



Design, Fabrication and Performance Evaluation of a Motorized and Manually Operated Mobile Maize Shelling Machine

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ABSTRACT

The study was conducted to design, fabricate and carry out performance evaluation of combined motorized and manually operated mobile maize shelling machine using three different moisture contents. The maize Sheller machine was driven manually and mechanically using a winding handle and a petrol motor connected to a belt and pulley system operated at a steady concave clearance of 25mm. In this study different parameters affecting performance of maize shelling were established. The performance of the maize Sheller was tested at three different moisture contents (7.10%, 9.12% and 11.51%) and feed rates of (2kg, 4kg and 6kg) the results were analyzed using ANOVA as a statistical tool for the machine performance. The results showed that crop moisture content significantly affected the performance of the maize Sheller machine. Among the three selected moisture content, 11.51% moisture content, produced the best output result without breakages. The motorized operation output of the machine (Mean = 126.96; SD = 127.79) significantly had higher performance output than the manual operation output (Mean = 34.03; SD = 36.21) with a shelling efficiency of 99.9%, shelling capacity of 276.92kg/hr, cleaning efficiency of 80%, Grain breakage of 0.44%. This machine can substantially reduce the human labour and time for shelling operation.

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INTRODUCTION

Many farmers and investors have gone into commercial maize farming with the aim of maximizing profit on investment, but only a few may have been successful, most may have abandoned their farms due to high cost of purchasing sheller, hiring and transporting them on farm for number of hours which require higher finance. Most mechanical shellers are designed for multi-grain threshing or shelling, which causes great damage to the maize. The locally available maize shelling machines either motorized or manually operated are without blower unit for cleaning (winnowing), some of the machines are been driven by electric motors which are powered by electricity and petrol which are sometimes scarce, conveying (movement) of these machines on farm or home yard is also another problem to

our rural farmers which is why these researchers have developed a motorize and manually operated mobile maize shelling machine incorporating a blower for ease of cleaning, tyer wheels and a push handle for easy movement and placement on the farm with a sitting for both petrol and electric motors with a replaceable concave housing. This housing has a great advantage to the farmers such that the same machine can also perform other functions of threshing and shelling by replacing with a specific designed concave.

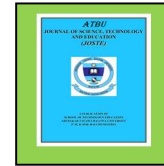
Maize, the American Indian word for corn literally means that which sustains life. After wheat and rice, it is the most important cereal grain in the world, providing nutrients for humans and animals and serving as one of the basic raw material for the production of starch, oil and protein, alcoholic beverages, food sweeteners

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and, most recently, fuel (Nwakire, Uguishiwu & Ohagwu, 2011). It is because of the importance of maize that its processing and preservation to an optimum condition must be analyzed. The major steps involved in the processing of maize are harvesting, drying, de-husking, shelling, winnowing, storing, and milling. For the rural farmers to maximize profit from their maize, appropriate technology that suits their needs must be developed. The processing of agricultural products like maize into quality forms not only prolong the useful life of these products but increases the net profit farmers make from mechanization technologies of such products. One of the most important processing operations done to bring out the quality of maize is shelling or threshing of maize.

In Nigeria, maize serves as a staple food for a very significant portion of the Nigerian population. Peasant farmers are responsible for more than 70% of the maize produced annually while large scale commercial farmers constitute the remaining 30% (Adewumi, 2004). Notwithstanding that Peasant farmers are responsible for more than 70% of the maize produced annually, they are faced with incessant challenges of post-harvest processing and storage. The problems of post-harvest processing and storage of agricultural produce are well documented and various approaches are being employed in tackling it. Kaul & Egbo, (1985) reported that maize harvested is traditionally shelled by hand or by beating sacks stuffed with maize cobs with wooden flails. Akubuo (2003) explain further that the traditional method uses pestle and mortar with the dry maize put into the mortar, and pestle is used to hit the maize with impact forces. These traditional methods of shelling maize are time wasting, hazardous and associated with lots of drudgery. By the traditional method, a considerable quantity of shelling is achieved per time but the amount of grain damage is high with low cleaning efficiency (Ologunagba, 2008).

Today, outside the traditional methods of beating sacks stuffed with maize cobs with wooden flails and use of pestle and mortar, various mechanical and electro-mechanical

methods are available. Adewale, Adelowo and Solagbade (2002) and Adegbulugbe, (2000) explained that the detachment of the grain from the cob is affected by its moisture content. This implies that shelling process is a function of moisture content. It is easier to shell maize dry than wet. Adewale *et al.* (2002) reported that the local techniques of shelling and winnowing of shelled maize is grossly inefficient judging by the serious bruises encountered by the crop. Given the serious losses and inefficiency in the post-harvest processing method of maize that is associated with traditional shelling methods arising from maize bruises as mentioned, there became a need for improved shelling methods. Today, there are varieties of improved maize shelling machines.

The motorized shelling machine which remains the most efficient and effective shelling machine is often imported but are also locally fabricated. Facts and evidences available as presented by Adewumi, (2004) revealed that locally fabricated motorized maize shelling machines by local welders are without both the machine and crop parameters suitable for curtailing damages associated with the traditional method. Similarly, designed and fabricated maize shelling machines, use electric motors which require availability of electricity which is not available in majority of the villages in the study area. Also for those that use fuel, the experience does not differ with the cost of running petrol or diesel engine, Nigeria farmers therefore have to pay exorbitantly to shell their produce.

In the quest to overcome these challenges, Adesuyi, (1983) suggested the design of a shelling machine that saves farmers cost associated with post-harvest losses that is attributed to damages incurred during shelling and cost of transportation of produce for shelling at the end of the processing operation. It is against this background that this study chooses to design a safe shelling parameters machine that will be motorized and manually operated, powered by a fuel engine which may also be powered via national electricity and incorporated with a blower and a mobile facility targeted at overcoming the challenges of kernel brushes, crushing of cobs

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drudgery, time consumption and shelling transportation cost noticed with the traditional method and existing fabricated machines. Hence the problem of the study is to design, fabricate and carry out performance evaluation of a low-cost combined motorized and manually operated mobile maize shelling machine.

Hussen, Teka and Dubale (2015) In their study, emphasis were given to avail compact multi-crop thresher accomplishing maize shelling by modifying the existing crop threshers to accommodate replaceable bar type drum besides units for threshing wheat, teff, sorghum and barley using peg type drum. The thresher operates on the principle of axial flow movement of the material. It was tested on maize, wheat, teff, sorghum and barley crops. The values for highest visible grain damage, optimum thresher's output capacity, threshing and cleaning efficiency were observed at the maximum threshing drum speeds of 910, 1600, 1550, 1600 and 1690 rpm for maize, wheat, teff, sorghum and barley crops respectively. These threshing drum speeds under grain moisture content of 13%, 9.6%, 7.6%, 9.8% and 12.1% wet basis (w.b) indicated optimum threshing performance for the mentioned crops respectively. The mean output capacities of 2526.31 kg/hr, 386.98 kg/hr, 237.2 kg/hr, 780.68 kg/hr and 121.62 kg/hr for average grain-straw (cob) ratios of 1:0.36, 1:2.22, 1:2.56, 1:0.21 and 1:1.29 were recorded for maize, wheat, teff, sorghum and barley crops respectively.

Tekalign (2018) improved on a small-engine driven sorghum thresher that was produced at Fadis Agricultural Research Center with an intention to solve critical threshing problem of farmers consecutively reducing cost of threshing, labor power and grain loss. The machine was produced in the work shop according to its improved design of drum; concave, and other machine parts. Drum and concave diameter, length, thickness of row materials made of and other machine parts were diminished. The weight of the machine and its cost was decreased. The machine was tested in East Hararghe Zone, Haramaya District at a place called Ganda Haqaa. The variables considered were grain 19 and 23 mm and three feed rates (30,

45 and 60 kg/min).The selected experimental design was split-split plot design with three replications. During testing grain moisture content was maintained at 14-16% wet basis. After the test it was observed that the threshing efficiency varied from 88.97 to 97.08%. The obtained output capacities were between 6-8.36 qt/h for the evaluated two sorghum varieties. The average specific fuel consumption was acquired 0.096 lit/qt and 0.103 lit/qt for Muira and Fendisha respectively. The machine in this study is also aimed at reducing cost to farmers.

Hossain, Tiwari, Gulandaz & Jahan (2017), who developed a cost effective two wheel tractor mounted mobile maize sheller for small farmers in Bangladesh (2WT). The shelling capacity, shelling broken kernel, and cylinder loss (the amount of corn left unshelled on the cob) of the mobile maize sheller of 2100 kg/h, 2.3%, 0.35%, respectively. The efficiency of the mobile maize sheller was 97%. The effective operating hours of the mobile maize sheller is more, compared to the traditional power sheller as a result of the 2WT, showing the effective hours used by the mobile maize sheller and the traditional maize sheller as 6.5 hrs and 4.5 hrs, respectively in a day. This indicates that the mobile maize sheller saves two hours per day, that is this sheller can be used two hours additionally in a day compared to, the traditional maize sheller. The basic concept of the mobile maize sheller is that the shelling unit is to be assembled with the transportation power unit and the service providers freely carry the maize sheller from farm to farmers' home yard in assembling position. So, it can reduce the maize sheller installation and starting time.

The current study is built on the mentioned concept; it is with it that the current study has designed a shelling unit with a blower attached to a frame with tyer wheels and a push handle. The difference between the design and current study is that the shelling unit was mounted on a two wheeled driven tractor which served a dual purpose of shelling and driving completely eliminating the human push efforts, but was without a cleaning unit (blower), the shelling unit was only attached to an already existing machine

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designed for tillage. In the current study the prime mover will no longer drive the wheels but will power the blower and the shelling unite. The current study has further designed a solid frame to accommodate the maize sheller designed components including the prime mover that can be pushed with less human effort.

Azeez et al (2017) evaluated the performance of a maize sheller machine that is capable of shelling maize of various sizes and has a shelling efficiency of 91.29 % and minimal 0.12 % grain damage and an average shelling capacity of 55 kg/hr. The machine operates smoothly and efficiently. The shelled grains flow freely through the grain outlet, the chaffs are being blown off in opposite direction by the blower while the cobs are discharged easily through the cob outlet. It is less bulky and the ergonomic considerations in the design would allow for its comfortable use in a standing posture for it can easily be operated by either male or female subjects. The difference with the design and current study is that the machine uses an electric motor which limits it to a stationary use; preventing the local farmers on the field in most rural areas access to usage which was one of its most targets. The current study intends to combine the manual, petrol and Electrical sources of power, which can be operated on the farm and at home.

The design also used a one way belt system for both shelling and winnowing, which the angle of contact was too wide causing slippage of the belt with high risk of damage to the belt. The intended design incorporates a double belt system for both the shelling and winnowing to create a more closed angle of contact that will create a high grip. Furthermore, the Azeez et al (2017) design also has a hopper attached directly to the cover of the shelling unit, which causes a (throw out) push out of the unshelled maize towards the end of the shelling process. The intended study has designed a hopper attached to the cover of the shelling unit at an inclined angle to minimize the push or throw out of the unshelled maize and cobs out of the machine during operation. Candia *et al.* (2004) designed only the shelling concave unit that could be able to withstand the shelling forces of the machine beaters. The modified design was

adopted in the design to enhance effective efficiency and higher output for commercial maize farmers as recommended by the institute.

STATEMENT OF THE PROBLEM

With the advancement of technology across the globe, machines have found important application in agriculture particularly in maize shelling. In Nigeria, shelling of maize by majority of local farmers is done by hand. Hand shelling involves the use of hands or hand operated simple devices in shelling maize. Hand shelling is cost effective, but the techniques take a lot of time and drudgery. At present, it is noticed that transportation of maize sheller from place to place by local farmers is a problem. Besides the high cost of purchasing sheller, hiring and transporting to farms for a number of hours also require higher finance. Overcoming these challenges, requires developing a maize shelling machine with higher efficiency, better product quality and powered with small petrol engine to reduce human drudgery associated with manual method of shelling and cleaning maize grain, shelling and cleaning losses and shelling time associated with the manual method and also to ensure affordability of the machine for rural and commercial farmers. The combined motorized and manual operation will enable the machine to be used in remote places that have no electricity, the incorporated winnower will serve as an advance separator of cobs that may penetrate concave opening which will curtail the time consumed for carrying out further manual winnowing while the mobile facility will facilitate mobility of the machine to any location thereby saving transportation cost required to move maize to the shelling venue.

Purpose of the Study

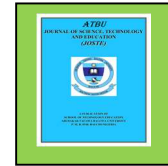
The purpose of this work is to design, fabricate and carry out performance evaluation of a combined motorized and manually operated mobile maize shelling machine. The specific purposes are to:

1. Compare the effect of moisture content on the performance of the maize shelling machine.

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2. Compare the performance of the motorized and manually operated methods.

Research Question

1. What is the effect of moisture content on performance of the machine?
2. What is the difference between manual operation and motorized operation on the output performance of the maize shelling machine?

Null Hypotheses

1. There is no significant effect of moisture content on performance of the maize sheller machine.
2. There is no significant difference between manual operation and motorized operation on the output performance of the maize sheller machine

Materials and methods

Figure 1 and 2 presents the pictorial views of the fabricated motorized and manually operated mobile maize shelling machine which consist of a pulley and belt system. It has a blower

which enables the farmers clean their produce after shelling. This machine also has tyer wheels and a push handle which enables the farmers' ease of movement and setting up the shelling environment. It also has a provision for a winding handle which enables operation when there is no alternative source of power and as such can be purchased in stages to the farmers' advantage. It has a replaceable or interchangeable designed concave for additional cereal crop processing as may be desired by farmers. Aside the machine being originally designed for maize shelling, it can as well be used for shelling of other cereal crops by interchanging the concave. (7.10%, 9.12% and 11.51%) moisture content and three different feed rates of (2kg, 4kg and 6kg) was used and the maize sheller machine was subjected to test and was found to shell maize very effectively. Hybrid maize (HAMMAZE 52) samples was cleaned, weighed and tested for each of the operation. Research questions were answered using the mean and hypotheses tested at 0.05 significant level using analysis of variance (ANOVA), t-test and the Graphic Rating Scale was used to represent the performance.

Table 1: Summary of component's design Analysis

A	Components Designed	Designed Specification Cons. Mat
1	Hopper	The hopper capacity is 0.00057m ³
2	shelling beater	The shelling beater has a volume capacity of 0.00053m ³ , attached to a shaft of diameter 26mm
3	Shelling beater and fan belt	The driver pulley has a diameter of 150mm while the driven has a diameter of 300mm, having a center to center distance of 450mm.
4	Motor(prime mover) and fan belt	The driver pulley has a diameter of 60mm and the driven 150mm having a center to center distance of 430mm.
5	Power source	The machine is motorized and manually operated with the use of a winding handle or a power source connected to the pulley and belt arrangement.
6	Concave	Concave has a volume of 6.475m and diameter 260mm connected with 8mm diameter steel rods in a Simi circular form of length 515mm.
7	Shaft	25mm diameter and 620 mm length

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A	Components Designed	Designed Specification Cons. Mat
8	Fan (blower)	The blower has a volume of 16.076N with a total air discharge rate of 0.231m ³ /s.
9	Bearing	The bearing type is a double sealed single row deep groove ball pillow block bearing ,number 205 with a bore of (25 mm diameter)



Figure 1: pictorial view of the motorized mobile maize shelling machine



Figure 2: pictorial view of the manually operated mobile maize shelling machine
 Evaluation of the machine

Hybrid maize samples was cleaned, weighed and tested for each operation. A maize sample of (2kg, 4kg and 6kg) at three different moisture contents (7.10%, 9.12% and 11.51%) was used to subject the maize sheller machine to test. Evaluation was done to compare the effect of moisture content on the performance of the maize shelling, machine and also to compare the performance of the motorized and manually operated method

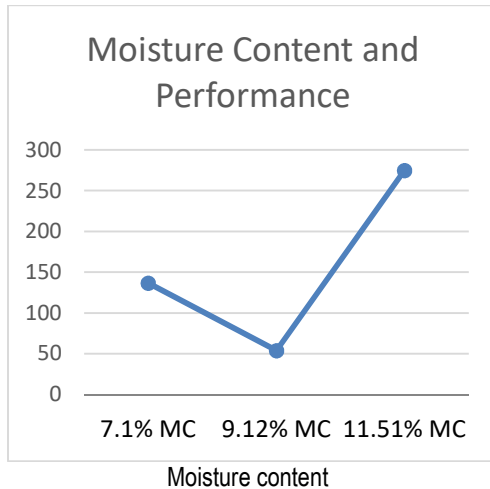
Determination of moisture content

The moisture content of maize were determined using seed moisture meter LDS-1H ModelPM-8188 (Gbabo et al., 2013; Ogunlade et al., 2014). Three different maize hybrid accession, (order of acquisition) were collected, cleaned and placed in nylon bags and taken to Joseph Saawuan Tarka University, Makurdi, Agricultural Engineering Processing Laboratory for initial moisture content determination. The first two accessions were sourced from the researchers farm at Genyi Yandev Gboko, the third sample was purchased at National Cereal and Research Institute Yandev Gboko Benue State. The moisture content for the first two was 7.10% and 9.12% moisture content respectively while the third had 11.51% moisture content. These moisture contents were the natural moisture contents of the crop at the time the Sheller was ready for evaluation on completion of its construction.

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RESULTS

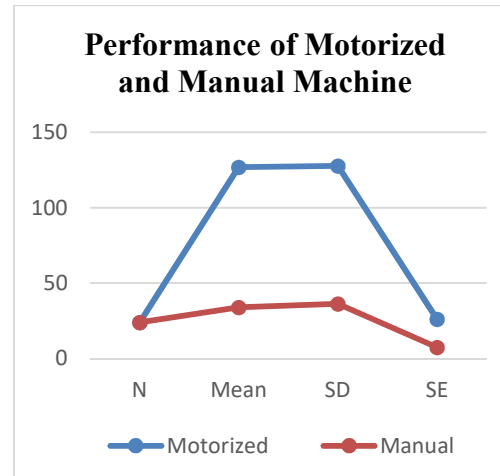
The effect of moisture content of maize on the performance of the maize shelling machine



Graph 1: Graph representing the effect of moisture content on performance

Result in graph 1 presents the effect of moisture content on performance of the maize shelling machine. Results shows that moisture of 11.51% had the highest mean performance, and this was followed by moisture content of 7.10% and lastly 9.12% moisture content respectively, indicating that at 11.51% moisture content the performance was higher with less grain breakages.

The difference between manual operation and motorized operation on the output performance of the maize shelling machine.



Graph 2 representing the difference between manual operation and motorized operation on the output performance of the maize sheller machine

A study of graph 2 shows the performance of motorized and manual machine operation on the output performance of the maize shelling machine. This result shows that, the motorized machine significantly has higher mean performance as compared to the manual operation. This shows that there is a decrease in manual operation with increase in motorized shelling as an advantage over the manual shelling in terms of shelling capacity output.

Table 2: Summary of One-Way Analysis of Variance (ANOVA) showing the effect of moisture content on performance of maize sheller machine.

Source of Variation	Sum of Squares	Df	Mean Square	F	Sig
Between Groups	788534.160	2	394267.080	9.159	.000
Within Groups	2814303.306	69	40787.004		
Total	3613837.470	71			

Result in Table 2 shows that, there is a significant effect of moisture content on performance of the maize Sheller machine [F (2, 69) = 9.159; p<.001].Based on this result the null hypotheses which stated that there is no

significant effect of moisture content on performance of the maize shelling machine is therefore rejected.

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Table 3: Summary of LSD multiple comparison showing the difference in moisture content on performance of the maize sheller machine

Variables	7.10%	9.12%	11.51%	Mean	SD	N
7.10%	-			136.95	117.79	24
9.12%	93.91	-		54.03	35.21	24
11.51%	140.09**	232.05**	-	275.05	334.60	24

To further test, the Least Significant Difference (LSD) multiple comparison test was conducted and the result is as presented in Table 3 showing the difference in moisture content on performance of the maize Shelling machine. The result in Table 3 shows that there is a significant difference between feed of 7.10% moisture content and 11.51% moisture content [LSD = 140.09; $p < .001$] as 11.51% moisture content significantly scores higher (Mean = 275.05; SD = 334.60) than 7.10% (Mean = 136.95; SD =

117.79). Furthermore, there was a significant difference between moisture content of 9.12% and 11.51% [LSD = 232.05; $p < .001$] as 11.51% (Mean = 275.05; SD = 334.60) significantly scored higher than 9.12% (Mean = 54.03; SD = 35.21). This implies that 11.51% moisture content (Mean = 275.05; SD = 334.60) is the best moisture content that produced the desired result as compared to 7.10% (Mean = 136.95; SD = 117.79) and 9.12% (Mean = 54.03; SD = 35.21).

Table 4: Summary of independent t-test showing the mean difference between manual operation and motorized operation on the output performance of the maize shelling machine

DV	Group	N	Mean	SD	SE	t	df	P
Performance	Motorized	24	126.96	127.79	26.08	3.427	46	<.01
	Manual	24	34.03	36.21	7.39			

Table 4 presents the summary of independent t-test showing the mean difference between manual operation and motorized operation on the output performance of the designed maize shelling machine. Result in Table 4 shows that, there was a significant difference between manual operation and motorized operation on the output performance of the maize shelling machine [$t(46) = 3.427$; $p < .01$]. Observation further revealed that, motorized operation output of the machine (Mean = 126.96; SD = 127.79) significantly had higher performance output than the manual operation output (Mean = 34.03; SD = 36.21). Based on this result, the null hypothesis which stated that 'there is no significant difference between manual operation and motorized operation on the output performance of the machine' was therefore rejected.

CONCLUSION

The results revealed that there is a significant effect of moisture content on performance of the machine; $p < .001$. The result further shows through observation of the mean difference that 11.51% moisture content (mean=275.05: SD=334.60) is the best moisture content that produced the desired result for the designed machine. This shows that the moisture content of maize played an important role in post-harvest operation, precisely in shelling to avoid deterioration of the grain. The motorized operation output of the machine also has the highest (mean 126.96; SD=127.79) against the manual operation, this implies that there is a decrease in manual operation with increase in motorized shelling as an advantage over the manual shelling in terms of shelling capacity output. This again implies that, the shelling time for maize is shortened and quality is assured, giving farmers

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better processed product with higher economic prospects.

RECOMMENDATIONS

1. Individuals who are capable should purchase the maize shelling machine for personal and commercial purpose.
2. Starter entrepreneurs could benefit as business ventures, creating widespread awareness by producing this machine in large quantities and making them available to maize farmers.

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