



Interactive Effect of Feed Rate, Beater Speed and Moisture Content on Motorized Mobile Maize Shelling Machine

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ABSTRACT

This study was conducted on a fabricated motorized mobile maize shelling machine using hybrid maize sample at three different moisture content, beater speed and feed rate. The maize Shelling machine was driven mechanically using 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%) three beater speed (300rpm, 350rpm and 400rpm) and three different feed rates (2kg, 4kg and 6kg) and the results were analyzed using ANOVA and Graphic Rating Scale as a statistical tool for the machine performance. The results showed that, there is a significant interactive effect of feed rate, speed and moisture content on performance of the maize shelling machine [$F(6, 63) = 3.492; p < .05$]. With eta coefficient [$\eta = 0.176$] showing that, feed rate, beater speed and moisture content significantly and jointly contributed 17.6% of the total variance in performance of the maize shelling machine. This implies that feed rate, beater speed and moisture content are all parameters that affected effective performance of the machine. The best combined factors most suitable for the detachment of maize grains from ear head for the designed machine is 350rpm at 6kg feed rate and 11.5% crop moisture content.

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INTRODUCTION

Maize, the American Indian word for corn, literally means that which sustains life. After wheat and rice, maize 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 and, most recently, fuel (Nwakire, Ugwuishiwu & Ohagwu, 2011). In Africa, maize has become a staple food crop that is known to poorest families. It is used to provide food in different forms such as pap, or maize flour, among others. 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-

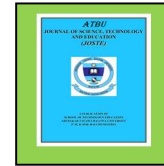
husking, shelling, winnowing, storing, and milling. For the rural farmers to maximize profit from their maize, appropriate technology that suites their needs must be developed. The processing of agricultural products like maize into quality forms not only prolong the useful life of these products but 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. It is also responsible for about 60% by weight of most of animal feed formulations like chicken, goats, cows, piggery, rabbit and fish feeds. A formulated 24% CP broiler starter contains 51.3% maize, 31.7% cotton seed

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cake, 3.0% blood meal, 5.0% beniseed, 3.0% of bone meal with DL – methionine, L – Lysine, HCL mineral and vitamin. Premix, salt all fixed at 0.25% and oil (red) 5.0% respectively (Aduku, 2013).

Also, 21% broiler finisher contains 55.25% maize, 27.56% ground nut cake, 5.0% beniseed, soyabeans cake 10%, bone meal 3.3% and methionine, premix, salt and L – Lysine, HCL all fixed at 0.25% (John and Gasha, 2015). 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. Maize farming has been slowly Expanding within the past few years in Nigeria and that this area would grow further to meet future food, feed, and other demands, especially in view of the booming livestock and poultry producing sectors of the economy. Since opportunities are limited for further expansion of maize area, future increases in maize supply will be achieved through the intensification and commercialization of current maize production systems. Maize shelling is one of the most important aspects of post-harvest operation of maize. The grains are detached from dried cobs by manual or mechanical device, which is known as shelling. This operation is highly labour intensive and more drudgery in addition to losses of grains in terms of quantity and quality (Chilur, Sushilendra, Veeranouda, Yaranal, Hiregoudar & Mareppa, 2014).

Maize shelling machines are divided according to their cylinders into (a) rasp-bar cylinder, which is used mainly for wheat, barley and other crops, (b) spike-teeth cylinder that is used for rice, beans and maize and (c) angle-bar cylinder, which used for all crops. On the other hand, those machines also are classified in respect to the flow direction (a) cross flow which is considered to provide good feed to the threshing clearance between the cylinder and concave at higher peripheral cylinder speed, and (b) axial flow with good performance of shelling but have higher power consumption El-Gayar (2005).

Many researchers have evaluated the factors affecting shelling performance such as: machine parameters which include Drum speed, Cylinder Concave clearance, Feed rate, concave length and Fan Capacities (Akaaimo & Nyon 2004). Crop parameters which include, moisture content, strength of the grain, shape and size of the grain, Density, specific gravity and also Variety of the crops (Akaaimo & Nyon 2004). The shelling peripheral speed of a cylinder is an important factor affecting thoroughness of shelling and grain quality (Dziki, 2004). Increase in moisture content causes a reduction in the friction coefficient between the grains with increase moisture content (Dziki, 2004).

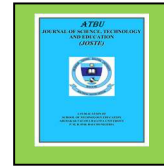
In a further study, machine productivity was also affected by the rotational speed cylinder, as well as the moisture content of grain. Increasing moisture content lead to increase the breakage percentage and decrease the total productivity of the machine (Alwan et al., 2016). El-Gayar (2005) studied the effect of thresher system and feed rates, results were obtained that, the unshelled seed losses decreased by decreased seed moisture content with higher feed rate (Al Sharifi et al. 2017) in a study, explained that there is a significant effect of the machine type, feed rate and moisture content on the energy consumption whenever the machine is on high speed with his final conclusion that, Increasing the machine rotational speed, cause a production increase.

Humburg (2016) reported that the capacity of a sheller is found significantly different for each sheller arrangement and speed combination at moisture contents, higher capacity of shelling (402.01 kg h⁻¹) was found when maize having 13 per cent moisture fed to sheller having cylinder rotating at a speed of 350 rpm with conclusion that, there was an influence of the machine type, clearance, moisture content, feed rate on whole grain and the production process of machine, an increased clearance and decreased moisture led to increase production process and whole grain percentage at a higher feed rate. Alwan et al (2016) concluded that the minimum mechanical damage of (3.1%) was obtained with the use of thresher with a speed of 600 rpm. This

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threshing speed resulted in good germination of (81.4%) and seed purity of (95.2%). (Kausal et al., 2003) reported that only the surface area and the kernel deformation are increasing with the increase of moisture content. Lupu et al. (2015) reported that organizing a machine has a direct effect on the productivity of the machine. The better the machine is organized, the higher the productivity is because of the low percentage of break-up and this is reflected positively on the increase machine productivity due to increased efficiency of the existing works (Abu Al Khair et al., 2005).

Purpose of the study

The main purpose of this work is to determine the interactive effect of the beater speed, feed rate and moisture content on the fabricated motorized mobile maize shelling machine. The feed rate beater speed and grain moisture content and their interactive effect on performance of the designed maize sheller machine are specifically determined.

Research Questions

1. What is the effect of feed rate on the performance of the maize sheller machine?
2. What is the effect of beater speed on the performance of the maize sheller machine?
3. What is the effect of moisture content of maize on the performance of the maize sheller machine?
4. What is the interactive effect of feed rate, speed and moisture content on the performance of the maize shelling machine?

MATERIALS AND METHODS

Description and operation principle of the machine

Figure 1 shows the pictorial view of the mobile maize Shelling machine. The machine consists of the hopper, shelling unit consisting of beaters and concave sieve, belt drives, bearings, shafts, fan (winnowing unit), pulleys, seed and chaff outlets. The frame is made of angle iron bars of adequate thickness of 35 x 35 x 2mm and 35 x 35 x 3mm for stability during operation, it will serve as a support base for all other components of the

mobile maize shelling machine, it is rigid such that it could withstand dynamic loading, (direct axial loading or torque). Its basic role is to provide a steady balance from all applied stress. The hopper is a major component that holds the unshelled maize, which then feeds it into the shelling chamber to be received by the rotating beaters.

The beaters (cylinder drum) is made up of structural members like, center plate, spike teeth and rails of mild steel materials formed in a cylindrical shape with a solid shaft arranged with spike teeth in rows, and a removable screen concave serving also as the sieve incorporated under with a fixed concave clearance that can accommodate the unshelled maize between the spike tooth and the screen concave. The operation of the Sheller machine is based on the use of beaters (spike tooth) which shells the crop with a rotary impact. The winnowing system (cleaning unit) this consist of the cleaning unit where the broken cobs and dust are separated by air current set below the terminal velocity of the seed with the aid of a blower powered by a 5.0hp petrol engine. When the mixture of seeds, broken cobs and dust fall through the cleaning unit, the horizontal air current from the blower lifts the cobs and dust out through the chaff and dust outlet. The power unit consists of the petrol engine, belt and pulley drives which transmit power to the cleaning and shelling units.

All these components are assembled and mounted unto the supporting frame. The raw materials to be shelled (maize) are introduced into the hopper and due to gravitational action; move in to the shelling unit, where it is received by the rotating cylinder spike and through the rubbing action against the fixed concave, the maize seed is shelled off the cobs. The shelled materials then fall by gravity into the cleaning unit where the blower then separates the chaff and dust from the seeds through the chaff outlet. The clean seeds then fall by gravity and are collected through the seed outlet. Rubber tyre wheels and push handles are attached to the frame for ease of movement. The Sheller can be operated by one person, who after assembling the shelling environment, starts and sets the engine to the required speed. Then feeds the machine with raw materials.

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PERFORMANCE EVALUATION OF THE MAIZE SHELLING MACHINE

The output performance of the machine in terms of shelling efficiency, was tested at three different moisture contents (7.10%, 9.12% and 11.51%) three beater speed (300rpm, 350rpm and 400rpm) and three different feed rates (2kg, 4kg and 6kg) Maize Sheller machine was subjected to test and it was found to shell maize very effectively. Hybrid maize samples was cleaned, weighed and tested for each operation. Research questions were answered using the mean and hypotheses tested at 0.05 significant level using analysis of variance (ANOVA), the graphic rating scale was used to represent the performance.

followed by 2 (kg) and lastly 4 (kg) feed rates respectively. The graph shows that there is an increase in the shelling throughput capacity of the machine with an increase in the feed rate.

Table 1: Component Parts of the machine

S/No.	Component	Engineering materials	Selection criteria
1	Hopper	Galvanized sheet, stainless steel, mild steel	Cost availability, workability and corrosion resistance
2	Beater	Mild steel rods	Availability, machinability, strength and cost
3.	Concave housing and casing	Mild steel sheet, stainless steel	Availability, machinability, strength and cost
4.	Frame	Mild steel angle bars	Strength, light in weight, rigidity
5.	Shaft	Mild steel	Machinability strength and availability
6.	Bearings/casing	High speed steel cast iron	Axial and radial loading
7.	Pulleys	Cast steel, mild steel	Machinability, strength
8.	Push handle	Stainless steel, galvanized steel, mild steel	Availability, machinability
9.	Belt guard	Mild steel, stainless steel	Strength, workability, machinability
10.	Rubber tyres	Rubber	Strength, resistance to wear, ability to withstand pressure
11.	Fan casing	Stainless steel, mild steel	Machineability, cost availability
12.	Fan blade	Mild steel sheet	Light in weight
13.	Chaff/grain outlet	Mild steel, stainless steel, plastic	Strength, corrosion resistance

RESULTS

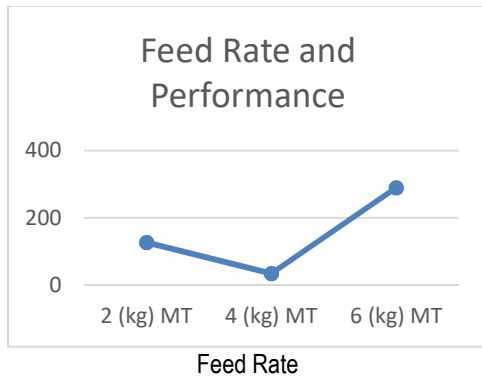
The Effect of Feed rate on the Performance of the Maize Shelling Machine

The effect of feed rate on the performance of the maize shelling machine can be interpreted from results as shown in Graph 1. A look at the graph shows that the mean performance was higher at 6 (kg) which was

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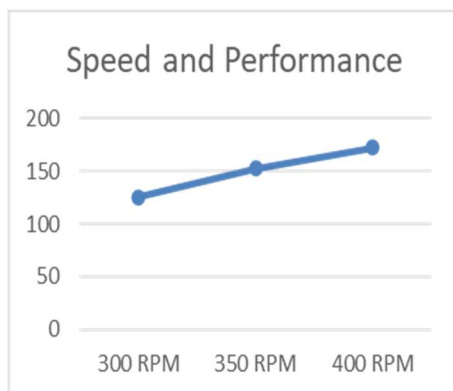
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Graph 1: Graph showing the effect of feed rate on performance of the maize shelling machine

The Effect of Beater Speed on the Performance of the Maize Shelling Machine

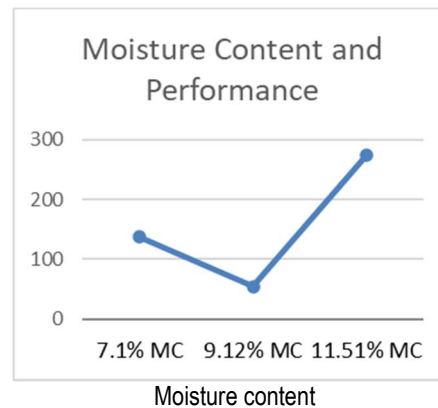
A study of graph 2 reveals the effect of beater speed on the performance of the maize shelling machine. The beater speed of 400 RPM had the highest mean which was followed by 350 RPM and lastly 300 RPM. This implies that at 400rpm speed the machine performed better without cohesive arching in the shelling chamber. This indicates that the speed increased the performance of the shelling machine, however broken and loosed grain are more at increased speed. That is to say that the throughput capacity increases as speed increase.



Graph 2: Graph representing the effect of beater speed on performance

The Effect of Moisture Content of Maize on the Performance of the Maize Shelling Machine

Result in graph 3 presents the effect of moisture content on performance of maize shelling machine. The results shows that moisture content 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.



Graph 3: Graph representing the effect of moisture content on performance



Table 2: Summary of Univariate analysis of variance showing the interactive effect of feed rate, beater speed and moisture content on performance evaluation of the maize shelling machine.

Source of Variation	Type III Sum of Square	df	Mean Square	F	Sig	H
Feed Rate	799534.164	2	399767.082	9.287	.000	.357
Speed	26257.924	2	13128.962	.305	.738	.010
Moisture Content	788534.160	2	394267.080	9.159	.001	.267
Feed Rate * Speed * Moisture Content	901907.821	6	150317.970	3.492	.036	.176
Error	2711929.649	63	43046.502			
Total	5234070.278	72				

Table 2 presents the Summary of univariate analysis of variance showing the interactive effect of feed rate, beater speed and moisture content on performance of the maize shelling machine which shows that, there is a significant interactive effect of feed rate, speed and moisture content on performance of the maize shelling machine [F (6, 63) = 3.492; p<.05]. Observation of eta coefficient [$\eta = 0.176$] shows that, feed rate, beater speed and moisture content significantly and jointly contributed 17.6% of the

total variance in performance of the maize shelling machine. This implies that feed rate, beater speed and moisture content are all parameters that affect effective maize shelling.

To further check the specific feed rate, beater speed and moisture content that could be suitable for the designed maize Shelling machine, a descriptive analysis test was conducted on the three determinant factors (feed rate, beater speed and moisture content) and the result is presented in Table 3.

Table 3: Descriptive analysis showing the best combined factors (feed rate, beater speed and moisture content) most suitable for the designed maize shelling machine

S/No	Feed Rate	Speed	Moisture Content	Mean	SD	No of Trials
1	2KG	300RPM	7.10%	111.48	120.87	8
2		350RPM	7.10%	92.32	131.64	8
3		400 RMP	7.10%	177.05	131.15	8
4	4KG	300RPM	9.12%	50.16	45.26	8
5		350RPM	9.12%	35.43	36.02	8
6		400 RMP	9.12%	16.51	17.66	8
7	6KG	300RPM	11.51%	214.86	148.25	8
8		350RPM	11.51%	329.58	401.86	8
9		400 RMP	11.51%	322.70	388.78	8

Result in Table 3 shows that the best combination factor for the use of the designed maize shelling machine is when it is fed with 6kg feed rate at 350rpm beater speed with a moisture

content of 11.51%. This is because this combination has the highest mean score of 329.59 with standard deviation of 401.86. This was closely followed by 6kg feed rate with beater

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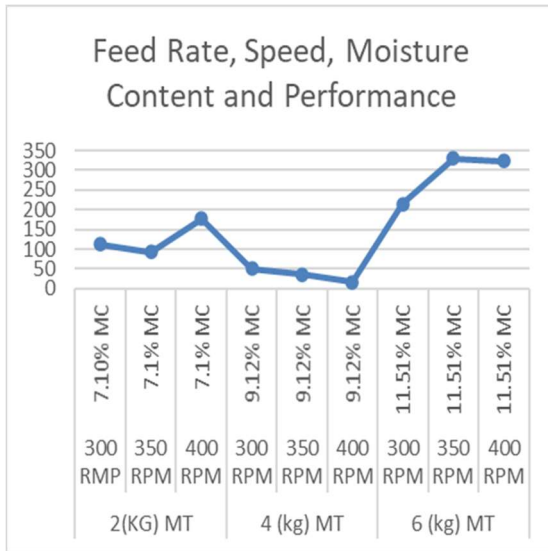
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speed of 400 rpm under the moisture content of 11.51%. Alternatively, the machine can also be used at feed rate of 6kg with 300rpm beater speed using 11.51% moisture content as it was with the third mean score of 214.86 with standard deviation of 148.25.

alleviate farmer maize shelling problems.

- Other moisture contents of maize could also be tried on the machine to determine performance



Feed rate, beater speed and moisture

Graph 4: Graph represents the interactive effect of feed rate, speed and moisture content on performance of the designed machine

CONCLUSION

The result finally, reveals that there is a significant interactive effect of feed rate, beater speed and moisture content on performance of the machine $p < 0.05$. The result further shows through observation the best combined factors (feed rate, beater speed and moisture content) most suitable for the machine is when fed with 6kg feed rate, 350rpm beater speed with 11.51% moisture content. From the result it is observed that this combination has the highest mean score of 329.59 and standard deviation of 401.86.

RECOMMENDATIONS

- Government should ensure that the machine is produced massively so as to

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