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Design and Construction of Animal Feed Chopping Machine

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Abstract
Dependence on animals for food by humans all over the world is unavoidable. To get healthy food (meat), the animal must be well fed. With the growing number of animals in the society, good natural pasture is not available especially during dry seasons, for all animals. Therefore, supplementary food for the animals must be made. It is common knowledge that production of supplementary animal feeds has over the years not being easy to both rural and urban animal farmers. This paper presents a report on the design, production and performance evaluation of an animal feed chopping machine whose features eliminates the shortcomings on the traditional method being used for producing animal feeds from farm waste. The new product will meet the need of both rural and urban farmers in producing animal feeds.

Keywords: *Design, Production, Evaluation, Animal Feed*

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I. Introduction

A animal feed chopping machine is a type of machine that is used for chopping the farm waste products such as corn stick, maize stick, rice chief, corn husk, millet stick, dry food. They can together be used to produce proper feed for animals such as cow, goat, sheep etc. The manufactured machine will produce animal feed from farm waste materials or substances mixed with other ingredients (additives) in a good ratio. Due to the increase in demand and improvement in mechanization farming, especially in the western world, a lot of machines are still being designed in order to ease the suffering of the livestock bearers. Therefore, the design and construction of the animal feed chopping machine is of paramount importance to the society for improved technology in mechanical engineering field and mechanization aspect. The machine can be used both in urban and rural areas since the engine is gasoline or petrol driven.

With regards to the features and operation, the new machine consists of a hopper, shaft, chopping chamber, perforated beam plate, 3mm, 4mm, 6mm pulley and belt, combination of lock and standard nut and discharge unit. The machine is to be power by diesel or petrol engine, to be mounted on a ragged frame wall and connected to the shaft by a pulley with driving belt. The movement of the pulley belt will be the means of feeding the raw material into the chopping chamber. After chopping the raw material into required sizes, the chopped material will pass through a sieve then to the discharge unit for collection of the finish feed. The production process is continuous.

From the ancient time, animal feed was produced using locally available materials (tools) such as bag mounted stones, cutlass, knife. The cutlass that was used for cutting grass in small size was manipulated by human hand which takes time and energy sapping. Traditional manual method has disadvantages. The disadvantages prompted this study;

1. Much effort is required in the cutting period
2. Improper mixing of two grasses and the additives
3. Much time is consumed in cutting process
4. Non-acceptability of the cut size of grass

To bring this difficulty to an end, another means of chopping farm waste into animal feed is being introduced. Specifically, the study intent

i. To design and construct prototype of a simple animal feed chopping machine which will be used to chopped agricultural waste by both urban and rural farmers.
ii. To carry out performance evaluation of the constructed prototype of animal feed chopping machine.

Based on the specific purposes of this study, the study is limited to designing, construction and evaluation of animal feed chopping machine. Furthermore, in line with the intends or purposes of this study answers to the following research questions were sought.

1. What are the impalpable features of the existing designs of animal feed chopping machine?
2. What desirable features should be seen on an appropriate animal feed chopping machine?

II. Literature Reviews

In most tropical regions, the majority of bovine feeds available are the poor quality crop residues and agro-industrial products. Improper management of feed resources, especially those of the bulky and fibrous crop residue is a contributing factor to low productivity of ruminant livestock in the tropical regions. Crop residue management should include the use of processing technologies for the manufacture of balanced complete straw-based feed for ruminants. (Walli *et al* 2012). Rushing of crop residues is on the increase with the global quest for sourcing of renewable energy through pre-processing of bio-masses. Physical and mechanical properties of biomasses species and varieties are very important when considering the energy requirements for particle size reduction of agricultural residues. Of the various types of grinding equipment available, hammer mills are the best-known equipment used for the shredding/grinding, in which the material fragment are subjected to complex forces and then the resulted particles are used in the following operations from the pellet obtaining technology. (Moiceanu *et al* 2012)

Due to high size reduction ratio, good control of particle size range with relatively good cubic shape of particles, hammer mills are wildly used and numbers of literature on grinding of different materials are available. Knife mills (or choppers) work successfully for shredding forages under various crops and machine conditions. Disc (or roller) mills produce very small particles if input feed is provided by knife mills or hammer mills. (Hoque *et al* 2007).

The soybean stalk, whose cross-section shape is solid, can be regarded as woody material with high stiffness. The core structure of broomcorn and corn stalk can be analyzed as circular structure, which has less density and smaller shearing resistance than those of solid structure at the same cross-sectional area. (Liang and Guo 2011).

III. Materials and Method

Materials for the construction of the component parts of the animal feed chopping machine include the hopper, chopping camber, chopping bitter, shafts pulleys, belt, bearing, mild steel plate angle, bar mild steel, galvanized pipe, diesel or petrol engine. These materials were locally purchased and they were selected based on the power requirement in the chopping of agriculture waste materials.

Laboratory experimental research design was chosen for this research. Preliminary investigation, to reliably establish the need for this product was carried out. Thirty (30) farmers, randomly selected from the study area - Adamawa State, were used as respondents to the open-ended questionnaire structured based on the research questions. The preliminary investigation revealed that much effort is required in using the traditional method in cutting the farm waste into animal feeds. Secondly, the mixing of the cut farm waste with the additives is usually improperly done. Another unpalpable revelation is that with the traditional method, much time is wasted in cutting the farm waste into required sizes. These revelations gave birth to the need for a more appropriate chopping machine that eliminate problem of much energy requirement and too much time consumption and which will also be affordable by even the poorest farmer anywhere on the globe.

Having established the need for the chopping machine, a technical illustration (isometric drawing) and three orthographic views of the machine, as in appendices A and B respectively, were made, based on the initial free hand sketches and the refined sketches. The design of the shape and size of the chopping machine as presented in appendix A was based on the design criteria, specifications and design calculations of the strength's requirement of the components of the device. Materials for the construction were subsequently selected based on the design calculation.

Design Criteria

Workability, durability and cost effectiveness were followed when designing and selecting materials for constructing the device for this study.

Design Specification

One of the research questions that guided the preliminary investigation sought information on desirable features that should be seen on an appropriate animal feed chopping machine. The knowledge gained informed the following specifications. That;

1. The animal feed chopping machine shall be made portable so it could be easy to be moved from one place to the other.
2. The device will be easy to operate.
3. The purchasing cost will not be high.

4. The component parts shall be made of locally available materials so that a manufacturer ill not have to go far.
5. Component parts shall be easy to assemble into a unit.
6. Component parts will be made maintainable so that they can be dismantled easily and replaced.

Design Calculation
This section presents design calculation for the shaft, belt, power input and power developed by the machine.

Shaft Design
This calculation is to determine the minimum shaft diameter that will be used by the chopping without failure. Bearing in mind that the shaft of the chopping camber will be subjected to circular moment rotary moment. Therefore, tensional equation will be used to determine the suitable diameter of the shaft.

Torsion Shaft
To transmit energy by rotary, it is necessary to apply a turning force for a solid shaft of uniform circular cross section throughout its length, torsion theory state that
$\frac{T}{J}=\frac{t}{l}=\frac{G\emptyset}{L}$ ------ (i) (knurmi et al 2007)
The poler moment of inertial of the shaft
$j=\frac{\pi D^4}{32}$ --------(ii)
Average Power Transmission to the Shaft
The average power transmitted to the shaft is work done per minute. Consider a force F, acting tangentially on the shaft of radius R, if the shaft, due to this turning moment (F and R) start rotating at N. rpm, then work supplied to the shaft is equal to force times distance moved per second.
W= F × $2\pi RN/60Nm$ (but T = F×12-------(iii)
Or power = T× $2\pi RN/60$
Average Toque Transmitted to Shaft
Work done by the shaft for minute is equal to the average torque multiplied by the angle turned in a minute.
Average power = $\frac{2\pi NT}{60}$ ---------(iv)
Average torque = $\frac{avarage\ human\ power}{avarage\ velocity}$ --------(v)
An average human power is one-tenth of a horse power. That is equivalent to 75N.
The shaft is expected to make 1.5rpm
From Equ (iv) above,
W =$\frac{2\pi N}{60}$ =$\frac{2\times\pi\times1.5}{60}$ = 0.1570 rads/s
From the Equation (v) the average torque:
T=$\frac{avarage\ human\ effort}{angular\ velocity}$
T = $\frac{75}{0.1570}$ = 477.71Nm
Note: to determine the suitable diameter of the chopping machine, the maximum and not the average torque is considered. This is because the maximum shear stress developed is ensured to the safe limit.
The maximum torque is twice the average torque i.e.
T_{max} = 2×477.71×1000 = 955420Nmm
From Equation (i)
$\frac{T}{J}=\frac{G\emptyset}{L}$
Where,
J =$\frac{\pi D^4}{32}$

$$\frac{T}{\frac{\pi D^4}{32}}=\frac{G\emptyset}{L}$$

Ø = Angle of twist (assumed to be 1^0)
D = $\sqrt[4]{\frac{955420\times32\times390\times180}{0.8\times10^5\pi^2}}$
D= $\sqrt[4]{2718264.331}$
D = 40.6mm = 41mm

Design for Vee Belt

The expression for vee belt length is given as

$$\mathbf{L} = \frac{F}{z}(D2_1 + D2_1) + 2C + \frac{(D2_1 - D2_1)2}{4C}$$

Where $\pi = 3.14$

C = center distance between pulleys

D_1= big pulley

D_2 = small pulley

This will enable the researcher determine the correct size of the vee-belt visa-vis the diameter of the pulley and their center distances

Power Output of the Machine

To determine the output power first, we will find the tensions T_1 and T_2. It is the tight and slack side of the vee belt by the expression

$$\frac{T_1}{T_2} = e^{\emptyset u}/\sin B$$

Where T_1 = tension of tight side

T_2 = tension of slack side

$$\emptyset = angle\ of\ the\ top\ of\ bigger\ pulley$$

B = half of include angle of the vee belt

μ= coefficient of friction between the vee belt and pulley = 0.3

Power Development by Machine.

Power of machine

P= T_1 –T_2)√

Where P = power

T_1 = tension of right side of vee belt

T_2 = tension of slack side of vee belt

√ = peripheral of slack side of vee belt

The efficiency of the machine can now be calculated using the formula below

$$M = \frac{output\ power}{input\ power} = \frac{power\ developed\ by\ machine}{rated\ power\ of\ disel\ engine}$$

Materials Selection for the Study

Based on the design calculation, appropriate semi-finished and finished materials for making the different component parts of the device were, selected. The selection of materials was made based on their quality, strength, affordability and availability of the material in the study area.

Selection of Engine

A diesel engine was chosen and the specification on a name plate is:

Rated output	=	4.41 KW
Rated speed	=	2600 RPM
Net weight	=	60 KG

Selections of Transmission Drives

The power transmission drove for the machine will be Vee belt and pulley which is suitable for medium machine (Khurmi 2006).

Materials Specification and Cost Analysis

Table 1 shows the component's name (item description), materials, quantity required, unit cost and total cost of the material to construct each component

S/N	Description of item	QTY	Unit	Amount (₦)
1	Engine 7.5 Hp (Petrol or Gas)	1	₦170000	170000
2	High carbon steel 2×2	5	₦20000	100,000
3	Angle iron (bar) 4×4	10	₦8000	80,000
4	Mild steel shaft	1	₦18000	18000
5	40mm diameter Chopper shaft	4	₦10,000	40,000
6	Galvanized pipe 10mm diameter	6	₦5000	30000
7	F16 Bearing	2	₦3500	7000
8	4" Screen |Sieve High carbon steel	1	₦200,000	200,000
9	Pulley cast iron 1.5^m	1	₦4000	4000
10	Pulley cast iron 10^u	1	₦3500	3500

11	V-Belt	2	₦1500	3000
12	Nut 13mm diameter	20	₦150	4500
13	Bolt 13mm diameter	20	₦150	4500
14	Electrode gage 12	4	₦3000	12000
15	Golden oil Paints	3	₦7500	22500
16	Hinges 15 inch	4	₦500	2000
17	Washer 13mm diameter	4	₦100	4000
18	Cutting disc 40mm diameter	15	₦1500	22500
	Grinding disc 40mm diameter	5	₦1500	7500
19	Locking Device	4	₦2000	8000
20	Fuel (diesel l)	70L	₦270	18900
21	Grease	2	₦2000	4000
22	Binding wire mild steel	2	₦7000	14000
	TOTAL			**₦381,400**

Table 1: Materials Specification and Cost Analysis Overall Total: ₦381,400

Production of Prototype

Development, bending, cutting, filing, welding and riveting were the construction techniques used in the production of the components. Working drawings as in appendixes C, guided in the accurate construction, within production tolerances of each of the component parts. Appendix D is complete photograph or image of the new machine

Total Cost of Production (TCP)

The TCP is the sum of material cost, direct labour cost and overhead cost. ₦550.00 was assumed to be the cost of semi-skilled labour. Six hours was required to procure, produce and assemble the device into a unit. Therefore, the total cost of labour for the production is ₦500.00 x 6 = ₦3300.00. 20% of labour cost was assumed to be the cost of overhead (OH). So, OH cost is 20/100 x 3300.00 = ₦660.00. Hence, the TCP was determined as follows: material cost + labour cost + overhead cost = ₦381,400 + ₦3300 + ₦660.00 = ₦450,700 Considering the durability of the product, its efficiency, human energy saving capacity and low purchasing cost, it is indeed a product which every animal farmer, rich or poor will want and can afford to buy.

Operational Test

To determine whether the produced prototype of the animal feed chopping machine will perform the function for which it was designed, the device was subjected to the following test parameters; test for technical function, test for strength, test for maintenance and test for production process.

Test of Technical Function; -

This is a test of performance compared against the original statement of the problem and specification. The prototype was set up easily and used to chop maize, rice and guinea corn stocks. The test revealed that the prototype carried out its designed function satisfactorily.

Strength Test; -

This test was meant to determine whether the product could withstand forces that will be applied during service life. The product was used for 21 days consecutively. After inspection, it was revealed none of the component parts failed. This means all the component parts has sufficient strength to withstand the operation forces.

Production Process Evaluation: -

This was an evaluation of the processes that were involved in production of the component parts of the machine. It determined the ease of production and the labour requirement. It was discovered that the processes were straight forward and did not require expensive specialized labour. This means the most appropriate techniques of construction were used which contributed to low total production cost.

Maintenance Evaluation: -

This test was meant to determine whether the component of the new machine can be dismountle and assembled quickly and easily so as to contribute to economical and safe servicing when the need arises. So, the trial dismounting was carried out. It was discovered that, each of the part removed without distracting other components. This observation will certainly contribute toward economical and safe servicing of the product.

Findings of Study

Having designed, constructed and evaluated the prototype of the animal feed chopping machine, the following findings emerged from the operational test

1. The device performed its designed technical function efficiently.
2. All the parts has sufficient strength to withstand all the operation of service forces
3. Production cost is low so selling price will also be low so that both the rich and poor farmers can afford to buy.
4. Maintenance cost is low.
5. The production process can be automated to, among other considerations, meet high demand.
6. High skill labour is not required is the production process, so salary bill will not be too high on entrepreneurs.

IV. Conclusion

The researchers conclude that the study is successful since the device performed is designed function very well. However, it is recommended that future researchers should consider modifying this product to meet future need.

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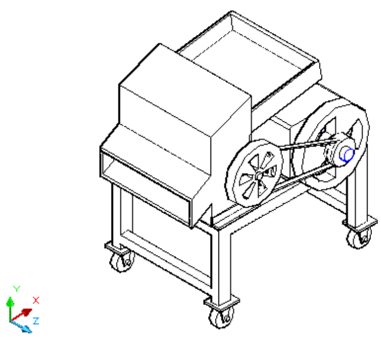
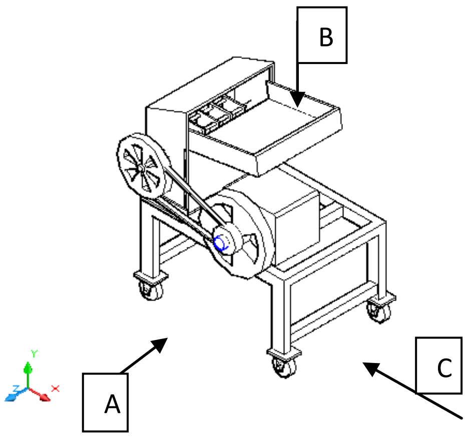
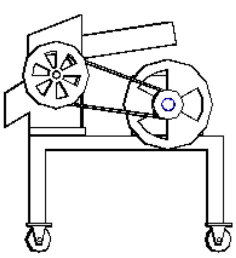
APPENDIX A - ISOMETRIC VIEWS

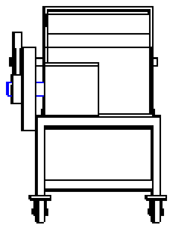




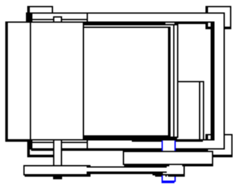
APPENDIX B - ORTHOGRAPHIC VIEWS



Front view – A



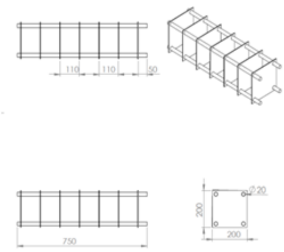
Side view - C



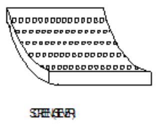
Plan view - B

PRODUCTION DRAWINGS

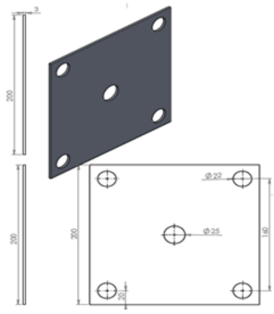
APPENDIX C1



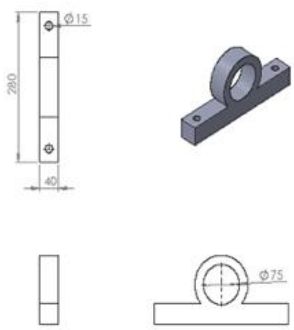
APPENDIX C2



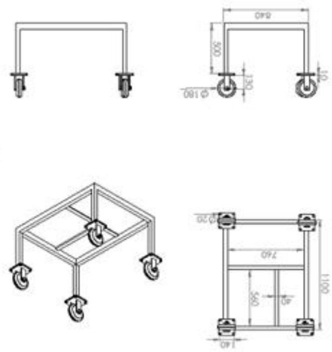
APPENDIX C3



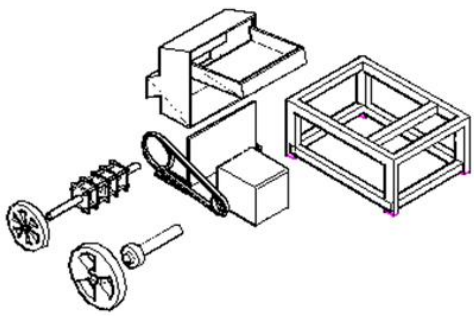
APPENDIX C4: BEARING



APPENDIX C5: FRAME



APPENDIX C6: EXPLODED VIEW



APPENDIX D: COMPLETE IMAGE