International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Email:editorijoer@gmail.com http://www.ijoer.in

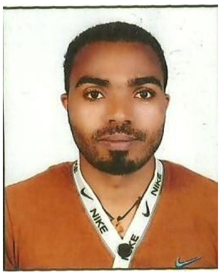
Vol.4., Issue.2., 2016
(Mar-Apr)

RESEARCH ARTICLE

ISSN: 2321-7758

DEVELOPMENT OF POULTRY FEED MIXER

GOSA BEKELE
Oromia Agricultural Research Institute
Asella Agricultural Engineering Research Center
Asella, Ethiopia



GOSA BEKELE

ABSTRACT

A poultry feed mixer was designed, constructed and evaluated for its performance using sodium chloride (NaCl) as tracer. The machine was tested using a feed composed of 40.05 kg cracked corn, 18 kg wheat bran, 7.50 kg nug cake, 3.75 kg cracked soybean, 3.75 kg fish meal, 0.75 kg lime stone, 0.75 kg premix, 0.075 kg methionine, 0.15 kg lysine and 0.225 kg salt (NaCl) replicated thrice at four mixing durations of 10, 15, 20 and 25 minutes and screw shaft speed of 100, 150 and 250 rpm. The effectiveness of mixing was assessed on the basis of percent salt content, and percent coefficient of variation (CV %) and percent degree of mixing (DM %) of sample collected at the end of each test. The best values of coefficient of variation (8.61 %) and degree of mixing (91.39 %) were obtained at mixing screw shaft speed of 150 rpm and holding/mixing time of 20 min. Hence, it can be concluded that the machine, the prototype poultry feed mixer, should be operated at speed of 150 rpm with maximum holding/mixing time of 2 in order to make the owning and operating of the machine productive (in terms of kg/hr) and economical (in terms labour and energy cost birr/kg of mixed quality feed.

KEYWORDS: Poultry, poultry feeds and feed mixer

1. INTRODUCTION

Feed is an essential requirement in poultry production as it is in all other livestock keeping. Oluyemi and Robert (1978) stated that once the poultry man has selected a good bird with long life ability, high genetic capacity to grow or lay eggs effectively and has prepared the housing and the management essential for the successful operation, the next thing is to produce the most efficient nutritionally complete diet to suit a particular environmental condition. Feed production for livestock, poultry or aquatic life involves a range of activities, which include grinding, mixing, pelleting and drying operations. New (1987) 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, mixers, extruders, cookers, driers, fat sprayers and steam boilers.

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 developed to characterized by low output, less efficient, labour 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*. (1998) 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. Brennan *et al.,* (1998) 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 Ethiopia, 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. Augusto *et al*. (1973), Fagbenro (1988), 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.

This study is an attempt towards developing and manufacturing vertical screw type poultry feed mixer that capable of mixing feed constituents, and performance evaluation of the same.

2. MATERIALS AND METHODS

2.1. Design Analysis

The prototype poultry feed mixer consisted of the following major parts: an electric motor, a mixing chamber, a mixing unit, a frame, a feeding hopper, feed outlet, drive and driven Pulleys, a screw (auger) conveyor, bearings, a shaft, supporting structures, and V-belt.

2.1.1. Volume of mixing chamber

The mixing chamber consists of two unequal cylinders (upper and lower cylinders) that are connected through a frustum with bolt and nut. This mixing chamber was made from 1.50 mm mild steel sheet metal pieces which were cut, rolled and welded together. The upper cylinder has a diameter of 600 mm and a height of 500 mm while the lower cylinder has a diameter of 150 mm and height of 100 mm. The connecting frustum has a height of 500 mm. The total volume of this chamber was computed using the relationship given by Balami, *et al*., (2013) and is shown below.

$$V_T = V_U + V_F + V_L \qquad (1)$$

The net volume of the mixing cylinder was determined as follow:

$$V_{net} = V_T - V_{sc} - V_S \qquad (2)$$

Where: V_T = total volume of mixing chamber, m^3; V_U = volume of upper cylinder, m^3; V_F = volume of frustum, m^3; V_L = volume of lower cylinder, m^3; V_{net} = net volume of the mixing chamber, m^3; V_{sc} = volume of screw casing, m^3 and V_s = volume of screw shaft, m^3.

2.2. Selection of Drive and Transmission

2.2.1. Selection of pulley diameters

The pulleys used in the drive system are made of steel iron. The diameter of the pulley for the mixing auger shaft is calculated by using Equation 3 below. The groove angle of the pulley is β = 40^0 as recommended by Pandya and Shah (1981).

$$\frac{N_2}{N_1} = \frac{D_1}{D_2}$$

2.2.2. Selection of the drive

V-belt and pulley arrangements were adopted in this work to transmit power from the electric motor to the auger shaft. The main reasons for adopting the v-belt drive was its flexibility, simplicity, and low maintenance costs. Additionally, the v- belt has the ability to absorb shocks there by mitigating the effect of vibratory forces (Khurmi and Gupta, 2005).

2.2.3. Determination of belt contact angle

The belt contact angle was given by the following equation (Khurmi and Gupta, 2005).

$$\varphi = Sin^{-1}\left(\frac{R-r}{C}\right) \qquad (4)$$

Where: R = radius of larger pulley, mm; r = radius of smaller pulley, mm; α_1 = angle of wrap for the smaller pulley, deg; α_2 = angle of wrap for the larger pulley, deg; C = was the center distance between the two center pulleys.

2.2.4. Determination of belt length

The length of belt appropriate to drive the system was calculated using the equation given below by Shigley and Mischike (2001).

$$L = 2C + \frac{\pi}{2}(D_2 + D_1) + \frac{(D_2 - D_1)^2}{4C} \qquad (5)$$

Where: L = belt length, m; D_2 = pitch diameter of driver pulley, m; D_1 = Pitch diameter of driven pulley, m.

2.2.5. Bearing selection

Bearings selection was made in accordance to American Society of Mechanical Engineers (ASME) standard as given by Hall *et al.* (1988). The bearings selected were pillow block ball bearing (single row, deep groove radial bearing). Radial bearings, number 205 with internal bore diameter, outer diameter and width of 25 mm, 52 mm and 15 mm, respectively, were selected as recommended by Khurmi and Gupta (2005).

2.3. Determination of Torque and Bending Moment

The forces that cause axial loads are weight of the feed and the weight of the follower pulley which was assembled on the screw shaft. The weight of the feed was determined as follows:

$$W_f = V_f \times \rho_f \times g = \frac{h\pi D_{sf}{}^2 \rho_f g}{4} \qquad (6)$$

Where: W_f = weight of the feed in N; V_f = volume of the feed in m^3; g = acceleration due to gravity in m/s^2; ρ_f = density of the feed in kg/m^3; D_{sf} = diameter of the screw flight in m; h = height of the screw conveyor in m.

The weight of screw flight was considered to be negligible due to its low volume compared to that of the feed and the driven pulley.

Weight of the driven pulley, fixed at the upper end of the screw shaft, could be estimated assuming the arm as solid disk, and using the equation given by Pandya and Shah, 1981 and show below.

$$W_P = W_r + W_a + W_b = \left[(\pi D_2 wt) + \left(\frac{\pi D_a{}^2 b}{4}\right) + \frac{\pi}{4}\left(D_{ho}^2 - D_{hi}^2\right)l_h\right] \times \gamma \qquad (7)$$

Where: W_P = weight of driven pulley, N; D_2 = diameter of driven pulley, m; D_a = diameter of solid circular arm, m; D_{ho} = outside diameter of hub, m; D_{hi} = inside diameter of hub, m; l_h = length of hub, m; γ = unit weight N/m^3; w = width of pulley, m; b = length of pulley arm, m; and t = thickness of the pulley, m.

2.4. Determination of Belt Tensions

To determine tensions on the tight and slack sides of the belt the following equations was used Khurmi and Gupta, (2005).

$$T_1 = T - T_c \qquad (8)$$

$$T = \sigma_{max} a \qquad (9)$$

$$T_c = mv^2 \qquad (10)$$

Where: T_c and T= the centrifugal and maximum tension of a belts (N); T_1 and T_2 = tension in the tight and slack sides (N); σ_{max}= maximum safe normal stress (N/mm^2); a = is cross sectional area of belt (mm^2); *m* = mass per unit length of belt (kg/m); *v* = is speed of belt (m/s). Values of σ_{max}, a and *m* are taken from standard tables.

Tensions on the tight and slack sides of the belt can be estimated using the equation given Khurmi and Gupta, (2005):

$$\frac{T_1 - T_c}{T_2 - T_c} = e^{\mu \alpha_1 \operatorname{cosec}\frac{\beta}{2}} \qquad (11)$$

Where: μ = coefficient of friction between a belt and a pulley = 0.25 from design book.β = groove angle which was equal to 40^0 and α_1 = angle of wrap on small pulley = 2.66 rad.

From Equation (8), (9) and (10) T_1, T and T_c were estimated to be 169.50 N, 170.10 N and 0.60 N, respectively. Using the values T_1, T and T_c and Equation (11) the value of T_2 was found to be 24.92 N.

Thus, the maximum vertical bending moment (M_{bt}) on the shaft due to belt tension was computed as follow:

$$M_{bt} = (T_1 + T_2) \times (H_S) = 194.42\,N \times 0.07\,m = 13.61\,Nm. \quad (12)$$

Where: H_s=was the center distance between the pulley and the nearest bearing (B) which was 70 mm.

According to Khurmi and Gupta (2005) torsional moment (T_r) due to belt tensions was determined using the following equation.

$$T_r = (T_1 - T_2)\frac{D_2}{2} \quad (13)$$

Where: T_1 = tension on tight side of a belt (N), T_2 = tension on slack side of a belt (N), D_2 = is the diameter of driven pulley (mm).

The total bending moment was determined by using equation (14).

$$M = \sqrt{M_a^{\ 2} + M_b^{\ 2}} \quad (14)$$

Assuming the axial load that may cause buckling on the screw shaft to be negligible; hence, bending moment due to axial load was take as zero. Therefore, the total bending moment was equal to 13.61 N-m.

Where: M_a = bending moment due to axial load, Nm; M_b = bending moment due to belt tension, Nm

2.5. Determination of Screw Shaft Diameter

According to American Society of Mechanical Engineers (ASME) code (ASME, 1995) for the design of solid transmission shafts. The maximum permissible shear stress may be taken as 56 MPa for shafts without allowance for key ways and 42 MPa for shafts with allowance for keyways. According to maximum shear stress theory, equivalent twisting moment (T_e) and that of a mixer shaft diameter (*d*) was determined as follow:

$$T_e = \sqrt{(M_b K_b)^2 + (T_t K_t)^2} \quad (15)$$

The equation below was also used to calculate the twisting moment (T_f) on a screw shaft,

$$T_f = \frac{\pi \tau d^3}{16 \times fs} \Rightarrow \tau = \frac{16 T_f \times fs}{\pi d^3} \quad (16)$$

Where: T_e = equivalent twisting moment, Nm; M = maximum bending moment, Nm; T_f = twisting moment, Nm; τ= maximum allowable shear stress, 42 MPa; *fs* = factor of safety for agricultural machinery; d = diameter of mixer shaft, m.

For rotating shafts, with load suddenly applied and minor shock, combined shock and fatigue factor were applied to bending and torsional moment as recommended; the values used were K_b = 2 and K_t= 1.5 (Khurmi and Gupta (2005).

2.6. Determination of Throughput of Screw Mixer

The volumetric capacity of the prototype poultry feed screw mixer was computed using the following equation (Balami *et al.* 2013):

$$Q = 60 N_2 \rho p \phi \left(D_{sf}^{\ 2} - d^2\right)\frac{\pi}{4} \times \frac{1}{1000} \quad (17)$$

Where: *Q* = capacity of screw mixer, t/h; ρ = bulk density of feed material, kg/m^3; N_2 = screw rotations, rpm; p = screw pitch, m; D_{sf} = pitch diameter of screw, m; d = diameter of shaft, m; π = a constant and ϕ = factor of filling introduced for vertical mixer = 0.30.

2.7. Power Requirement and Sources

The power requirement could be divided into two: - power to run the mixer while it was empty and the power to run the mixer when loaded. The power (P) required to operate the feed mixer was computed by using equation (18) as suggested by Shigley and Mischike, (2001).

$$P = T_t \omega = T_r \times \frac{2\pi N_1}{60} \quad (18)$$

Where: P = power required by the screw mixer, W; ω = angular momentum, rad/s; T = tensional moment, Nm; N_1 = speed of motor, rpm.

Table 1. Technical Characteristics of the Mixing Machine

No.	Technical characteristics	Determined and selected values
1	Volume of mixing chamber (theoretical)	0.205 m^3
2	Capacity of conveyor	2.69 t/hr

3	Power required to operate the mixer	2.28 kW, therefore an electric motor of 3 hp is selected
4	Diameter (D_2) of pulley for the mixing auger	D_2 = 255 mm
5	Belt speed	2.36 m/s
6	Belt length	L = 1594 mm
7	Diameter (d) of the mixer shaft	24 mm, therefore a 25 mm shaft diameter is selected

2.8. Description of Poultry Feed Mixer

A vertical poultry feed mixer was designed and constructed at Asella Agricultural Engineering Research Center (AAERC). The mixer consists of the essential component parts as shown in Figure 1. The mixing section has two cylindrical bodies (upper and lower) with different diameters that are connected together through a frustum. The upper cylinder has a diameter of 600 mm and its height is 500 mm. The lower cylinder has a height of 100 mm and a diameter of 150 mm. The height of the frustum, which connects the two cylinders, has 500 mm. Both cylinders and the frustum were constructed using a mild steel sheet metal of 1.5 mm thickness. An opening of 80 mm diameter was provided at the lower end of the frustum. This opening was connected to the discharge chute. The mixing chamber is provided with a centrally based, vertical acting auger conveyor that operates inside a close fitting tube of 150 mm diameter and 800 mm in length. The auger is formed with inside diameter of 25 mm that corresponded to the screw shaft made of mild steel rod with 25 mm diameter. The helix of the auger is made with a uniform diameter of 145 mm having pitch of 100 mm. All these machine components are connected to each other with bolt and nut.

The feed ingredients to be mixed were introduced into the mixing chamber via a trapezoidal hopper. The hopper was constructed with the following dimensions: major width 400 mm, minor width 200 mm, length 300 mm had a height of 100 mm. The hopper was made to stand at an inclined angle of 60^0 with respect to the mixing chamber when fixed in place. All the parts that make up the machine were mounted on a trapezoidal frame robustly built with detachable stands. An angle iron of 50 mm x 50 mm x 5 mm was used in the construction of the frame, for its rated strength and stability in service. The frame has the following dimensions: 1500 mm height, 1000 mm lower length, 800 mm lower width and 800 mm upper length and 700 mm upper width. The source of power was electric motor and connected to the auger shaft through v-belt and pulleys. The auger shaft is supported by two radial ball bearings hinged at the top and bottom part to simplify and facilitate efficient power transmission.

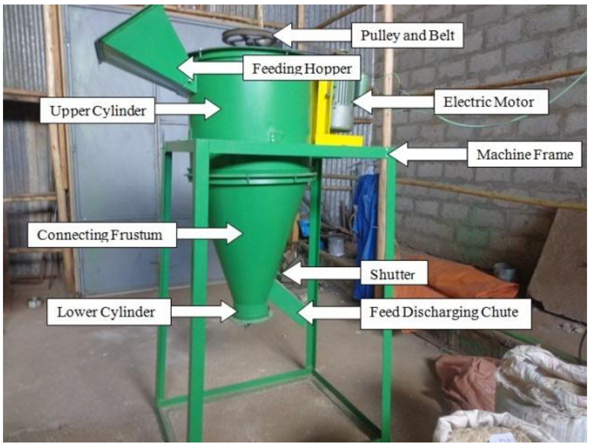


Figure 1. Major components of the prototype poultry feed mixer

2.9. Working Principle of the Machine

Feed ingredients were introduced into the mixer via a trapezoidal shaped hopper located at the upper part of the mixing compartment. Material introduction into the mixer was in order of quantity for cereals, with the bulkier material among the feed components being introduced into the machine first and finally loaded with premixes and tracers. The switch of the driving electric motor was set at "ON" position and mixing operation then started.With the material inside the mixing chamber, the rotating action of the centrally located vertical screw, lifted the material up from the lower part of the cylinder through the close fitting tube called auger casing and ejects the same at the upper end of the casing. After a thorough mixing was achieved, the discharge chute was opened to allow the flow of mixed feed material out of the mixer. Complete evacuation of the material was facilitated by the rotating action of the screw. At the end of evacuation operation, then the motor switch is put off.

2.10. Mixer Performance Evaluation

The poultry feed mixer designed and manufactured was loaded with all the feed ingredients` prepared on the basis of recommended values. The tracer material, NaCl, was added last and the mixing was started. For vertical poultry mixers, sampling was only possible during discharge; hence from each test run, 100 g sample was taken during the discharge of the mixed feed. The sodium chloride concentration was determined according to the method developed by FAO (1981).

$$NaCl_{cons} = \frac{Titre \times factor \times 0.1}{weight\ of\ sample} \times 100\% \quad (19)$$

Where: Titre value = volume of the Titre used; factor = 0. 0058; 0.1 = concentration of $AgNO_3$

The performance of the prototype feed mixer assessed on the basis of salt concentration as analyzed in the laboratory and its mean concentration, variation between samples (standard deviation) and coefficient of variation (CV) using equations 20 – 22 as recommended by Herrman and Behnke (1994).Mixers with salt concentration CV values of 10% and below were considered to be the best.

$$CV\% = \frac{SD}{\bar{y}} \times 100 \quad (20)$$

$$\bar{y} = \frac{\sum y_i}{n} \quad (21)$$

$$SD = \sqrt{\sum \left(y_i - \bar{y}\right)^2 / (n-1)} \quad (22)$$

Where: CV % = percent coefficient of variation; SD = standard deviation = mean

$\sum$ = sum; y_i= individual sample analysis results; n = total number of samples.

3. RESULT AND DISCUSION

The necessary design parameters needed for the development of a vertical poultry feed mixer were considered in depth. Proper design analysis was carried out on the machine to avoid failure on both auger blades and auger shaft. A prototype poultry feed mixer was manufactured using local materials, skill, experience and expertise. Tests were carried out at four mixing periods (holding time) and three mixing speeds (auger shaft speeds, rpm) and replicated thrice each to evaluate the mixing performance of the prototype feed mixer based on salt concentration of mixed feed as measured by mean value of concentration, standard deviation and coefficient of variability. Results obtained and discussions on the same are presented in the following sections.

3.1. Effect of Mixing Duration and Screw Shaft Rotation on Feed Uniformity

Table 1 gives the mean concentration of salt (sodium chloride, NaCl), coefficient of variation and degree of mixing of feed ration mixed using the prototype poultry feed mixer developed at the auger shaft speed of 100, 150 and 250 rpm and various levels of holding/mixing time.

Table 2. Prototype poultry feed mixer performance at auger shaft of 100, 150,250 rpm and mixing time of 10, 15, 20 and 25 minutes.

Mixing duration (min)	Shaft Speed (rpm)	Mean NaCl Concentration (%)	Mean Standard Deviation (SD)	Mean CV %	Degree of mixing (%)
10	100	0.25	0.0499	19.96	80.04
15	100	0.24	0.0368	15.33	84.67
20	100	0.24	0.0311	12.96	87.04
25	100	0.24	0.0271	11.31	88.69
Mean	-	***0.243***	***0.0362***	***14.89***	***85.11***
10	150	0.24	0.0430	17.93	82.07
15	150	0.24	0.0367	15.29	84.71

20	150	0.25	0.0215	8.61	91.39
25	150	0.24	0.0253	10.54	89.46
Mean	-	***0.243***	***0.0316***	***13.09***	***86.91***
10	250	0.23	0.0402	17.48	82.52
15	250	0.23	0.0334	14.53	85.47
20	250	0.25	0.0326	13.02	86.98
25	250	0.24	0.0308	12.80	87.20
Mean	-	***0.238***	***0.0343***	***14.46***	***85.54***

The mean percent concentration of NaCl, and percent coefficient of variation (% CV) and degree of mixing (% DM) of the prototype machine at mixing auger speed of 100 rpm and holding/mixing time of 10, 15, 20, and 25 minutes were found to be 0.250, 19.96 and 80.04; 0.240, 15.33 and 84.67; 0.240, 12.96 and 87.04; and 0.240, 11.31, and 88.69 respectively. Though the salt concentration over the test periods (10, 15, 20, and 25 minutes) remained almost identical and the degree of mixing increased with increasing holding/mixing time in minutes, the coefficient of variations were well above 10%, which is considered to be the turning point; values above that indicate inadequate level of mixing, i.e. none uniformity in mixing feeds. Mixing poultry feed, using the prototype mixer, at auger shaft speed of 100 rpm for duration of 25 minutes gave a mean percent coefficient of variation of (% CV) 11.31, which is close to optimum level.

The mean percent concentration of NaCl, CV and DM of the prototype machine at mixing auger speed 150 rpm and holding/mixing time of 10, 15, 20, and 25 minutes were found to be 0.24, 17.93 and 82.07; 0.24, 15.29, and 84.71; 0.250, 8.61 and 91.39; and 0.250, 10.54 and 89.46 respectively. From Table 2, it can be seen that, at the mixing auger shaft speed of 150 rpm, holding/mixing time of 20 and 25 minutes resulted in % CV of 8.61 % and 10.54 %, respectively. The two values of coefficient variations obtained at holding/mixing times 20 and 25 minutes were within upper boundary of rating as indicated by Herrman and Behnke (1994) (values of % CV < 10, 10 – 15, 15 -20 and > 20 are rated excellent, good, fair and poor, respectively in terms of uniformity/thoroughness of mixing). Hence, the mixing uniformity was superior at the combination of 150 rpm and 20 minutes of mixing time.

Table 2 gives values of the performance indicators of the prototype poultry mixer when operated at a constant mixer auger shaft speed, 250 rpm and different holding/mixing time (10, 15, 20, and 20 minutes). The mean percent CV and mean percent DM of the prototype machine at mixing auger speed 250 rpm and holding/mixing time of 10, 15, 20, and 25 minutes were found to be 17.48 and 82.52; 14.53 and 85.47; 13.02 and 86.98; and 12.80 and 87.20 respectively.

Table 2 clearly indicate that the % CV and % DM decreased and increased, respectively, as the speed of mixer shaft speed and holding/mixing time increased. Nonetheless, the optimum level of mixing with % CV of 8.61 and % DM of 91.39 were observed at the mixer auger shaft of 150 rpm and holding/mixing time of 20 minutes. Hence, it can be concluded that the machine, the prototype poultry feed mixer, should be operated at speed of 150 rpm with maximum holding/mixing time of 20 minutes in order to make the owning and operating of the machine productive (in terms of kg/hr) and economical (in terms of labour and energy cost birr/kg of mixed quality feed (Crenshaw, 2000).

From Table 2 it can be noted that the least % CV was obtained at mixing auger speed of 150 rpm at mixing time of 20 minutes duration, and the of CV was below 10 % indicating excellent mixing. The % CV of speeds below and above 150 rpm was higher though the mixing time was increased up to 25 minutes. The findings of Gbadamosi and Magaji (2005) indicated similar trend. This is due to the very fact that at low mixing auger shaft speeds (rpm) the magnitudes of both axial (lifting accelerations) and radial (centripetal accelerations) acceleration of the feed ingredients were so small that all materials might tended to move as a unit. On the other hand, at high mixing auger shaft speeds (rpm) the magnitudes of both axial (lifting accelerations) and radial (centripetal accelerations) acceleration of the feed ingredients were so high that segregation of individual feed ingredient became inevitable; hence increase percent of coefficient of variation is consequence.

Results of the analysis of variance (ANOVA) revealed that the mixing auger shaft speed and the interaction of the same with mixing/holding time had high significant effect ($p < 0.05$) on percent coefficient of variation, percent degree of mixing and percent concentration of NaCl.

4. CONCLUSION AND RECOMMENDATION

4.1. Conclusion

The poultry feed mixer was successfully designed, constructed and evaluated. The results clearly indicate that the percent coefficient of variations and percent degree of mixing decreased and increased, respectively, as the speed of mixer shaft speed and holding/mixing time increased. Nonetheless, the optimum level of mixing with percent coefficient variation of 8.61 and percent degree of mixing of 91.39 were observed at the mixer speed of 150 rpm and holding/mixing time of 20 minutes. Hence, it can be concluded that the machine, the prototype poultry feed mixer, should be operated at speed of 150 rpm with maximum holding/mixing time of 20 minutes. Increase in holding/mixing time beyond the time indicated above will require the farmers to spend extra money on electrical power and labor costs during feed mixing. The results of this study clearly indicated that the mixing machine designed and locally manufactured using the skill, knowhow and expertise of technicians at AAERC from available materials was effective, efficient, simple, cheap and easy to maintain.

4.2. Recommendations

Based on the experimental results, the following recommendations are made.

- The machine is recommended for use by small and medium poultry raisers;
- This mixer must be operated at mixing auger speed of 150 rpm for a period of 20 minutes per batch of mixing.

5. REFERENCES

Alemu Yami and Tadelle Dessie, 1997. The status of poultry research and development. Research Bulletin No 4. Poultry Commodity program, Debre Zeit Agricultural Research Center, Alemaya University of Agriculture.

ASME, 1995. Design of Transmission Shaft. American Society of Mechanical Engineering, New York, USA.

Augusto A. A, M. G. Cuca and J. A. Pino, 1973. Poultry nutrition in Latin America with special reference to scientific poultry raising. Proc. International Symposium on Animal Production in the Tropics. University of Ibadan, Nigeria. 26-29 March 1973. pp 219-225.

Balami, A. A., D. Adgidzi and A. Mua'zu, 2013. Development and testing of an animal feed mixing machine. International Journal of Basic and Applied Science, Jan 2013, 1(3): 491-503.

Brennan, J. G., J. R. Butters, N. D. Cowell and A. E. V. Lilley, 1998. Food engineering operations, 3rd ed. Elsevier Applied Science, London, 91-107 and 287-89.

Crenshaw, M., 2000. Particle size in swine diet: Factors for consideration. Information Sheet 1633. Extension Service of Mississippi State University.

Diarra, S. S, I. D. Kwari and H. D. Kwari, 2001. Effect of substituting wheat bran with millet bran on nutrients digestibility and intestinal morphology of broiler chickens. Proc. 6th Annual Animal Science Association of Nigeria, 17 – 19 Sept., 2001. pp.64.

Fagbenro, O. A., 1988. Evaluation of cotton seed cake as fish feed and pond fertilizer in the production of non-chichlid fishes. Journal of Applied Fisheries and Hydrobiology 3:9 - 14.

Gbadamosi, L. and S. A. Magaji, 2005. Development and performance evaluation of a poultry feed mixer. Journal of Agricultural Engineering and Technology (JAET) 13:42-47.

Gomez, K. A. and A. A. Gomez, 1984. Statistical Procedures for Agricultural Research.2[ed]. John Willey & Sons, Inc. New York, USA.

Hailemariam Teklewold, Legesse Dadi, Alemu Yami and Negusse Dana, 2006. Adopting poultry breeds in the highlands of Ethiopia. Ethiopian Institute of Agricultural Research. Pp. 26.

Herman, T. and K. Behnke, 1994. Testing Mixer Performance.MF-1172. Kansas State University Agricultural Experiment Station and Cooperative Extension Service Bulletin.Kansas State University, Manhattan, KS.

Khurmi, R. S. and J. K. Gupta, 2005. A Textbook of Machine Design, 14[th] ed. S. Chand and Company Limited, New Delhi.

Kwari, I. D. and J. U. Igwebuike, 2001. Performance of broiler chickens fed with graded levels of African locust bean (Parkiabiglobosa) pulp. Proc. 6th Annual Animal Science Association of Nigeria, Sept. 17-19, 2001. pp. 67.

New, M. B., 1987. Feed and feeding of fish and shrimp, ADCP/REP/87/26, FAO/UNDP, Rome.

Oluyemi, J. A. and F. A. Robert, 1978. Poultry Production in Warm Wet Climates, Macmillan Press Publishers, Hong Kong, 133-137.

Shigley, J. E. and C. R. Mischike, 2001. Mechanical engineering design, 6[th] ed. McGraw-Hill Publication, New York.

Sitkei, G., 1986. Mechanics of Agricultural Materials. Elsevier Publishing Co. Inc. New York.