Sustainable Animal Feeding Production System: A Case Study for a Stand-Alone Animal Feed-Mixer for Rural Subsistence Pastoral Farmers during Covid-19 Pandemic

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Abstract:
Animal compound and supplement feed play a significant part in rural subsistence pastoral farming. During these challenging times presented by the advent of covid-19 pandemic, small farmers were left with no choice but to practice small-scale and / or makeshift feedlot systems in their backyards. Due to the pandemic no-movement policy was enforced by the Botswana government which lead to zero grazing and causing detrimental effects to subsistence farmers. In realising these problems, the government offered subsidises to rural farmers so that they can afford different animal compound and supplement feeds for their stock. However, the main challenge comes with achieving homogenous animal compound and supplement feeds mixtures due to lack of manpower caused by restricted movements and curfews. Hence there is a profound need to aid subsistence farmers with a comprehensive process and / or system of achieving this homogenous animal compound and supplement mixture. Traditional animal feeds are general characterised as dispersible multi-ingredient-mixtures in which particles differ in size, density and shape and tend to segregate. The segregation of animal feeds is frequently a reason for customer and official complaints. To avoid segregation, usually small volumes of liquids – e.g., molasses or vegetable oils – are added in the main mixer of a feed production line to cause fine particles. The presence of small volumes of liquids will affect the distribution behaviour of particles during mixing and it may also influence the material and technological properties. However, the mixing homogeneity of typical compound feeds that can be achieved when small volumes of liquids are present is not adequately characterised at the moment. There is insufficient knowledge of the design process and specifically the time of the mixing application will take.

This study strived to investigate the process of mixing amounts of traditional animal feed compounds and supplement to achieve a homogenous mixture. The major material properties, such as flow ability and dusting potential, were determined to evaluate both the results and the product quality. An intensive efficient mixer equipped was used as test facility. The results show that, under certain conditions an intensive mixer may have a positive effect on the achievable mixing homogeneity of mineral feeding stuffs.

Keywords: *Less-intensive mixer, Animal supplement feed, Mixture homogeneity, efficient-effective mixing, sustainable design*

1. **Introduction**:

Animal feeds provide the basic nutrients required for animal production, including energy, proteins and amino acids, and minerals, vitamins and other micro-nutrients. Feeds may be broadly classified as concentrates and roughages, depending on their composition. Concentrates are feeds that contain a high density of nutrients, usually low in crude fibre content (less than 18% of dry matter and high in total digestible nutrients. Roughages are feeds with a low density of nutrients, with crude fibre content over 18% of DM, including most fresh and dried forages and fodders (McDonald et al. 2003). The use of hand in mixing animal feeds by subsistence farmers was very inefficient. This method was subsequently developed by the use of manually operated machine after the advent of industrial revolution. There is urgent need and demand for an effective and efficient mixer due to its use in subsistence animal farming as machinery for feed production. Small-scale farmers in Botswana are in dire need of a highly nutritious animal feed to increase production output.

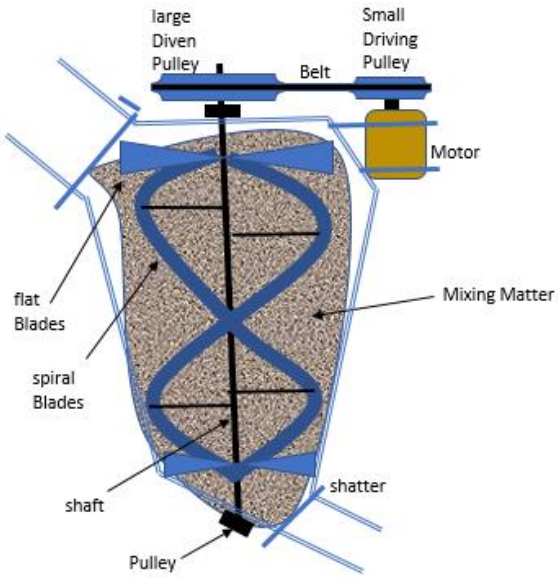
2. Materials and methods:

2.1 Design Analysis

The industrial animal feed mixer is made up of the following major parts; electric Motor, mixing Bucket, Shaft Pulley, Motor Pulley, set of blades mounted on the shaft, ribbon blades, Bearings, Shaft, Supporting Structures, V-Belt. The animal feed mixer has to achieve the desired poultry feed mixing based on the following design specification of the various components of the machine.

2.2 Design Schematics and Flow of material

Figure 1 Mixing Parts



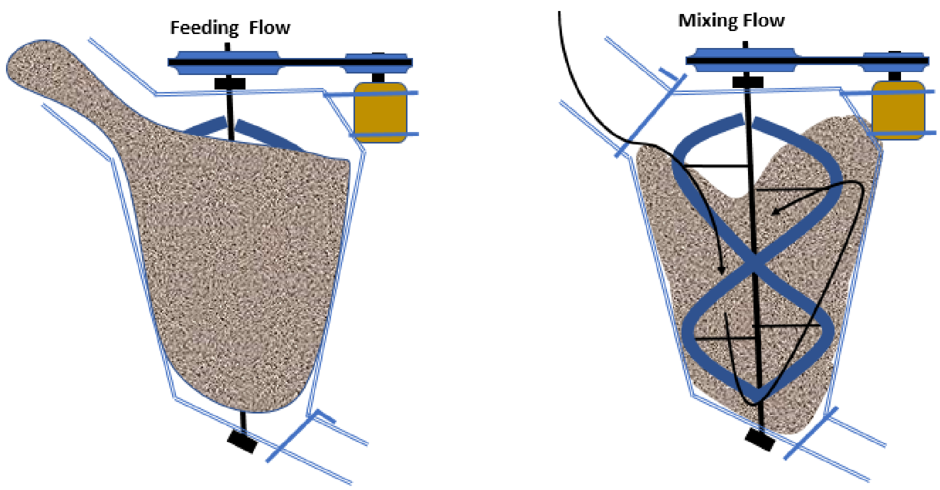


Figure 2 Feeding and Mixing Direction

2.3 Determining the Torsion on the shaft and selection of pulleys

The torsion on the shaft [Ts] is from the specified Power [P] of 15 hp on the motor and the maximum revolutions or speed of the motor [N] of 5000 rpm, the Torsion of the shaft [Ts] is as below;

$$\boldsymbol{T_s = \frac{P*60}{2\pi N}} \qquad \textbf{(1)}$$

2.4 Determining the Design Power

The design power [Pd] is to take assure that there is maximum allowable power on the mixer. The design power is governed by the correction factor [Fa] which depends upon the type of driving unit, the type of driven machine and the operational hours per day.

$$P_d = F_a * P \qquad (2)$$

Where **P** is the power rating of the motor.

2.5 Determining the Driver [V1] and the Driven Pulley Linear Speeds[V2]

The speed of the driven pulley has to be converted to the useable speeds of meters per second. The diameter of the Driven pulley [D1] and the Speed of the Driver Pulley [N1] which in this case is equal to the speed of the Motor [N] thus the linear Speeds of the Driver Pulley V1 is;

$$V1 = \frac{\pi\, D1 * N1}{60000} \qquad (3)$$

The diameter of the Driven pulley [D2] and the Speed of the Driven Pulley [N2] thus the linear Speeds of the Driven Pulley V2 is;

$$V2 = \frac{\pi\, D2 * N2}{60000} \qquad (4)$$

NOTE; The circumferential speeds of the driving and the driven pulleys and the linear speed of the belt are equal.

2.6 Determining the Tangential Force [F], shaft Diameter [Dshaft] and the Torque [Tr] at the on the shaft

$$F = ma \quad \textit{(Force = mass * tangential Acceleration)} \qquad (5)$$

$$Dshaft = \sqrt{\frac{1.33 * 10^6 * P}{N}} \; [\textbf{diameter of the shaft}] \qquad (6)$$

$$A = \pi Dshaft^2/4 \quad \textit{(CSA of the body) [Area of Shaft C/s with Diameter of shaft]} \qquad (7)$$

$$Ss = F/A \quad \textit{(Maximum shear stress of Force [F] per Area [A]} \qquad (8)$$

$$Tr = \frac{Ss * \pi * D_s{}^2}{16} \textit{(Torque required on SHAFT)} \qquad (9)$$

2.7 Determining the Belt length [L] and the Centre Distance [C]

From the Governing principle of the belts, the mean of the centre distance Cmean is expressed as follows;

$$Cmean \le \left(\frac{D_1 + D_2}{2} + 50m\right) \qquad (10)$$

The Belt length is calculated as follows, use the mean of the centre distance as C;

$$L = 2C + \pi \frac{(D2+D2)}{2} + \frac{(D_2 - D_1)^2}{4C} \qquad (11)$$

2.8 Determining the Number of Belts

The number of belts are calculated as follows;

$$Number\ of\ belts = \frac{P * f_a}{P_r * f_d * f_c} \qquad (12)$$

Where; Where P is the power rating of the motor and Pr is the belt power rating, fa, fd,fc are the correction factors from the belt dimension standard IS:2494-1974.

3. Results and Discussions

The design parameters needed for the fabrication of the animal feed ribbon mixer was computed using MS Excel. The results are shown in Table 1. The prototype of the design to produce **100kg** of poultry feed was to being fabricated to be used in experimental mixing tests.

Parameter	Symbol	Value	Unit
Torque on the motor	Tm	0.028662	Nm
Linear Velocity of the pulley 1	V1	19.625	m/s
Linear Velocity of the pulley 2	V2	19.62498	m/s
Torque of the shaft	Tr	12440.17	Nm
Shear stress on shaft	Ss	3128.841	N/m
Diameter of the shaft	Ds	63.16645	mm
Distributed Force on the shaft	F	9800	KN
Diameter of the Driven Pulley	D1	750	mm
Diameter of the Driven Pulley	D2	6756.757	mm
Mean Centre Distance	C mean	14310.37	mm
Length of Belt	L	21215.71	mm
Centre distance	C	890.0472	mm
Belt power rating	Pr	16.57517	Hp

Table 1

4. Conclusions:

The computation design of the animal feed mixer was completed. The prototype of the design to produce 100kg of poultry feed was to being fabricated to be used in experimental mixing tests. The machine is to be made safe to use. More test is to be made and mixing performance has to be rated for homogeneous feed mixing.

5. References:

1. Akpobi J.A, Ovuworie G.C., **Computer-Aided Design of the Critical Speed of Shafts,** Journal of Applied Science and Environmental Management, 2008, 12, p. 79-86.

2. Akpobi J.A., Ardey M., **Computer-Aided Design for Machine Vibrations, Technical Transactions of the Nigerian Institution of Production Engineers**, 2002, 7(3), p. 41-62.

3. Akpobi J.A, Lawani I.A., **Computer Aided Design of Flywheels, Advances in Engineering Software** (Elsevier Publishers), 2006, 37(4), p. 222-235.

4. Okojie V.A., **Software Approach in Solving Shaft Design Problems, Project Solutions Domain** Journal of Mechanical Engineering, 2011, 1, p. 15-28.

5. Ear T.S, Johnson B.P., **Production engineering**, Third Edition, Tata Mcgraw Hill Company Limited, New Delhi, 2007.

6. Khurmi R.S., Gupta J.K., **A Textbook of Machine Design**, Fourteenth Edition, S. Chand and Company Limited, New Delhi, 2005

7. Suresh P., Carry-Over, **Prevention in Machines, Machine Design Development**, 1997, p. 345-349.

8. Deane A., **Developing Mathematics Creativity with Spreadsheets**, Journal of Korea Society of Math. Educ., 2005, 9(3), p. 187-201.

9. Diemuodeke E.O., Momoh O.L.Y., **Design and Fabrication of a Direct Natural Convection Solar Dryer for Tapioca**, Leonardo Electronic Journal of Practices and Technologies, 2011, 18, p. 95-104.

10. Oko C.O.C., Diemuodeke E.O., **Analysis of Air-Conditioning and Drying processes Using Spreadsheet Add-In for Psychrometric Data**, Journal of Engineering Science and Technology Review, 2010, 3(1), p. 7-13.

11. Rajput R.K., **Strength of Materials**, Fourth Edition, S. Chand and Company Limited, New Delhi, 2006.

12. Ashby F.M., Jones R.B.H., **Engineering Materials: An Introduction to Their Properties and Application**, Second Edition, Butterworth Heinemann, Oxford, 2002.