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Development and Performance Test 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 hopper, 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. A 3hp single phase electric motor supply power to the machine with two V-belt drive connected to double and single pulley on pelleting and mixing chamber respectively. The electric motor drives the mixing and pelleting auger simultaneously. The main objective was to mechanize mixing and pelleting feed in order to reduce the tedious ways of producing it in manual form. It was observed that the mixing and pelletizing efficiency, through put capacity and the percentage recovery of the machine increased with increase in moisture content and the speed of the machine. An average machine capacity of 68kg/h was obtained on using 2litres of water and 70.37kg/h on using 3litres of water in feed formulation I .The machine showed higher throughput capacity of 166.67 kg/hr with maximum pelletizing and mixing efficiency of 97.24%. The material hold up is likely to occur at higher feed rate then the lower feed rate. The material recovery rate was highest at 35minutes (68.06 Kg) and lowest at 25minutes (65.13 Kg) in formulation II. The Analysis of Variance (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: Development, Performance Test, Poultry Feed, Mixing, Pelleting.

1. Introduction

Feed production for livestock, poultry or aquatic life involves a range of activities, which include grinding, mixing, pelleting and drying operations. According to Kwari, and Igwebuike (2001), they gave a summary of the different types of machinery needed for the production of various types of feeds and they 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. 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, pellet. 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 intended animals, birds or fishes for which the feed is prepared. 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. Some commonly used solid mixers as discussed 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.

Processing and densification of finely ground and mixed ingredients of animal feed into high density and durable pellets are pertinent to enhance homogeneity of feed and thereby improve animal growth, free flowing agglomerates (pellet), handling, storage and transportation. According to New, (2007) reported the quality of pellets from single pelleting experiments by measuring their respective density and durability. They also, measured change in pellet density after a storage period of one month to determine its dimensional stability. It was concluded that applied pressure and pre-treatment were significant factors affecting the pellet density. Also, bigger grind sizes and lower applied pressures resulted in higher pellet relaxations (lower pellet densities) during storage of pellets. The choice of pelleting technique to be employed will depend on the feeding habit of the poultry to be fed and its physical requirements (such as, feed size, buoyancy, texture, palatability and desired water stability) for all stages of the culture cycle.

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. Similarly, Oyenuga (2007) cited that protein from animal sources contribute about 17% of the total protein consumption in the average Nigerian diet compared to a contribution of approximately 68% of the total protein consumed in New Zealand, 71% in USA, 67% in Denmark and 60% in the UK. The reason for the low level intake of animal product in African countries he argued is due, partly, to the low population of cattle in some regions in relation to human population and requirements, but primarily due to low level of animal productivity in terms of slow growth, long calving intervals, slow reproductive cycle and low milk yield all occasioned by poor quality and or insufficient feeds. Augusto *et al*. (2005), Fagbenro (2008), Kwari and Igwebuike (2001), Diarra *et al*. (2001) and many other researchers have indicated the feasibility of the utilization of various forms of farm and agro-industrial wastes and by-products in the formulation of complete feeds for livestock, poultry and aquatic life. Although the major essential raw materials required for the formulation of complete feeds from the results of such researches are within easy reach of the farmers and at low cost, the major limiting factor to taking the full advantages offered by the results of such researches has been the lack of available appropriate equipment to process the identified raw materials into the required feeds.

A holistic review of poultry pelleting machines revealed that only a handful of pelleters are available for the poultry industry world wide 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 objective of this work to design and fabricate machine capable of mixing and pelleting poultry feed and its performance was tested.

2. Materials and Methods

A motorized vertical poultry feed mixer and pelleter, efficient and economically viable was desined and fabricated with readily available and cheap materials (suitable engineering materials that could give optimum performance in service). Materials for fabricating the machine and for feed compoundments and pelleting were chosen on the basis of their availability, suitability, economic consideration, viability in service etc. The components parts of the machine were designed fabricated and tested. The parts and their quantity are given in the part list below.

2.1 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;

$$d^3 = \frac{16}{\pi \delta_{sy}} [(K_b M_b)^2 + (K_t M_t)^2]^{\frac{1}{2}}$$

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

2.2 Capacity of the Conveyor

A horizontal mixing auger conveyor (Fig.1) which operates inside a close fitted tube to effect blending of feed components was designed for the machine. The auger is designed with helices of uniform diameter of 145 mm and a pitch 16 mm.

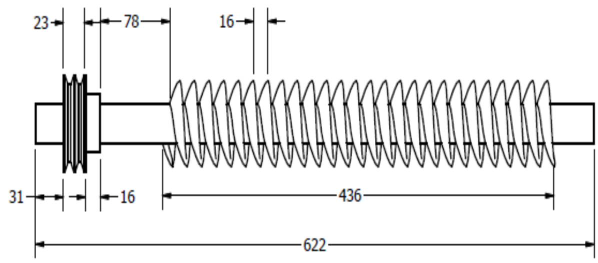


Figure 1: Feed Mixer Auger

For mixing auger, the capacity was determined using the formula below;

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

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:

$$Q = 60\, n\, p\, \gamma\, (_2 - d_2)\frac{\pi}{4}$$

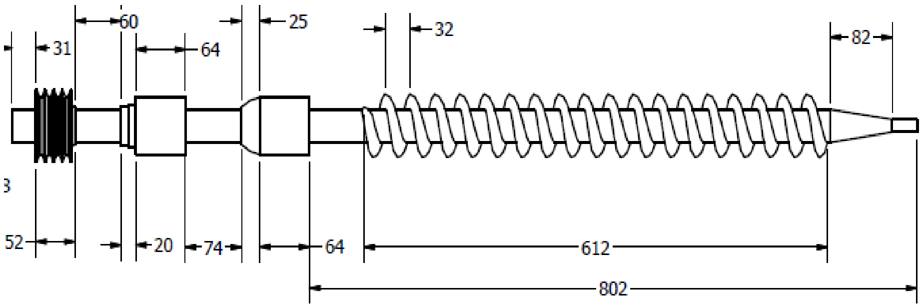


Figure 2: Feed Pelletizer Screw Auger

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,

Principle of Operation of the machine

The machine for mixing and pelleting poultry feed has two compartments. These are the mixing and pelleting chambers. 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. A 3 hp electric motor provides drive through belt connections to drive the double and single pulley on pelleting and mixing chamber respectively.

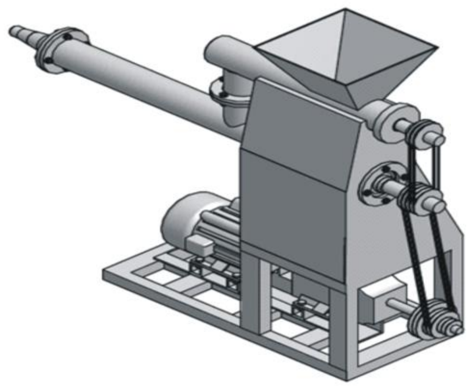
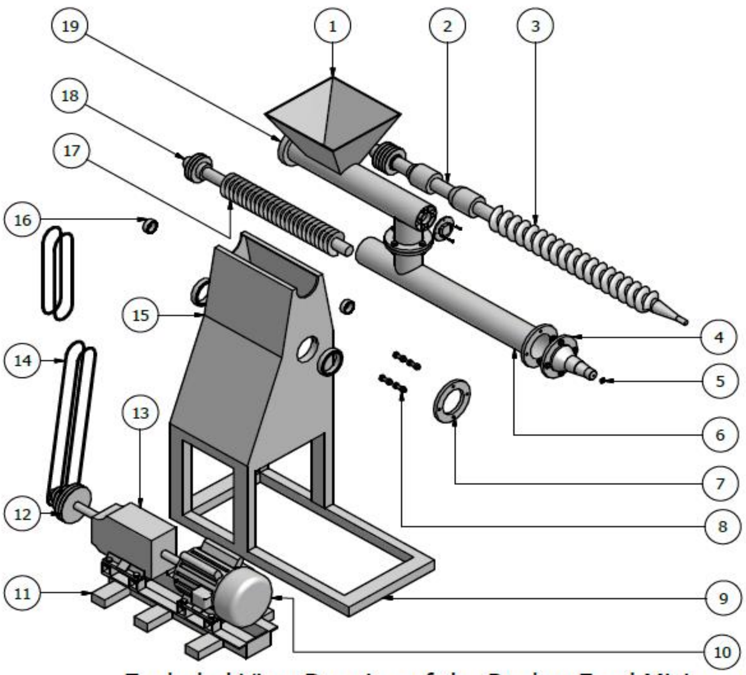


Figure 3: Isometric Drawing of the poultry feed Mixing and Pelleting Machine



PARTS LIST		
ITEM	QTY	PART NAME
1	1	hopper
2	1	pelletizer shaft
3	1	pelletizer screw auger
4	1	extruder head
5	1	dice
6	1	pelleting chamber
7	4	cover
8	20	bolt & nut
9	1	machine stand
10	1	electric motor
11	1	driver's stand
12	3	pulley
13	1	reducing gear
14	4	belt
15	1	machine housing
16	4	bearing
17	1	mixer auger
18	1	mixer shaft
19	1	mixer chamber

Exploded View Drawing of the Poultry Feed Mixing and Pelleting Machine

The material needed for the compoundment include maize, wheat offal, groundnut cake, salt, lysine, methionine premix, palm kernel cake, furaltazone and bone meal. After grinding the material with hammer mill, then each of the materials was weighed. The ground grain was first introduced into the machine through the hopper and after some minutes of recycle, then other ingredients were introduced through the same hopper. The mixing chamber was allowed to recycle the materials for about 20 minutes before allowing the mixed material to go down the second chamber for pelleting. Incoming material flows into the feeder and is delivered uniformly into the conditioner for the controlled addition of steam or liquids. The feed is discharged over a permanent magnet and into a feed spout leading to the pellet die.

Pelleting auger that carries die cover distribute the material evenly to each of the rolls. Friction drive rolls force the material through holes in the dies as the die revolves. Cut-off knives mounted on the swing cover cut the pellets as they are extruded from the die. The pellets fall through the discharge opening.

Testing the Machine

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. Results and Discussion

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 respectively. From the result presented in table 1, it was seen that machine capacity increases with an increase in quantity of liquid used in moisturizing the feed. An average machine capacity of 68kg/h was obtained with 2litres of water, then the capacity rose by 2.37kg/h to reach 70.37kg/h at 3litres of water used in feed formulation I. The material hold up in the machine decreases from 6.97k/h to 4.63kg/h for the 2 and 3 litres of water respectively. This means that lower quantity of water leads to higher material hold up in the machine. On the feed rate, the average material recorded using 70kg/h was 64kg/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. 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 was influenced by material feed rate. At 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. 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.

The proximate analysis of feed nutrients for the formulation of feeds was given in table 3.The percentage nutrients required for the formulations of any type of feed was given in the table.

The machine performance on the four durations of 20minutes, 25minutes, 30minutes and 35minutes was presented in table 4. 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%.

Figures 4 and 5 are the graphs for the effect of liquid quantity and feed rate on the machine performance on feed formulations I and II. The machine performed higher at higher liquid quantity and higher feed rate. Figure 6 shows the performance of the machine at different durations. The machine performance varies according to the graph but it showed highest at the highest time used.

Table 5 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

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

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: 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 4: 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 5: 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

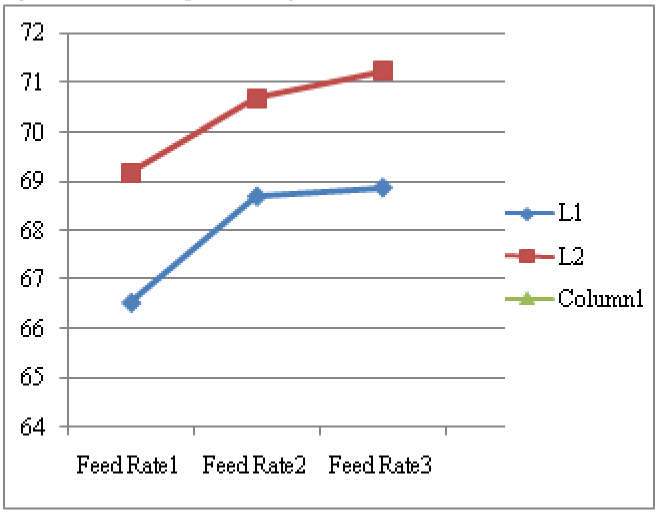


Figure 4: Effect of liquid quantity and feed rate on the performance of the machine on Feed formulation I

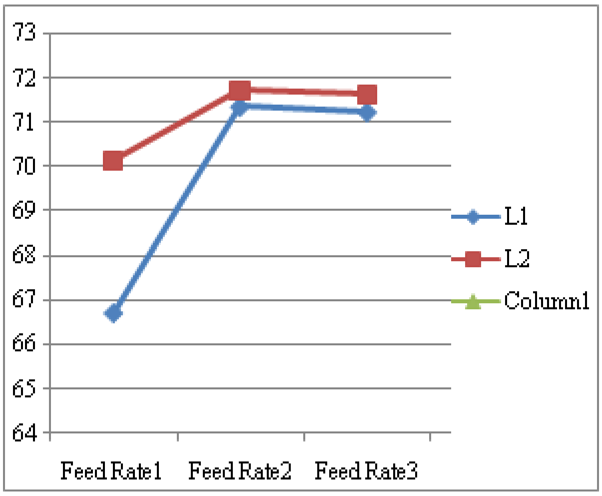


Figure 5: Effect of liquid quantity and feed rate on the performance of the machine on Feed formulation II

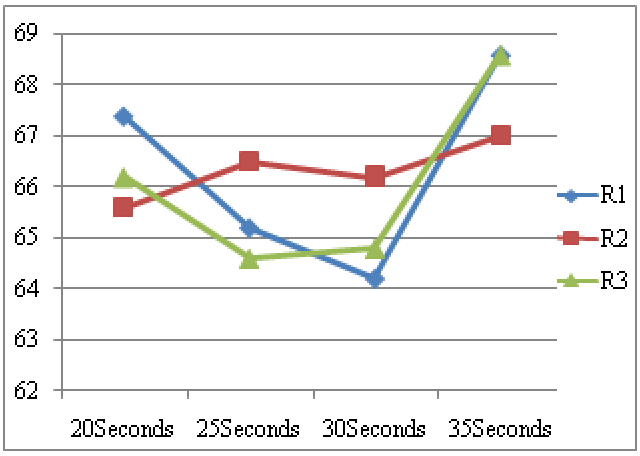


Figure 6: The performance of the machine at different durations

4. Conclusions and Recommendation

The Mixing and Pelleting machine has been designed, fabricated and tested. The result obtained showed that the machine performance was 97.24%, 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 has shown that at appropriate mixing ratio a high quantity and quality of feed was obtained. Henceforth the traditional method of mixing and pelleting poultry feed can be improved and modified. 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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