Digital Innovations & Contemporary Research in SCIENCE, ENGINEERING & TECHNOLOGY
Vol. 11. No. 1, 2023

**Article Citation Format**
Fatukasi S. O., Ajayeoba A.O., Oladosu K.O.,4Ajayeoba A. S. & Orowole I. A. (2023):
Design and Construction of Vertical Livestock Feed Mixer
.. Journal of Digital Innovations & Contemporary Research in Science, Engineering & Technology.
Vol. 11, No. 1. Pp 39-50
DOI: dx.doi.org/10.22624/AIMS/DIGITAL/V11N1P3

**Article Progress Time Stamps**

Article Type: Research Article
Manuscript Received:27th January, 2023
Review Type: Blind Peer
Final Acceptance: 15th March, 2023

# Design and Construction of Vertical Livestock Feed Mixer

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## ABSTRACT

The development of a feed mixer plays a vital role in optimizing the feed production process in various agricultural and livestock industries. Thus, for better nutrition, improved feed efficiency, cost, and waste reduction, locally designed and fabricated feed mixers using locally available materials are essential and highly required. The volume of the mixing chamber, shaft diameter, belt selection, pulley diameter, and required power to drive the shaft were well designed for. The developed feed mixer comprises the mixing chamber, hopper, auger, bearings, electric motor, and pulley, which are major components of the machine. Angle Iron bars and 2mm sheet metal made of mild steel were used in the fabrication of the frame and the mixing chamber, respectively. The degree of mixing of the sample that was collected at the end of each test and the coefficient of variation percentage were used to evaluate the effectiveness of the machine mixing operation. At a mixing shaft speed of 560 rpm and a mixing time of 4.5 minutes, the optimum values of coefficient of variation (12.01%) and degree of mixing (88.21%) were achieved. However, the fabricated feed mixing machine was evaluated to be 92% efficient.

**Keywords:** Design, Construction of Vertical Livestock Feed Mixer

## 1. INTRODUCTION

One of the necessities for animals, including hogs, is food. Thus, there is a connection between food and equipment in terms of food production, preparation, and other operations. Small-scale farmers who raised hogs, calves, and chickens in the past, mixed the crushed feed by hand or manually. According to Adenigba and Olalusi, (2021), the manual method of mixing feed ingredients is typically characterized by poor output, reduced efficiency, labour-intensive, and potentially unsafe conditions that endanger the health of the target animals, birds, or fish for which the feed is being made. The mechanical way of mixing is accomplished by utilizing mechanical mixers that have been developed over time to mitigate the drawbacks and tedium associated with the manual method (Ishola, et, al. 2021).

The mixing operation, in particular, as explained by Jongho et al., (2023), is essential because it allows two or more feed ingredients to be distributed evenly throughout one another to create a homogeneous mixture that can meet the nutritional requirements of the target livestock, poultry, or aquatic life being raised. Therefore, machinery is required to mix ingredients to produce healthy animal feed most especially for medium-scale production **(**Makange, et, al, 2016). A machine is a physical structure made up of moving elements and a frame that makes a task easier, faster, and more effective.
An effective mixing procedure yields a uniform feed in the shortest amount of time and for the lowest possible cost of overhead, electricity, and labour.

Although some variance between samples is to be expected, the ideal mix would have little compositional variation (Balami, et, al. 2013). There is typically the best mix time, which must be established by experimentation. Because the standard deviation of a key component is used to determine mixing, the experiment is laborious. This necessitates repeatedly collecting samples from different areas of the mixer **(**Gosa, and Tamrat, 2019). Gosa, (2020) documented 10 minutes as the optimum mixing time for attaining the best value of the coefficient of variation and mixing degree at 13.09% and 86.91% respectively when the author designed and tested the performance of a livestock feed mixer machine. However, 6 and 8 minutes were fixed by Adedeji et al. (2021) as the maximum mixing time when the authors tested the performance of their fabricated vertical motorized feed mixer.

Reporting the low cost of maintenance of vertical feed mixers, Adusei-Bonsu et al. (2021), range the mixing time, mixing speed and coefficient of variation percentage between 15-30 minutes, 250-500 rpm and 30-1.8 % respectively. The average rate of discharge was the focus of Olaniyan and Odewole, (2013) when the author designed, constructed and tested a livestock feed Mixer with a spring-controlled packaging unit. An average discharge rate of $0.356\ Kg/s$ with a mixing capacity of $4.124\ m^3/h$ was exhibited by their developed mixer.Although a certain number of studies have been dedicated to the design and fabrication of livestock feed mixer machines, particularly vertical type, however, its availability to rural area farmers is still a challenge majorly because of the high purchasing price. Hence, this paper seeks to design and fabricate a cost-effective vertical livestock feed mixer with a higher degree of mixing operation attainable at a low mixing time for low-income rural farmers in particular. The design entails the use of local raw materials for the construction.

## 2. METHODOLOGY

Materials were acquired locally and selected based on their physical and mechanical characteristics, such as density, strength, ductility, elasticity, durability, and availability, taking into consideration economic and environmental factors as well as the machine's accessibility to the end users. The main body comprises the following: upper cylinder, frustum (of a cone) both end open, lower cylinder, angle iron, hopper, screw conveyor (auger), conveyor shaft, electric motor, and pulley.

### Upper and lower cylinder

Made from 2mm sheet metal, were cut, rolled, and welded in a cylindrical shape with a standing frame.
The cylinder volume of the upper cylinder ($V_u$) and the lower cylinder ($V_l$) were estimated with Equation 1

$$V = \pi r^2 h \qquad 1$$

$$V_u = 1026.4\, m^3$$

$$V_l = 54.5\, \mathrm{m}^3$$

where r and h are the radius and height of the cylinder, respectively.

**The frustum of the mixer**

The frustum is constructed from sheet metal of 2mm. The diameters of the upper and lower ends are 1100 mm and 170 mm, respectively, while the height is 800. mm. The volume of the frustum was then calculated using Equation 2

$$V_f = 0.2618h\,(D^2 + (D\ x\ d) + d^2) \quad 2$$
$$V_f = 298.6m^3$$

**The volume of the mixing chamber**

The mixing chamber of the developed machine comprises of upper cylinder welded with an upper frustum connected with a lower cylinder which was also welded with a lower frustum.
If $V_u, V_l, and\ F_r$ represents the volume for the upper cylinder, lower cylinder, and frustum respectively, then the total volume for the mixing chamber $V_c$ was estimated by Equation 3

$$V_c = V_u + V_l + F_r \quad 3$$
$$= 1026.4 + 298.6 + 54.5 = 1379.5\text{m}^3$$

**Shaft diameter**

For effective transmission of power, a $30\ mm$ shaft diameter was designed for this machine using Equation 4

$$d^3 = \frac{16}{\pi S_3}\sqrt{(K_b M_b)^2 + (K_t\,M_t)^2} \quad 4$$

Where,

$d = Shaft\ diameter, mm$
$Ss = Maximum\ allowable\ shearing\ stress, N/M2$
$K_b = Combined\ shock\ and\ fatique\ factor\ applied\ to\ bending\ moment$
$M_b = Bending\ moment, Nm$
$K_t = Combined\ shock\ and\ fatigue\ factor\ applied\ to\ torsional\ moment$
$M_t = Torsional\ moment, Nm$

Recommended values of the combined shock and fatigue factors for load gradually applied are:

$$K_{sh} = 1.5; \qquad K_t = 1.0$$

Recommended allowable stress for shaft with keyway is:

Ss = $1.4x10^{-3}$N/m$^2$

Estimated parameters are: $M_b$ = 2.00Nm; Mt = 6.55Nm

Hence, on substitution into the Equation above:

$$d^3 = \frac{16}{\pi\ x\ 1.4\ x\ 10^{-3}}\ x\ \sqrt{((1.5\ x\ 2.0)^2 + (1.0\ x\ 6.55)^2)}$$
$$d = 30\ mm$$

**Torque on the shaft**

The torque $(T_S)$ on the shaft is determined with Equation 4 as stated below.

$$T_S = r \times \frac{J}{\tau} \qquad 5$$

And

$$J = \left(\frac{\pi}{2}\right) r^4 \qquad 6$$

Where $r, J$ $and$ $\tau$ represent the lever arm or the radius of the shaft, polar moment of inertial and shear stress, respectively.

**Belt drive selection**

In this work, a V-belt and pulley setup was used to transfer power from the motor to the vertical feed mixing shaft. The versatility, simplicity, and cheap maintenance costs of the V-belt drive are the primary justifications for its adoption. Additionally, the v-belt can absorb shocks, which lessens the impact of vibratory forces.

**Length of the belt**

For an effective and efficient driving system, the estimated 1590 mm length of the belt in this study is determined as given by Shigley and Mischike (2001) in Equation 7

$$l_b = 2C + \frac{\pi}{2}\left(d_2 + d_1\right) + \frac{(d_2+d_1)^2}{4C} \qquad 7$$

$l_b, d_2, d_1$ and $C$ respectively represent the length of the belt, the pitch diameter of the driven pulley, the pitch diameter of the driver pulley and the canter distance between pulleys.

**The speed of the belt**

For appropriate conveyor system starting and stopping times as well as power consumption rate, the speed of the belt adopted for the developed mixer machine in this work is calculated based on Equation 8 as expressed by Gosa, 2020.

$$V = \frac{\pi d_1 N_1}{60} \qquad 8$$

$V$ and $N_1$ represent the speed of the belt and the speed of the driving pulley, respectively.

**Selection of pulley diameter**

The selected pulley diameter for this work is calculated based on Equation 9 according to Gosa,2020.

$$d_1 = \frac{d_2 \times N_2}{N_1} \qquad 9$$

Note: $N_2$ is the speed of the driven pulley.

**Required power to drive the shaft**

With 30mm and 60 mm shaft diameter, and length respectively, the required power to drive the shaft also known as the power to drive an empty conveyor is calculated with Equation 10 as expressed by Culpin, (1981).

$$P = T\omega \qquad 10$$

Where $T = \frac{G\theta J}{L}$ 11

$T, \omega, G, \theta, and\ L$ represent torque, angular velocity, angle of twist and Length of shaft respectively.

**Maximum transmissible power**
Calculated as $3727.38\ W$, the maximum transmissible power of the shaft is estimated according to

Equation 12 as described by Shigley and Mischke (2001).

$$P_m = \frac{2\pi V T_s}{60} \qquad 12$$

Where $P_m$ signified maximum transmissible power

## 3. PERFORMANCE TEST

Fifty kilogrammes (50 kg) of broiler and pig feed meal ingredients were fed differently into the machine mixing chamber through the hopper to evaluate the machine mixing operation performance. Adopting the test procedure of Gosa, (2020), this study considered machine mixing operation at the different time intervals of 1.5, 3, 4.5 and 6 minutes with two shaft speeds of 410 and 560 rpm. The feed meal ingredients and their respective quantity in kg are shown in Table 1.

**Table. 1. The feed meal ingredients**

| Broiler | | | Pig | |
|---|---|---|---|---|
| S/N | Feed components | Quantity (kg) | Feed components | Quantity (kg) |
| 1 | Maize | 10 | Maize | 1 |
| 2 | Soya meal | 1 | Soya meal | 2 |
| 3 | Groundnut cake | 2 | Wheat offal | 5 |
| 4 | Wheat offal | 13 | Corn bran | 4 |
| 5 | Corn bran | 7 | Palm kernel cake | 19 |
| 6 | Palm kernel cake | 5 | Bone meal | 1.85 |
| 7 | Fish meal | 2 | salt | 0.3 |
| 8 | Bone meal | 1.5 | Blood meal | 1.85 |
| 9 | Oyster shell | 0.5 | Brewery waste | 14.85 |
| 10 | Vitamin and Minerals | 0.135 | Vitamin and minerals | 0.15 |
| 11 | Methionine | 0.065 | | |
| 12 | Lysine | 0.065 | | |
| 13 | Salt | 0.135 | | |
| 14 | Blood meal | 2 | | |
| 15 | Brewery waste | 3 | | |
| 16 | Rice bran | 3.5 | | |
| Total | | 50 | | 50 |

**Table 2. Vertical livestock feeds mixer performance at 410 rpm shaft speed with mixing duration of 1.5, 3, 4.5 and 6 minutes.**

| Mixing operation time (minutes) | Mean weight of ungrounded ingredients (kg) | | Mean Coefficient of Variation (%) | Degree of Mixing (%) |
|---|---|---|---|---|
| | Broilers | pig | | |
| 1.5 | 0.0195 | 0.0191 | 39.05 | 69.25 |
| 3 | 0.0204 | 0.0201 | 23.85 | 80.32 |
| 4.5 | 0.0184 | 0.0180 | 21.32 | 83.61 |
| 6 | 0.0219 | 0.0221 | 16.51 | 86.05 |

Table 3. Vertical livestock feeds mixer performance at 560 rpm shaft speed with mixing duration of 1.5, 3, 4.5 and 6 minutes.

| Mixing operation time (minutes) | Mean weight of ungrounded ingredients (kg) | | Mean Coefficient of Variation (%) | Degree of Mixing (%) |
|---|---|---|---|---|
| | Broilers | pig | | |
| 1.5 | 0.0125 | 0.0122 | 45.52 | 66.04 |
| 3 | 0.0116 | 0.0112 | 32.31 | 69.07 |
| 4.5 | 0.0119 | 0.0114 | 12.01 | 88.21 |
| 6 | 0.0148 | 0.0143 | 30.22 | 61.13 |

**The efficiency of the Machine**

The efficiency of the machine was then calculated using Equation 13

$$Efficiency = \frac{Volume\ of\ Output\ Power}{Volume\ of\ Input\ Power} \qquad 13$$

## 4. RESULTS AND DISCUSSION

The composition of mixing feed meal ingredients after the mixing operation with adequate mixing products is achieved as shown in Figures. 1 and 2. However, it was found that efficient feed meal ingredients mixing operation is a function of shaft speed and time spent for mixing operation in the mixing chamber as shown in Tables 2 and 3. The insignificant disparities in the mean weight of ungrounded ingredients between broiler and pig feed meal signified the machine's capacity to effectively mix any type of livestock feed meal ingredients.

With a shaft speed of 410 rpm, Table 2 shows that the average weights of unground feed meal ingredients recovered from the replicates are respectively 0.0195 kg, 0.0204 kg, 0.0184 kg, and 0.0219 kg, for broiler as well as 0.0191Kg, 0.0201 Kg, 0.0180 Kg and 0.0214 Kg for the pig with corresponding Coefficients of Variation (CV) of 39.05%, 23.85%, 21.32%, and 16.51% for mixing times of 1.5, 3, 4.5 and 6 minutes, respectively. A similar scenario was documented in Table 3 with a shaft speed of 560 rpm as the lowest CV at 4.5 mins of mixing operation time. Except for the mixing time of 4.5 mins in Table 3, all the CVs were found to decrease with mixing time as the mixing degree rises with time (Tables 2 and 3).

Meanwhile, according to Adedeji et al. (2021), the percentage coefficient of variations values of < 10, 10 - 15, 15 -20, and >20 were rated excellent, good, fair, and poor, respectively, in terms of uniformity/thoroughness of mixing. The value of coefficient variations obtained at mixing times of 4.5 minutes is within the upper boundary of the rating. As a result, the mixing uniformity was found better at 560 rpm and 4.5 minutes of mixing operation time (Table 3). However, the developed livestock mixer machine operated with an estimated 92% value of efficiency.

## 5. CONCLUSION

The design, development, and testing of the vertical livestock feed mixing machine were successful. In 4.5 minutes of operation, a mixing degree of up to 88.21% was attained with insignificant noise and vibration levels. 12.01% on average was found for the replicates' coefficient of variation. The most important conclusion of the study's results is that the mixing machine developed with locally available material is efficient, simple, and easy to maintain. It is then recommended that the mixing machine should be operated at a shaft speed of 560 rpm within the mixing duration of 4.5 minutes.

**Fig. 5. Composition of Broiler Feeds after Proper Mixing**

**Fig. 6. Composition of pig Feed after Proper Mixing**

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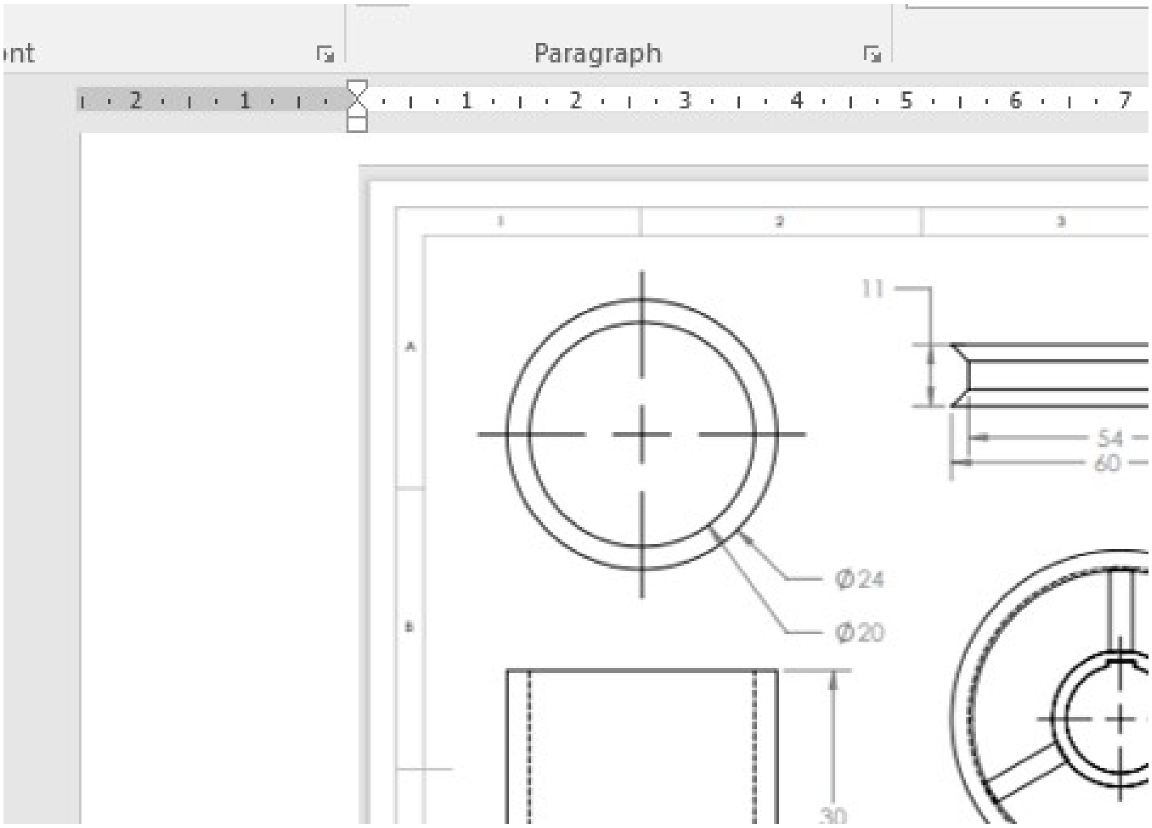
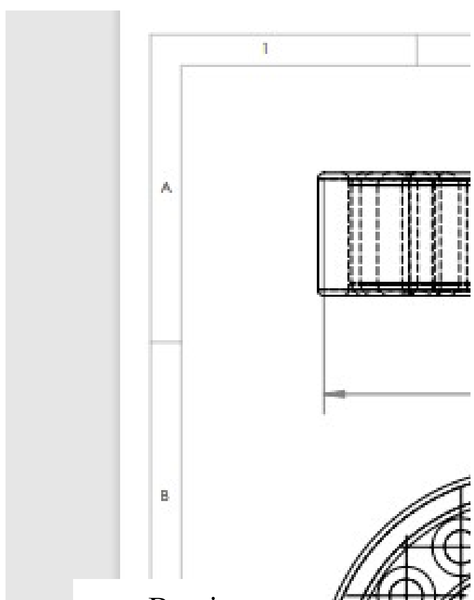
**APPENDICES**



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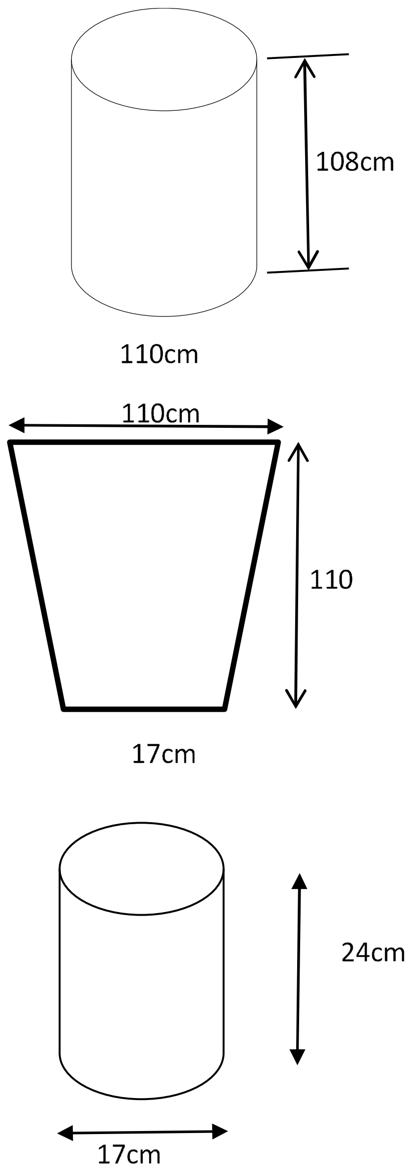
Vol. 11. No. 1, 2023

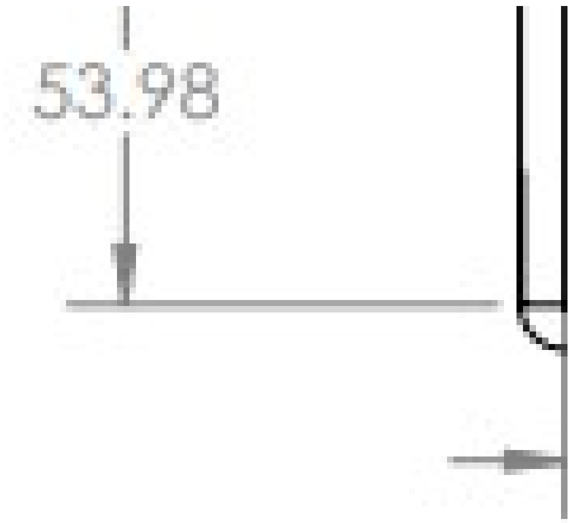




Upper Cylinder

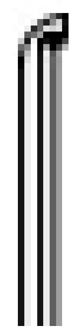
Frustum

Lower Cylinder

Vertical Conveyors (Auger)




Electric Motor



Locally Fabricated Feed Mixer