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Development and Performance Evaluation of Maize Threshing and Grinding Machine

Ugwu K. C.[1] and Omoruyi A.[2]
[1]*Department of Agricultural and Bioresource Engineering, Enugu State University of Science and Technology, Enugu, Nigeria*
[2]*Department of Agricultural Engineering Technology, Edo State College of Agriculture, Iguoriakhi, Edo, Nigeria*

ABSTRACT: *The Maize threshing and grinding machine was designed, fabricated and its performance was evaluated. The machine consists of two compartments which include the threshing and grinding chamber. Threshing chamber is where the maize grain is been separated from the cob, and the cob will be collected through the outlet chute. Therefore, before the maize grain enters into the grinding chamber, blower will separate the grain from the chaff. The separated grain enters the grinding chamber and is being grounded by compressive means through the stationary disc and the grinding plate. A 2 hp electric motor provides drive through belt connections to drive the pulley on threshing chamber and another 2 hp electric motor provide drive for the grinding chamber. The actual test was conducted using three different moisture contents and feed rates. It was observed that the efficiency of the machine was hindered by high moisture content. The results obtained showed that the machine performed well at low moisture content. The efficiency of the machine was 99.01% on the moisture content of 10%. The analysis of variance (ANOVA) of the results obtained at 5% percent probability confirmed that the moisture content of the maize was an important parameter that affects the performance of the machine.*

Keywords*: Development, Performance Evaluation, Maize, Threshing, Grinding, Machine.*

I. INTRODUCTION

Maize, the American Indian word for corn, means literally that which sustains life. It is, after wheat and rice, the most important cereal grain in the world, providing nutrients for humans and animals and serving as a basic raw material for the production of starch, oil and protein, alcoholic beverages, food sweeteners and, more recently, fuel [6]. In Nigeria, maize has become a staple food crop that is known even to the poorest family. It is used in various forms to alleviate hunger, and such forms include pap or ogi, maize flour, etc. It is because of the relevance of maize that it's processing and preservation to an optimum condition must be analyzed; the major steps involved in the processing of maize are harvesting, drying, de-husking, storing, threshing and grinding. For the rural farmers to maximize profit from their maize, appropriate technology that suites their needs must be used. The processing of agricultural products like maize into quality forms not only prolongs the useful life of these products, but increases the net profit farmers make from mechanization technologies in such products. One of the most important processing operations done to bring out the quality of maize is threshing and grinding of maize [2].

Maize is a tall, determinate, monoecious, annual plant. It produced large, narrow, opposite leaves, borne alternatively along the length of stem. All maize varieties follow same general pattern of development, although specific time and interval between stages and total number of leaves developed may vary between different hybrids, seasons, time of planting and location.

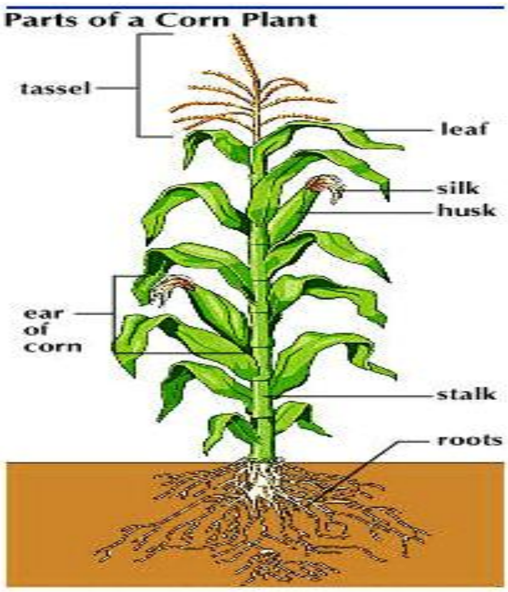


Fig 1: Parts of a fully matured maize plant [3].

Harvesting, handling and storing of maize on farm can help producers and farm managers control elevator discounts and improve economic returns to their operation. The use of such facilities requires operators to maintain grain quality from the field to the point of sale to capture market premiums [4].

Treatment of maize soon after harvest often determines the storability of a crop and can strongly influence its quality when delivered to the end user which may be several weeks, months, or even years after harvest. Thus, it behooves maize farmers to implement sound maize harvest, handling, and storage practices to maintain good quality maize to the global market. Successful post-harvest grain processing with on farm facilities requires a thorough understanding of the factors that influence grain quality [5]

There are different types of maize threshing machines which include the hand held thresher, small rotary hand thresher and free-standing manually operated thresher. The different methods of maize grinding can be categorized based on various mechanization technology used. These includes: manually operated and electric motor driving. Manually operated involves the use of hand in operating the maize grinding machine, while electric motor driving involves the use of motor for running the engine. The electric motor technology involves the use of mechanical assistance in grinding the maize [8].

The physical and mechanical properties of maize are a wide knowledge that can be useful in maize fanning, harvesting and storage or in processing such as drying, freezing and others. This knowledge is important in the designing and constructing of maize thresher and grinder and also in preparation of processing chain from grain to food. Accurate design of machines and processes in the food chain from harvest to table requires an understanding of physical properties of raw material [1].

The maize grain gives the highest conversion ratio to meat, milk and eggs when is compared with others grains used as livestock feed, this is due to its high starch and low fibre content which make it a very concentrated source of energy for livestock production. Although there is not available statistic for maize and livestock use, it is believed that greater portion is used as poultry feed in tropical countries. Yellow maize is preferred for livestock feed and it is used as whole grains, cracked or coarse ground, dry or wet or steamed and generally supplemented with vitamins and others proteins [9].

Traditional threshing and grinding methods do not support large-scale processing of maize, especially for commercial purposes. In Nigeria, the region that is the highest producer of maize is the northern part of the country and it was observed that most processing of maize is done manually. The multipurpose processing machine helps to reduce the work load of moving the materials from one location to the other.

The main objectives of this project are to design and construct a maize threshing and grinding machine and to test its performance.

II. MATERIALS AND METHODS

An electrically operated vertical maize threshing and grinding machine, efficient and economically viable was designed and fabricated with readily available and cheap materials (suitable engineering materials that could give optimum performance in service). The materials used in fabricating the machine were chosen on the basis of their availability, suitability, economic consideration, viability in service etc. The components parts of the machine were designed, fabricated and tested. The parts and their quantity are given in the part list below.

Shafts design consideration.

The shaft is a cylindrical solid rod for transmitting motion through a set of load carried on it. The shaft uses for the threshing is loaded by a perforated drum, bearings, pulley, and belt tension. All these forces act on the shaft. The design is based on fluctuating torque, bending moment and shearing force. These called for knowing the combined shock and fatigue on the shaft. To determine the shaft diameter, we adopt the formula;

$$d^3 = \frac{16}{\pi \delta_{sy}} [(K_b M_b)^2 + (K_t M_t)^2]^{\frac{1}{2}} \quad [7]$$

Where;

d = diameter of shaft (mm)

K_b = combined shock and fatigue factor for bending moment.

K_t = combined shock and fatigue factor for torsional moment.

M_b = Resultant bending moment (Nm)

M_t = Resultant torsional moment (Nm)

δ_{sy} = Allowable shear stress (MN/m^2)

π = constant, 3.142

Capacity of the Thresher

A horizontal threshing drum (Fig.2) which operates inside a close fitted tube to effect the threshing of the maize from cob was designed for the machine. The threshing drum is designed with perforated openings at uniform diameter.

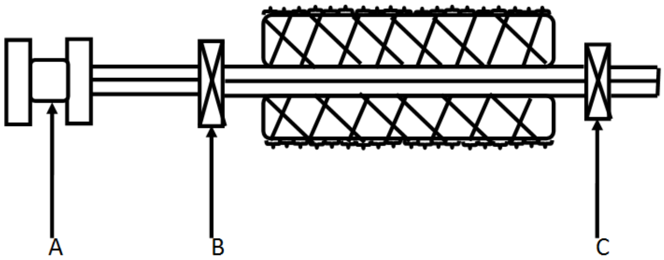
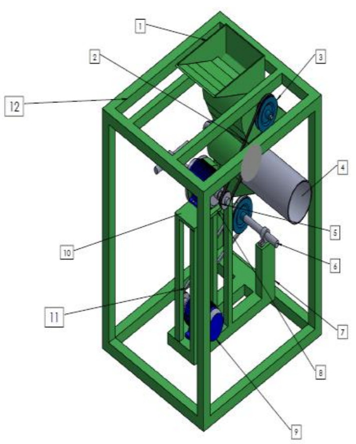


Fig 2: Maize Thresher Shaft with Perforated Drum

Principle of Operation of the machine

The machine for threshing and grinding maize has two chambers. These are the threshing and grinding chambers. A 2 hp electric motor provides drive through belt connections to drive the pulley on threshing chamber and another 2 hp electric motor provide drive for the grinding chamber. The maize cobs were introduced to the machine through the hopper which will be received by the first chamber. The threshing will be done with the help of the perforated drum and the blower which was incorporated close to the threshing chamber separates the chaff from the corn. The whole corn will enter into the second chamber for grinding through the help of stationary and moving plates against each other.



NO	NAME
1	HOPPER
2	BELT 1
3	PULLEY
4	CHAFF OUTLET
5	ELECTRIC MOTOR
6	GRINDING SHAFT
7	CARRIAGE
8	ELECTRIC MOTOR 1 SEATING
9	ELECTRIC MOTOR 2
10	ELECTRIC MOTOR2 SEATING
11	BELT 2
12	FRAME

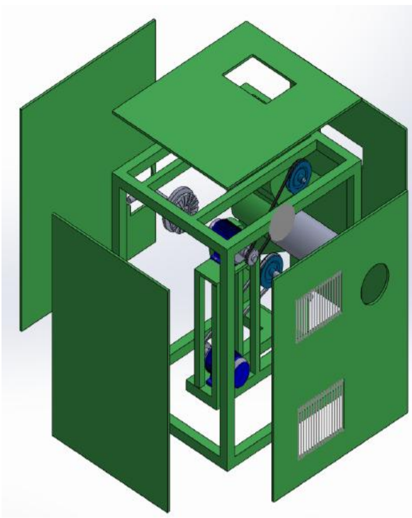


Fig 3: Isometric view of the threshing and grinding machine

Fig 4: Exploded View of the Machine

Testing the Machine

The machine was first run without load using two quantity of an electric motor of 2 hp to ascertain the smoothness of operation for the machines rotating parts. The actual test was conducted using three different moisture contents and feed rates. Testing of the machine was targeted at evaluating its threshing and grinding efficiency, through put capacity and percentage recovery rate. The results obtained were analyzed using analysis of variance (ANOVA).

III. RESULTS AND DISCUSSION

The efficiency of the machine was determined at three different moisture contents which include 10%, 15% and 20% using three different feed rates of 75kg, 95kg and 115kg of maize. The performance test carried out was to determine the machine shelling and grinding efficiency, the through put capacity and percentage recovery rate at a fixed time of 20 seconds. From the results presented in table 1, it was seen that the machine efficiency increases at a reduced moisture content. The average efficiency of the machine recorded highest, which was 96.52% at 10% moisture content and lowest, which was 87.18% at 20% moisture content. It was also observed that the average recovery rate of the grounded maize was highest, which was 35.25kg at 10% moisture content and lowest, which was 33.43kg at 20% moisture content.

The results obtained from the machine using 95kg of maize as feed rate at 10%, 15% and 20% moisture contents was shown in table 2. The average efficiency of the machine was highest, which was 99.01% at 10% moisture content and lowest, which was 88.48% at 20% moisture content. The results also showed that the average recovery rate of the grounded maize was highest, which was 37.96kg at 10% moisture content and lowest, which was 27.75kg at 20% moisture content.

The results obtained using 115kg of maize as feed rate at three different moisture contents was shown in table 3. It was also seen that the average efficiency of the machine was highest, which was 98.43% at 10% moisture content and lowest, which was 87.07% at 20% moisture content. The average recovery rate of the grounded maize was highest, which was 39.83kg at 10% moisture content and lowest, which was 36.53kg at 20% moisture content.

Table 4 showed the analysis of variance (ANOVA) of the results obtained at 5% percent probability, which signified that the moisture content of the maize was an important parameter that affects the performance of the machine. Feed Rate does not affect the performance of the machine significantly according to the analysis of variance results

Table 1: Machine performance at 75kg feed rate on three different Moisture Contents

Moisture Contents (%)	Weight of maize introduced (kilograms)	Weight of cobs received (kilograms)	Weight of maize ground (kilograms)	Weight of chaff (kilograms)	% variation	Machine efficiency (%)	Time of operation (Seconds)
10	75	36.18	35.98	1.62	1.63	95.20	20
	75	35.12	34.63	2.12	4.17	97.18	20
	75	37.34	35.31	1.20	1.53	95.12	20
	75	35.86	36.34	1.79	1.35	96.67	20
	75	36.97	33.98	2.76	1.72	98.41	20
	Average	**36.29**	**35.25**	**1.90**	**2.08**	**96.52**	**20**
15	75	35.73	36.44	2.61	0.29	93.87	20
	75	36.76	32.90	2.67	3.56	92.83	20
	75	34.94	33.93	2.73	4.53	93.47	20
	75	35.47	34.69	2.67	2.89	93.65	20
	75	37.43	34.12	1.33	2.83	93.28	20
	Average	**36.07**	**34.42**	**2.40**	**2.82**	**93.42**	**20**
20	75	35.20	32.80	3.40	4.80	89.71	20
	75	36.55	34.78	1.55	2.82	86.44	20
	75	36.23	32.79	2.32	4.88	85.47	20
	75	38.21	32.15	2.14	3.33	87.11	20
	75	37.33	34.61	1.87	1.59	87.17	20
	Average	**36.70**	**33.43**	**2.26**	**3.48**	**87.18**	**20**

Table 2: Machine performance at 95kg feed rate on three different Moisture Contents

Moisture Contents (%)	Weight of maize introduced (kilograms)	Weight of cobs received (kilograms)	Weight of maize ground (kilograms)	Weight of chaff (kilograms)	% variation	Machine efficiency (%)	Time of operation (Seconds)
10	95	48.45	42.63	3.12	0.84	99.16	20
	95	61.23	31.50	1.97	0.32	99.68	20
	95	60.83	32.12	1.27	0.82	99.18	20
	95	51.39	41.24	1.21	1.22	98.78	20
	95	49.39	42.30	1.67	1.73	98.27	20
	Average	**54.26**	**37.96**	**1.85**	**0.97**	**99.01**	**20**

15	95	62.45	28.97	2.23	1.42	91.59	20
	95	64.33	27.12	1.81	1.83	94.01	20
	95	56.32	36.78	1.25	0.68	92.29	20
	95	57.97	33.22	2.08	1.82	93.56	20
	95	62.89	28.12	2.23	1.85	92.72	20
	Average	**60.79**	**30.84**	**1.92**	**1.52**	**92.85**	**20**
20	95	55.67	32.13	3.96	3.41	88.58	20
	95	61.96	30.15	1.95	0.99	88.17	20
	95	64.76	25.21	2.46	2.71	89.32	20
	95	63.34	29.13	1.16	1.44	88.18	20
	95	68.66	22.12	2.05	2.28	88.15	20
	Average	**62.88**	**27.75**	**2.32**	**2.17**	**88.48**	**20**

Table 3: Machine performance at 115kg feed rate on three different Moisture Contents

Moisture Contents (%)	Weight of maize introduced (kilograms)	Weight of cobs received (kilograms)	Weight of maize ground (kilograms)	Weight of chaff (kilograms)	% variation	Machine efficiency (%)	Time of operation (Seconds)
10	115	70.98	40.13	1.97	1.67	98.33	20
	115	67.23	45.34	1.12	1.34	98.66	20
	115	70.76	40.05	2.53	1.44	98.56	20
	115	72.73	38.43	2.72	0.97	99.03	20
	115	74.67	35.21	2.32	2.43	97.57	20
	Average	**71.27**	**39.83**	**2.13**	**1.57**	**98.43**	**20**
15	115	76.97	32.44	1.84	3.26	94.04	20
	115	66.34	43.55	2.46	2.30	93.67	20
	115	65.12	43.23	2.67	3.46	94.14	20
	115	74.32	36.45	2.14	1.82	91.48	20
	115	73.56	38.95	1.53	0.83	92.07	20
	Average	**71.26**	**38.92**	**2.13**	**2.33**	**93.08**	**20**
20	115	80.50	31.69	1.71	0.96	86.74	20
	115	77.93	32.91	2.63	1.33	87.70	20
	115	71.74	41.22	1.05	0.86	86.54	20
	115	69.43	38.96	2.56	3.52	88.18	20
	115	72.33	37.86	1.44	2.93	89.17	20
	Average	**74.39**	**36.53**	**1.88**	**1.92**	**87.67**	**20**

Table 4: ANOVA for the effect of moisture content and feed rate on the machine performance

Variate: EFF					
Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
FER	2	8.8265	4.4132	4.42	0.019
MC	2	782.5655	391.2827	392.16	<.001
FER.MC	4	13.4281	3.3570	3.36	0.019
Residual	36	35.9191	0.9978		
Total	44	840.7392			

EFF = Efficiency
FER = Feed Rate
MC = Moisture Content

IV. CONCLUSION AND RECOMMENDATION

The threshing and grinding machine was designed, fabricated and tested. The results obtained showed that the machine performed well at low moisture content. The highest average efficiency of the machine was 99.01% at 10% moisture content using 95kg of maize as feed rate and the lowest average efficiency was 87.07% at 20% moisture content using 115kg of maize as feed rate. It was observed that moisture content affect the performance of the constructed machine. The recovery rate of the grounded maize was highest at 10% moisture content and lowest at 20% moisture content. The feed rates used to test the fabricated machine do not show any significant variation on the machine efficiency. The dual purpose of threshing and grinding of maize at the same time reduced the labour cost and time involved in processing of maize. The machine is recommended to the farmers and other processors of maize because of its time limitation, ease of operation and good quality of grounded maize. For hygienic, better purposes, and better quality of grounded maize, a stainless steel materials is recommended for the construction. I recommend the use of one electric motor on modifying the machine.

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