 2 for newly designed machine and tables 3 and 4 for existing machine.. From the results presented in table 1,2,3 and 4, it was seen that machine capacity increases with an increase in quantity of liquid used in moisturizing the feed. With newly designed machine and the existing machine, an average machine capacity of 68.04kg/h and 61.24kg/h were obtained with 2litres of water respectively. The machine capacity rose by 2.33kg/h and 2.10kg/h to reach 70.37kg/h and 63.34kg/h respectively at 3litres of water used in feed formulation I. In table 1 and 3 the material hold up in the machine decreases from 6.97k/h to 4.63kg/h and 13.77kg/h to 11.67kg/h for the 2 and 3 litres of water respectively. This means that in machines, the lower the quantity of water, the higher the material hold up in the machine. In table1, the average material feed rate recorded using 70kg/h was 64.54kg/h and at 80kg/h was 71.53kg/h on 2 litres of water as against 67.44kg/h and 73.30kg/h on 3 litres of water. In table 3, the average material feed rate recorded using 70kg/h was 58.09kg/h and at 80kg/h was 64.38kg/h on 2 litres of water as against 60.70kg/h and 65.97kg/h on 3 litres of water. This means that higher quantity of materials was recorded using higher quantity of water at different feed rate. The material hold up in table 2 using newly designed system was influenced by material feed rate. On using 2 litres of water, material hold up rose from 4.07kg/h at 70kg/h feed rate to 6.38kg/h at 80kg/h feed rate and from 2.87kg/h at 70kg/h feed rate to 4.77kg/h at 80kg/h feed rate using 3litres of water. In table 4, using existing system it was observed that when using 2 litres the material hold up increases from 8.66kg/h with 70kg/h feed rate to 13.74kg/h with 80kg/h feed rate. Again when using 3 litres of water, the material feed rate increases from 9.58kg/h feed rate to 12.29kg/h feed rate. This implies that regardless of the quantity of water used, material hold up or blockage is more likely to occur at higher feed rate than at lower feed rate levels. But with the new designed system, the material hold up is lesser than that of the existing system by using the same quantity of material feed rate. The proximate analysis of feed nutrients for the formulation of feeds was given in table 5.The percentage of nutrients required for the formulations of any type of feed was given in the table5. The machine performance on the four durations of 20minutes, 25minutes, 30minutes and 35minutes was presented in table 6. The material recovery rate was highest at 35minutes (68.06 Kg) and lowest at 25minutes (65.13 Kg). This shows that the more the time used on the machine, the more materials recovered. The average performance of the machine using the four durations was 97.24% while that of the existing machine was 87.52%. Table 7 shows the ANOVA for the effect of liquid quantity in moisturizing the feed, feed formulation and feed rate and their interactions on the capacity of the mixing and pelleting confirms that these factors are significant processing parameters that affect the performance and capacity of the machine.

Table 1: Effect of liquid quantity and feed rate on the mixing-pelleting feed formulation I for new designed machine

Quantity of Liquid(Litres)	Replicates	70kg/h Feed rate	80kg/h Feed rate	Total	Average
2	1	64.03	69.03	133.06	66.53
	2	66.20	71.20	137.40	68.70
	3	63.40	74.35	137.75	68.88
	Total	193.63	214.58	408.21	204.11
	Mean	64.54	71.53	136.07	68.04
	Material Hold up	5.46	8.47	13.93	6.97
3	1	66.03	72.32	138.35	69.18
	2	67.05	74.33	141.38	70.69
	3	69.23	73.25	142.48	71.24
	Total	202.31	219.90	422.21	211.11
	Mean	67.44	73.30	140.74	70.37
	Material hold up	2.56	6.70	9.26	4.63

Table 2: Effect of liquid quantity and feed rate on the mixing-pelleting feed formulation II for new designed machine

Quantity of Liquid(Litres)	Replicates	70kg/h Feed rate	80kg/h Feed rate	Total	Average
2	1	63.05	70.38	133.43	66.72
	2	68.50	74.24	142.74	71.37
	3	66.25	76.25	142.50	71.25
	Total	197.80	220.87	418.67	209.34
	Mean	65.93	73.62	139.55	69.78
	Material Hold up	4.07	6.38	10.45	5.23
3	1	66.11	74.22	140.33	70.17
	2	67.23	76.23	143.46	71.73
	3	68.04	75.24	143.28	71.64
	Total	201.38	225.69	427.07	213.54
	Mean	67.13	75.23	142.36	71.18
	Material hold up	2.87	4.77	7.64	3.82

Table 3: Effect of liquid quantity and feed rate on the mixing-pelleting feed formulation I for the existing machine

Quantity of Liquid(Litres)	**Replicates**	**70kg/h Feed rate**	**80kg/h Feed rate**	**Total**	**Average**
2	1	57.627	62. 13	119.76	59.88
	2	59.58	64.08	123.66	61.83
	3	57.06	66.92	123.98	61.99
	Total	174.27	193.13	367.40	183.70
	Mean	58. 09	64.38	122.47	61.24
	Material Hold up	11.91	15.62	27.53	13.77
3	1	59.43	65.09	124.52	62.26
	2	60.35	66.90	127.25	63.63
	3	62.31	65.93	128.24	64.12
	Total	182.09	197.92	380.01	190.01
	Mean	60.70	65.97	126.67	63.34
	Material hold up	9.30	14.03	23.33	11.67

Table 4: Effect of liquid quantity and feed rate on the mixing-pelleting feed formulation II for the existing machine

Quantity of Liquid(Litres)	**Replicates**	**70kg/h Feed rate**	**80kg/h Feed rate**	**Total**	**Average**
2	1	56.75	63.34	120.09	60.05
	2	61.65	66.82	125.47	64.24
	3	59.63	68.63	128.26	64.13
	Total	184.03	198.79	382.82	191.41
	Mean	61.34	66.26	127.60	63.80
	Material Hold up	8.66	13.74	22.40	11.20
3	1	59.50	66.80	126.30	63.15
	2	60.51	68.61	129.12	64.56
	3	61.24	67.72	128.96	64.48
	Total	181.25	203.13	384.38	192.19
	Mean	60.42	67.71	128.13	64.07
	Material hold up	9.58	12.29	21.87	10.94

Table 5: Proximate analysis of feed nutrients

Nutrients (%)	Starter's mash	Growers mash	Finisher's mash	Layer's mash
Crude protein	25.00	14.00	16.00	14.00
Crude fat/oil	4.40	2.40	2.10	3.20
Crude fibre	6.10	2.40	2.30	4.80
Vitamin	16.00	31.00	27.90	30.00
Minerals	3.60	4.00	3.30	5.00
Energy	33.70	36.80	40.80	36.80
Additives	3.10	4.00	1.60	2.00

Table 6: Machine Performance at different durations

Time (Seconds)	Replicates of Material recovered (Kg)			Mean	Coefficient of variation (%)	Machine Performance (%) (Degree of Mixing-Pelleting)
	I	II	III			
20	67.40	65.60	66.20	66.40	3.26	96.87
25	65.20	66.50	64.60	65.13	3.40	96.59
30	64.20	66.20	64.80	65.73	2.82	97.18
35	68.60	67.00	68.60	68.06	1.70	98.30
Total	265.40	265.30	264.20	264.96	11.18	388.94
Mean	66.32	66.33	66.05	66.24	2.80	97.24

Table 7: ANOVA for the effect of Liquid, Feed Formulation and Feed rate on Mixing-Pelleting Performance.

Sources of Variations	Sum of Squares	Degree of Freedom	Mean Square	Computed F
Liquid (A)	9.790	2	4.895	0.703*
Formulation (B)	20.930	2	10.465	1.503*
Feed rate(C)	48.390	2	24.195	3.475*
AB	1.310	2	0.655	0.094
AC	3.260	2	1.630	0.234
BC	0.190	2	0.095	0.014
ABC	0.880	2	0.440	0.063
Error	62.660	9	6.962	
Total	147.410	23		

Significant at 5% probability level

4. CONCLUSIONS AND RECOMMENDATION

The Mixing and Pelleting machine was developed, fabricated and tested. The results obtained shows that the machine performance was 97.24% while that of the existing system was 87.52% which was obtained in 35minutes of operation. The performance and capacity of the machine was found to be dependent of water quantity, feed rate and feed formulation. Also, regardless of the type of feed formulation, the possibility of material hold up was caused by material feed rate and quantity of liquid used. From the testing, it was shown that at appropriate mixing ratio, a high quantity and quality of feed was obtained.. A combination of mixer and pelletizer reduced the labour cost of manual mixing and pelleting and the time involved. Poultry feed mixer and pelletizer can be fabricated vertically and horizontally, but the vertical type requires less power to horizontal type. For hygienic, better purposes, and better quality of feed, a stainless steel materials is recommended.

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