

Design and Development of a Livestock Feed Mixer with Spring-Controlled Packaging Unit

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[Date received: 19 January 2012. Date accepted: 15 March 2013]

Keywords: Conveyor, Design, Discharge rate, Feed mixer, Spring-controlled packaging unit

Abstract. A vertical livestock feed mixer with spring-controlled packaging unit was designed, constructed and tested. This design had in focus a weighing and gauging mechanism which made possible a semi-automatic packaging in conjunction with feed mixing and discharge operations. The main components of the machine included a double-wall cylindrical mixing chamber consisting of recycling gate, discharge gate, evacuating gate, window and a screw conveyor inside an inner cylinder. The packaging mechanism is attached to the discharge gate and the base of the frame with the frame serving as the structural support for the machine and its contents. The main design parameters included screw conveyor features such as helix angle, fill ratio, normal pressure due to bulk load on screw shaft, axial force per pitch, total screw torque, capacity and power requirements of the screw conveyor. The design concept of the packaging mechanism involved determination of free length of spring, total active length, pitch of spring, spring index, stiffness of spring, maximum shear stress and total spring rate. In a hitch-free operation, the machine was designed to package 25 kg of mixed feed ingredients at a time. In operation, the feed ingredients are scooped and moved upward by the rotary movement of the screw conveyor and then sprayed back into the smaller cylinder without passing through the internal tube. A preliminary testing was carried out on the machine to determine the actual discharge rate and hence the performance of the packaging mechanism. Results revealed that an average discharge rate of 0.356 kg/s was obtained. Powered by a 2 hp single phase electric motor, the machine has a mixing capacity of 4.124 m³/h with a production cost of \$470.

Nomenclature

A	-	Area of cross section of vertical member of support	D _{sc}	-	Diameter of small cylinder
A _e	-	Helix angle of screw blade	d	-	Diameter of screw shaft
C	-	Centre - to - centre distance	d _w	-	Diameter of spring wire
C _f	-	Fixity coefficient	E	-	Modulus of elasticity
C _r	-	Radial clearance	E _q	-	Equivalent coefficient of friction
D	-	Screw diameter	F	-	Material factor
D ₁	-	Diameter of pulley on electric motor	F _{an}	-	Screw friction angle
D ₂	-	Diameter of pulley on screw shaft	F _{sa}	-	Factor of safety
			F _{sp}	-	Axial factor per screw pitch

h	-	Smaller dimension of rectangular cross section	R_i	-	Inner radius of screw
h_{bc}	-	Height of big cylinder	R_o	-	Outer radius of screw
h_{cs}	-	Height of conical section	T	-	Total torque on screw shaft
h_{sc}	-	Height of small cylinder	T_q	-	Time of discharge
k	-	Maximum radius of gyration	T_{sh}	-	Torque due to bulk movement of material relative to shaft
k_a	-	Constant that accounts for pressure distribution around the shaft	T_{sp}	-	Torque per screw pitch
L_b	-	Length of belt	V_{bc}	-	Volume of big cylinder
l_b	-	Length of horizontal member of support (beam)	V_{cs}	-	Volume of conical section
l_c	-	Length of vertical member of support (column)	V_m	-	Volume of material (feed) to be occupied by the machine
l_s	-	Length of anchor shaft	W	-	Axial load on spring (weight of feed)
N	-	Rotational speed	W_{cr}	-	Crippling of buckling load
N_1	-	Speed of electric motor	W_q	-	Weight of feed at discharge
N_2	-	Speed of screw shaft	W_{sa}	-	Safe load
P	-	Screw pitch	Z	-	Sectional modulus
P	-	Power of electric motor	σ_n	-	Normal pressure
P_r	-	Power required to drive the screw conveyor based on capacity	δ_o	-	Yield stress
P_{sc}	-	Power requirement of the screw conveyor due to torque on screw shaft	θ	-	Angle of inclination of screw conveyor
Q	-	Capacity of the screw conveyor	ρ	-	Bulk density of feed
Q_r	-	Discharge rate	η_d	-	Drive efficiency
R_e	-	Effective radius of screw	η_r	-	Filling ratio
			ϕ	-	Filling factor
			τ_{max}	-	Maximum shear stress induced on spring wire

Introduction

Mechanical mixing is one of the most important unit operations in livestock feed manufacturing. It is done after size reduction of different feed ingredients to aid palatability of feed, minimize waste

requirements of targeted livestock. A mechanical mixing process produces a uniform mixture in a minimum time with a minimum cost for overhead, power and labour; hence it is highly desirable for small and medium scale feed mills.

There are basically two types of mechanical feed mixers which are horizontal feed mixers and vertical feed mixers. Though, not so common, the horizontal feed mixers have the major advantage of being able to handle wet materials [1]. A typical horizontal feed mixer is made up of a horizontally laid metal drum containing screw augers or paddles which conveys materials from one end of the mixer to the other while it is being tumbled within the mixer. The device is equipped with openings at intervals along the bottom and, in some cases, blower to aid product discharge and evacuation. Powered by electric motors, most horizontal mixers complete the mixing cycle between 5–10 minutes [2]. On the other hand, a vertical feed mixer consists of a large diameter auger inside a tube in the centre of a cylindrical hopper which has conical bags. Driven by electric motors with operation speeds ranging between 250–400 rpm, typical vertical mixers can complete the mixing cycle within 15–25 minutes [1].

The current government agenda of food security, poverty reduction and economic development in the developing world is hinged on private sector-driven economic self reliance and employment creation. This can be better realized through sustainable micro, small and medium scale agro-industrial enterprises such as cottage livestock feed mills. Therefore, the objectives of this work were: to design a small scale livestock mill with a spring-controlled packaging unit; to fabricate the machine based on the design specifications using locally available construction materials and; to test the machine for performance after assembly. It is hoped that such a machine could be easily affordable by the micro, small and medium enterprises as found in Sub-Saharan Africa and other regions of the world in terms of local fabrication and maintainability.

Machine Description and Working Principles

The machine is made up of a big cylinder (cylindrical section) welded to an inverted frustum of a cone (conical section) with a small cylinder welded to the main body internally with short length of iron rods. Inside the small cylinder is an internal cylinder which houses the screw conveyor otherwise known as auger. There is a clearance between the internal cylinder and the small cylinder and between the upper parts of the big cylinder internally. A screw conveyor is placed at angle 90° at the centre of the machine and passing through the internal cylinder with radial clearance to allow its free movement during operation.

The small cylinder is with a hopper through which feed ingredients are fed into the machine. There is a recycling gate on one side of the conical section that is directly above the hopper while a discharge gate is at the other side. An evacuating gate is at one side of the small cylinder below the discharge gate and very close to the base of the small cylinder. A spring and gravity operated packaging mechanism is attached to the discharge gate and the base of the frame. The packaging mechanism allows the desired quantity of mixed feed aggregate per bag to be accurately measured. There is a rigid frame platform which carries the weight of the machine and provides structural support and stability for the machine.

In operation, the machine is actuated prior to feeding in the feed aggregates into it through the hopper. The feed aggregates are scooped as a result of the rotation of the screw conveyor and they are moved upward and sprayed back into the small cylinder without passing through the internal cylinder. As the feed aggregates are gradually fed into the machine, a time is reached when the quantity fed in would be greater than the capacity of the small cylinder. At this time, the feed aggregates are taken up along the internal cylinder with the aid of the screw conveyor to the upper

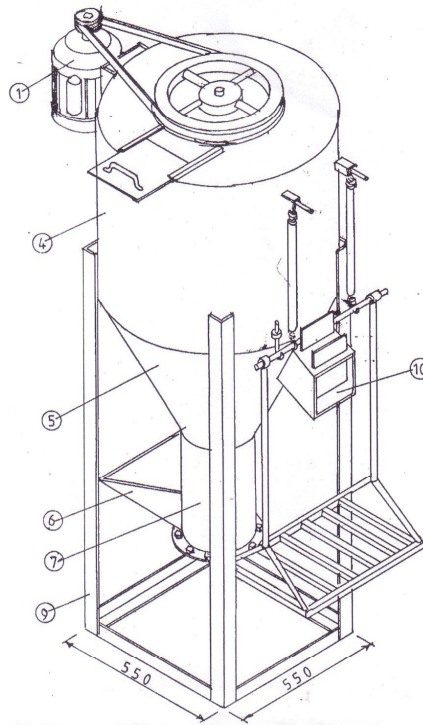


Figure 1 Isometric view of the livestock feed mixer with the packaging unit: 1-Electric motor, 4-Big cylinder, 5- Conical section, 6- Hopper, 7- Small cylinder, 9- Structural frame, 10- Discharge gate

A field movement is generated within the machine and the feed aggregates fall back under gravity into the available space. The recycling gate is then opened to allow improperly mixed feed aggregates to return into the mixing chamber via the mixing hopper. The actual mixing process is achieved by a combination of the scooping, spraying and recycling processes which also makes the mixed feed to form a homogeneous end product. After feeding enough feed aggregates, the machine is left in operation for about 20 minutes with the recycling gate opened and the process of scooping, spraying and recycling continues; after this, packaging of the homogeneously mixed feed follows.

In the packaging unit, the mechanism is such that the first cover is opened while the springs control the closing and opening of the second cover. As the mixed feed comes out of the mixing chamber into the packaging material, the cover closes gradually. When the quantity of feed in the packaging material reaches 25 kg, the second cover closes completely and the process of feeding, scooping, spraying and recycling continue again. Powered by a 2 hp single phase electric motor, the machine has a mixing capacity of 2061.94 kg/h and a packaging capacity of 1271.62 kg/h with an overall efficiency of 61.67 %. The isometric view of the livestock feed mixer is shown in Figure 1.

Design

packaging unit to accommodate the required quantity of feed aggregates and mixed feed respectively and both units to ensure maximum mixing and packaging efficiency. Also considered was a strong main frame to ensure structural stability and strong support for the machine.

Design of the Screw Conveyor: According to Zhi and Jiang [3] screw conveyors are widely applied in food processing, fodder mixing, ceramic forming, oil extraction, construction and mining industries. The major functional part of the screw conveyor is the screw blade and they are of three types based on configuration and application: equal-radius with cylindrical axis, equal-radius with conic axis, and decreasing-radius with cylindrical axis [3]. In this study, the design was based on equal-radius with cylindrical axis type

(i) Design of Screw Conveyor Helix Angle: The helix angle of the screw conveyor was determined from the equations given by Roberts [4] and stated below as:

$$A_e = \tan^{-1} \left\{ \left(\frac{P}{\pi D} \right) \left(\frac{R_o}{R_e} \right) \right\} \quad (1)$$

and

$$R_e = \frac{2}{3} \left\{ \frac{(R_o^3 - R_i^3)}{(R_o^2 - R_i^2)} \right\} \quad (2)$$

where, A_e is helix angle, R_o is outer radius of screw, R_i is inner radius of screw, R_e is effective radius of screw, C_r is radial clearance, D is screw diameter, D_{sc} is diameter of small cylinder and P is screw pitch. Given that $D = D_{sc} - C_r$ and substituting $C_r = 30$ mm, $D_{sc} = 150$ mm, $R_i = 10$ mm, $R_o = 60$ mm and $P = 100$ mm; hence, $R_e = 40$ mm and $A_e = 21.69^\circ$. For precise measurement during fabrication, $A_e = 25^\circ$ was used for this design.

(ii) Design for Normal Pressure on Screw Shaft: The normal pressure on screw shaft due to bulk solid materials was calculated as [4]:

$$\sigma_n = k_a \rho g P \eta_r \quad (3)$$

where, σ_n is normal pressure, ρ is density of material, P is screw pitch, g is gravitational acceleration, η_r is filling ratio and k_a is a constant that accounts for pressure distribution around the shaft [4]. Given that $k_a = 0.4$, $\rho = 500$ kg/m³, $g = 9.81$ m/s², $P = 100$ mm and $\eta_r = 0.25$; hence, $\sigma_n = 49.050$ N/m².

(iii) Axial Force per Screw Pitch: The axial force per screw pitch was determined using the equation below [4]:

$$F_{sp} = \pi(R_o - R_i) \times \rho g P \eta_r (\sin \theta + E_q \cos \theta) \quad (4)$$

where, F_{sp} is the axial force per screw pitch, θ is angle of inclination of screw conveyor and E_q is equivalent coefficient of friction between the bulk material and the screw and casing surfaces during motion. With $\pi = 3.142$, $\theta = 90^\circ$ (vertical screw conveyor) and $E_q = 0.99$; hence, $F_{sp} = 19.265$ N.

(iv) Torque per Screw Pitch: The torque per screw pitch was determined using the equation [4] below as:

$$T_{sp} = \frac{2}{3} \times \left\{ \frac{L_{sc}}{R_o} \times F_{sc} \times R_o \tan(A_e + F_{sc}) \right\} \quad (5)$$

(v) **Torque due to Bulk Solid Movement of Material relative to the Shaft:** The torque due to bulk solid movement of material relative to the shaft was calculated from the expression [4] given below as:

$$T_{sh} = 2\pi R_i \sigma_n \frac{L_{sc}}{P} \quad (6)$$

where, T_{sh} is torque due to bulk movement of material relative to the shaft. Substituting $\pi = 3.142$, $R_i = 10$ mm, $\sigma_n = 49.050$ N/m², $L_{sc} = 1200$ mm and $P = 100$ mm in Equation (6) gives $T_{sh} = 36.988$ Nm.

(vi) **Total Torque on the Screw Shaft:** The total screw torque was determined from the equation below [4] as:

$$T = T_{sp} + T_{sh} \quad (7)$$

where, T is total torque on the screw shaft. Substituting $T_{sp} = 6.165$ Nm and $T_{sh} = 36.988$ Nm into Equation 7 gives $T = 43.153$ Nm.

(vii) **Power of the Screw Conveyor due to total Torque on the Screw Shaft:** The power of the screw conveyor due to total torque on the screw shaft was determined thus [4]:

$$P_{sc} = \frac{0.105TN}{\eta_d} \quad (8)$$

where, P_{sc} is power requirement of the screw conveyor due to total torque on screw shaft, N is rotational speed of the screw shaft and η_d is drive efficiency. Given that $N = 250$ rpm and $\eta_d = 80\%$ or 0.80 ; hence, $P_{sc} = 1.416$ kW or 1.898 hp. Therefore a 2 hp single phase electric motor was selected to drive the machine.

(viii) **Capacity of the Screw Conveyor:** The capacity of the screw conveyor was determined using Onwualu et al [5] equation as:

$$Q = 60 \left\{ \frac{\pi}{4} (D^2 - d^2) PN \varphi \right\} \quad (9)$$

where, Q is capacity of screw conveyor, d is shaft diameter and φ is filling factor. Substituting $D = 120$ mm, $d = 20$ mm, $P = 100$ mm, $N = 250$ rpm and $\varphi = 0.25$; hence, $Q = 4.124$ m³/h.

(ix) **Power Requirement of the Screw Conveyor based on Capacity:** The power required to drive the screw conveyor based on the throughput capacity was determined from a modified form of Onwualu et al [5] equation as:

$$P_r = \frac{QL_{sc}\rho g F}{3.6} \quad (10)$$

where, P_r is the power required to drive the screw conveyor based on capacity, ρ is bulk density of feed material, g is acceleration due to gravity and F is material factor. Substituting $Q = 4.124$ m³/h, $L_{sc} = 1.2$ m, $\rho = 500$ kg/m³, $g = 9.81$ m/s² and $F = 0.15$; hence, $P_r = 1.011$ kW or 1.356 hp. The power of the electric motor to drive the system was determined from the expression below [5]:

$$P_m = \frac{P_r}{\eta_d} \quad (11)$$

Design of Pulley and Belt:

(i) **Pulley Design:** The effective diameter of the screw shaft pulley was determined using the equation given by Khurmi and Gupta [6] as:

$$N_1 D_1 = N_2 D_2 \quad (12)$$

where, N_1 is speed of electric motor, D_1 is diameter of pulley on electric motor, N_2 is speed of screw shaft, D_2 is diameter on screw shaft pulley. Given that $N_1 = 1450$ rpm, $D_1 = 60$ mm and $N_2 = 250$ rpm; hence, $D_2 = 348$ mm. Therefore, a pulley of diameter 350 mm was selected for the screw shaft.

(ii) **Belt Design:** In order to select appropriate belt to drive the screw conveyor, relevant belt parameters such as centre to centre distance, pulley-belt contact angle and length of belt must be determined.

Centre-to-Centre Distance: The centre to centre distance was determined using Equation 13 below as:

$$C = \frac{D_1 + D_2}{2} + D_1 \quad (13)$$

where, C is centre-to-centre distance. With $D_1 = 60$ mm and $D_2 = 350$ mm; hence, $C = 265$ mm.

Length of Belt: The length of belt the belt was determined from the expression in Equation 14 below as [7]:

$$L_b = \frac{\pi}{2} (D_1 + D_2) + 2C + \frac{(D_1 - D_2)^2}{4C} \quad (14)$$

where, L_b is length of belt. Substituting the values of the parameters in Equation 13 gives $L_b = 1019.34$ mm. Therefore, a V-belt of specification A-39, 12.5 x 1050 mm was selected.

Design of Spring-Controlled Packaging Mechanism: (i) Design of the Spring: The design of the packaging mechanism ensures the selection of helical springs with high tensile strength and can withstand high stresses under repeated loading. In operation of this machine, the spring is subjected to axial load due to the weight of mixed and packaged feed aggregates. Thus torsional shear stress is induced in the spring wire due to twisting moment in addition to direct shear stress due to the action of the weight of the feed [6]. Therefore, the maximum shear stress induced in the spring wire due to the axial load from the weight of mixed and packaged feed is a combination of the torsional shear stress and the direct shear stress. This is determined from the expression [6] given in Equation 13 below as:

$$\tau_{max} = \frac{8WD_m}{\pi d_w^3} \pm \frac{4W}{\pi d_w^2} \quad (15)$$

where, τ_{max} is the maximum shear stress induced in the spring wire, W is the axial load on the spring (weight of feed), D_m is the mean diameter of the spring coil and d_w is the diameter of the spring wire. Given that $W = 250$ N, $D_m = 20$ mm, $\pi = 3.142$ and $d_w = 2.946$ mm ≈ 3 mm (SWG 11) [6] and substitute these values into Equation 14, hence, $\tau_{max} = 471.509 \pm 35.363$ MPa i.e $\tau_{max} = 506.872$ MPa (in compression) and $\tau_{max} = 436.146$ MPa (in tension). In this design, two tension helical springs were used and they were under tensile loading from the weight of the feed; thus, $\tau_{max} = 436.146$ MPa was distributed over the two springs making each spring experiencing $\tau_{max} = 218.073$ MPa. This implies that the maximum tensile stress that would be applied on each of the two springs is 218.073 MPa. From the table of allowable shear stress for various spring materials

(ii) **Design of the Anchor Shaft:** The anchor shaft is the component that links the springs with the packaging unit. The design should ensure that the shaft will not fail by bending due to the weight of feed and the packaging platform. The sectional modulus of the shaft was determined from

$$Z = \frac{Wl_s}{4\delta_0} \quad (16)$$

where, Z is the sectional modulus, l_s is length of the anchor shaft and δ_0 is the yield stress. With $W = 250$ N, $l_s = 380$ mm and $\delta_0 = 200$ N/mm², hence, $Z = 0.119$ cm³. From the table, the dimension of mild steel shaft suitable for this design is diameter 12 mm. Therefore, a mild steel rod of diameter 12 mm and length 380 mm was used for the shaft. It will be able to support the packaging unit without failure.

Design of Structural Support: Made up of mild steel angle iron of thickness 3 mm, the main frame is the component that provides structural support and stability for the whole machine. The two failure possibilities are bending of the horizontal members (beam) and buckling of the vertical members (column) of the frame. Since the total weight of the machine and its content to be carried by the structural support is 2.011 kN, the design should predict that the horizontal members will not fail by bending and the vertical members by buckling or crippling.

(i) **Design of Horizontal Member of Support (Beam):** The sectional modulus of the horizontal section of the frame (beam) was determined using the Equation 17 below as:

$$Z = \frac{Wl_b}{4\delta_0} \quad (17)$$

where, Z is the sectional modulus, l_b is the length of the beam and δ_0 is the yield stress. With $W = 2.011$ kN, $l_b = 550$ mm and $\delta_0 = 200$ N/mm², hence, $Z = 1.383$ cm³. From the table of equal angles, the dimension of mild steel angle bar suitable for this design is 45 x 45 x 3 mm. Therefore, a mild steel angle bar of dimension 45 x 45 x 3 mm was selected for the beam. It will be able to support the machine without failure.

(ii) **Design of Vertical Member of Support (Column):** The crippling or buckling load on the column due to weight of the machine is determined by Euler's equation [6,8] given by:

$$W_{cr} = \frac{C_f \pi^2 EA}{\left(\frac{l_c}{k}\right)^2} \quad (18)$$

where, W_{cr} is the crippling or buckling load, E is the modulus of elasticity known as Young's modulus for the material of the column (mild steel), A is the area of cross section of the column, l_c is the length of the column, k is the minimum radius of gyration of the cross section of the column and C_f is a constant known as end fixity coefficient. For a rectangular cross-section, k is determined using the expression below [8]:

$$k = \frac{h\sqrt{3}}{6} \quad (19)$$

where, h is the smaller dimension of the rectangular cross section. With $C_f = 4$ (both ends fixed), $E = 200$ GN/m², $A = 105$ mm², $l_c = 1100$ mm, $h = 3$ mm; hence, $k = 0.8660$ mm and $W_{cr} = 0.513975078$ MN $\approx$ 513.975 kN. The safe load was determined as:

$$W_{sa} = \frac{W_{cr}}{F_{sa}} \quad (20)$$

vertical member of the frame (column) will not fail during operation. From steel table, the mild steel angle bar suitable for this design is 45 x 45 x 3 mm in dimension.

Design of Body: The various dimensions of the body were fixed as follows [6]: $l_c = 2l_b$; $D = 6d$; $D = 1.2P$; $V_{bc} = \frac{2}{3}V_m$ and $V_{cs} = \frac{1}{3}V_m$; where, V_{bc} is volume of big cylinder, V_{cs} is volume of conical section and V_m is volume of material (feed) to be occupied by the machine. With $l_b = 550$, $d = 20$ mm, $P = 100$ mm and $V_m = 0.250 \text{ m}^3$; hence, $l_c = 1100$ mm, $D = 120$ mm, $V_{bc} = 0.167 \text{ m}^3$ and $V_{cs} = 0.083 \text{ m}^3$. Consequently, $h_{bc} = 540$ mm, $h_{cs} = 500$ and $h_{sc} = 340$ mm; where, h_{bc} , h_{cs} and h_{sc} are heights of big cylinder, conical section and small cylinder respectively in mm.

Fabrication

Figures 2 and 3 show the exploded and orthographic views of the livestock feed mixer respectively. The frame was fabricated from a standard length of mild steel angle iron of dimensions 45 x 45 x 3 mm. Using a power hacksaw, four pieces of length 1100 mm each and four pieces of length 550 mm each were cut from the standard length. These components were welded together, using a welding machine, to form the main frame (structural support) of the machine. The big cylinder, small cylinder, internal cylinder, conical section were made from two standard lengths of mild steel sheet of 1 mm thickness which were cut to specified dimensions using a treadle-operated guillotine. The cut pieces were folded and welded to form diameter 700 mm and height 540 mm for the big cylinder, diameter 200 mm and height 340 mm for the small cylinder and diameter 150 mm and height 900 mm for the internal cylinder. The conical section was made from one of the cut pieces which was folded and welded to form an inverted frustum of base and tip diameters of 700 mm and 150 mm respectively with height 500 mm.

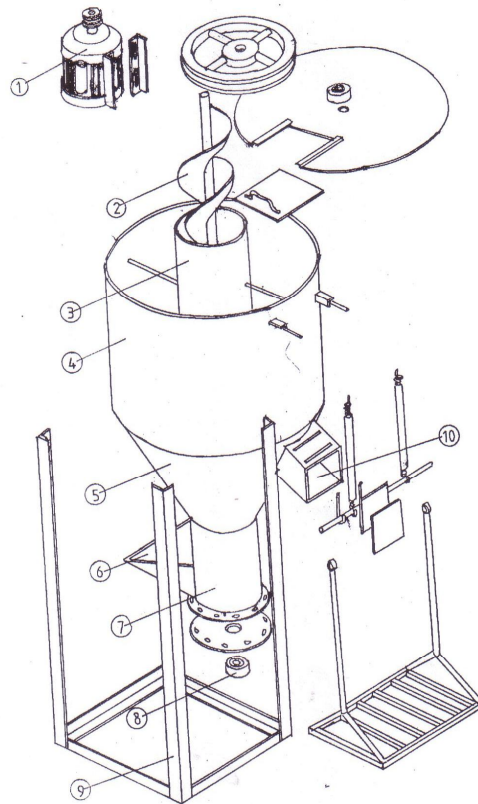


Figure 2 Exploded view of the livestock feed mixer with the packaging unit: 1-Electric motor, 2-Screw conveyor, 3-Internal cylinder, 4-Big cylinder, 5-Discharge gate, 6-Conical section, 7-Hopper, 8-Small cylinder, 9-Bearing, 10-Structural frame

The top cover was made from the same 1 mm thick metal sheet cut to form a circular disc of diameter 702 mm. The bottom cover was made from a mild steel plate of 3 mm thickness which was machined and shaped to a circular disc of diameter 260 mm. A hole of diameter 25 mm was drilled at the centre of each of the two covers to allow for the screw shaft and bearing. The bottom cover was bolted to the lower end of the small cylinder. For the construction of screw blade, a circular plate of diameter 120 mm was cut from the mild steel sheet and used to mark out other circular plates. A circle of diameter 20 mm was marked out and drilled from the centre of each plate to accommodate the screw shaft. The plates were then twisted at angle 25° (helix angle) and then welded to the shaft sequentially to form the screw conveyor.

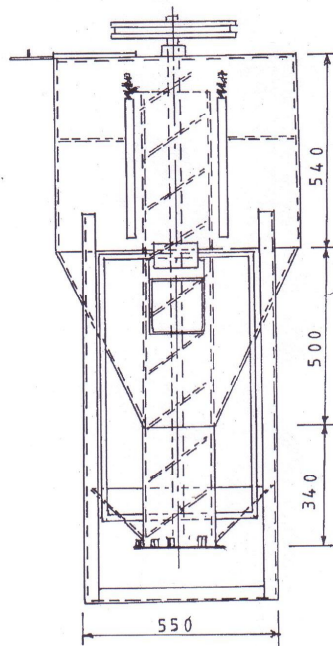


Figure 3 Orthographic view of the livestock feed mixer

Table 1 Materials for Construction of the Livestock Feed Mixer and their Specifications

Materials	Specifications	Quantity
Mild steel sheet	1 mm thickness, standard size	2
Mild steel sheet	3 mm thickness, $\frac{1}{4}$ standard size	1
Mild steel rod	Φ 25 mm, $\frac{1}{2}$ standard length	1
Mild steel rod	Φ 12 mm, $\frac{1}{4}$ standard length	1
Angle iron	45 x 45mm x 3, standard length	2
Flange bearing	Φ 25 mm	6
Cast iron pulley	Φ 60 mm	1
Cast iron pulley	Φ 350 mm	2
Spring	SWG 11, Φ 2.946 mm	2
V-Belt	A-39, 12.5 x 1050 mm	1
Bolts and nuts	M 17	15
Bolts and nuts	M 19	10
Welding electrode	Gauge 12 mild steel	$\frac{1}{2}$ packet

A sheet of dimension 500 mm x 160 mm was cut from the standard length and welded to form the hopper of slant angle 40° and height 150 mm. The packaging mechanism was constructed from a hollow mild steel square pipe of dimension 40 x 40 mm and thickness 2 mm. Using a hacksaw, ten pieces of length 300 mm, two pieces of length 600 mm and two pieces of length 900 mm were cut from the square pipe and welded together to form the seat and linkage bar of the packaging

The shaft of the packaging mechanism was constructed from a mild steel rod of

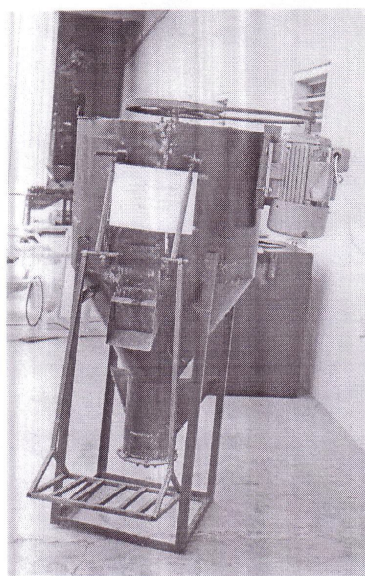


Figure 4 Pictorial view of the livestock feed mixer

Materials and Methods used for Preliminary Testing

Granular animal feed aggregates were obtained from a Feed Mill in Ilorin area of Kwara State, Nigeria. After assembly as shown in the figures above, the machine was set in operation and the feed was introduced through the feeding hopper. The time of discharge and weight of feed at discharge were taken and recorded with the trial being replicated thrice. Discharge rate was then calculated using the equation:

$$Q_r = \frac{W_q}{T_q} \quad (21)$$

where, Q_r is the feed discharge rate, W_q is the weight of feed at discharge and T_q is the time of discharge.

Results of Preliminary Testing

The result of preliminary testing of the machine is shown in Table 2. From the table, the average weight of feed at discharge, time of discharge and discharge rate were 24.17 kg, 68.00 s and 0.356 kg/s (21.34 kg/min) respectively. The weight at discharge obtained (24.17 kg) compared favourably with the designed value (25 kg) showing that the machine performed satisfactorily.

Table 2 Result of Preliminary Testing

Measured Parameters	Replicate 1	Replicate 2	Replicate 3	Average
Weight at Discharge (kg)	24.50	24.00	24.00	24.17
Time of Discharge (s)	70.80	67.20	66.00	68.00
Discharge Rate (kg/s)	0.346	0.357	0.364	0.356
Discharge Rate (kg/min)	20.76	21.43	21.82	21.34

Conclusion

A livestock feed mixer with spring-controlled packaging unit was designed, constructed and tested. All the materials of construction were available locally at affordable costs. Powered by a 2 hp single-phase electric motor, the machine has average feed discharge rate of 21.34 kg/min with a production cost of about \$470. The machine can be used for small scale livestock feed manufacturing in the rural and urban communities.

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