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Design and Development of a Sorghum Winnowing Machine

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Authors' contributions

This work was carried out in collaboration among all authors. Author AIT wrote the first draft of this manuscript and played a part role in the modeling of the machine. Author OJA wrote the second draft of this manuscript and was in charge of the working drawings of the machine both as a model and in the manuscript format. Author OOA played a pivotal role in the development of the machine on the workshop floor and supervised the development of the machine on the workshop floor. Author OTI was in charge of the Quality Control and assurance processes of the machine. Author KO was the final supervisor of the modeling and development of the machine. Author OAK was in charge of the final approval of the project and ensured that the Machine was developed to conform to the organizational standards expected by the necessary standards regulation. All authors read and approved the final manuscript.

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ABSTRACT

The process of winnowing grains such as SORGHUM has been widely done manually in a lot of developing countries, such as Nigeria and this comes with a lot of stress and reduced output/productivity hence the need to develop a machine that will ease such burdens so that there is a better productivity and a reduced human effort in the winnowing process. As such, an electric-powered sorghum winnowing machine was designed and fabricated with locally sourced materials to ensure ease of maintenance and at no compromise to its efficiency and reliability. The machine

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component parts include the blower, hopper, feed gate, lever, and the machine frame. Sorghum sample was tested with the machine for operational effectiveness and the result shows that the machine has a winnowing capacity of 530kg/hr and a winnowing efficiency of 96%. The fabricated winnowing machine performed well with high winnowing efficiency, reliability, and durability with an estimated cost of $450. It was also discovered that the cost of winnowing 1kg sorghum is highly encouraging. The study was carried out in Akure, Ondo State, Nigeria. A performance evaluation was carried out on the machine and a cleaning efficiency of 96% was achieved.

Keywords: Grains; sorghum; Chaffs; optimum speed; cleaning efficiency; winnowing; efficiency.

1. INTRODUCTION

"A grain winnower is a device used to separate grains from chaff by means of a wind or current of air. Threshing operations leave all kinds of trash mixed with the grain; they comprise both vegetable (e.g. foreign seeds or kernels, chaff, stalk, empty grains etc.) and mineral materials (e.g. earth, stones, sand, metal particles etc.) and can adversely affect subsequent storage and processing conditions. The cleaning operation aims at removing as much trash as possible from the threshed grains. Traditional cleaning method is winnowing, which uses the wind to remove light elements from the grain" [1].

Fig. 1. Traditional means of winnowing

Fig. 2. Ancient Winnowing Machine [Raid and Gray, 1902]

"Winnowing is the natural removal of fine material from coarser sediment by wind or flowing water, analogous to the agricultural separation of wheat from chaff. Wind winnowing is an agricultural method developed by ancient cultures for separating grain from chaff" [2]. "Wind winnowing is used to remove weevils or other pests from stored grain. It involves throwing the mixture (grain, seeds, husks, straw and chaff) into the air so that the wind blows away the light chaff" [4].

"Over the years it has been observed that there have been changes in the design of the winnower in various countries in the world that practice grain farming. Currently, most of the farmers use wind winnowing. Wind winnowing is an agricultural method developed by ancient cultures for separating grain from chaff" [3]. "It is also used to remove weevils or other pests from stored grain. Threshing, the loosening of grain or seeds from the husks and straw is the step in the chaff-removal process that comes before winnowing. "Winnowing the chaff" is a common expression. In its simplest form, it involves throwing the mixture into the air so that the wind blows away the lighter chaff, while the heavier grains fall back down for recovery. Techniques used included using a winnowing fan (a shaped basket shaken to raise the chaff) or using a tool (a winnowing fork or shovel) on a pile of harvested grain" [5,6]. "In 2016, Rahul Gajanan Kadam And K.G. Dhande concluded that the power operated paddy winnower after been tested at three feed rates 112 kg/hr, 127 kg/hr and 138 kg/hr, respectively that the highest cleaning efficiency of 99.3 per cent was found at feed rate of 127 kg/hr and highest output capacity was found at feed rate of 138 kg/hr. The percentages of blown grain were less than 1 per cent in case of all three feed rate" [7-11]. Usman D. Drambi et al also concluded that "as the feed rate and fan speed increases, the cleaning efficiency decreases, hence the need to determine the optimum cleaning efficiency and minimum percentage grain loss. However, with an average feed rate of 3.04kg/s, the average cleaning efficiency (86.04%) and percentage grain loss (13.82%), it indicates that room exist for an improvement" [12-15].

2. AIM OF THE PROJECT

The aim of this project is to develop an efficient winnowing machine suitable for winnowing SORGHUM out of locally sourced materials and at a reduced production and maintenance cost. This will play a vital role in the cereal production industry, especially in application to food making for infants and babies

3. OBJECTIVES OF THE PROJECT

The objectives of this project are to:

1. Develop an efficient grain winnower, and
2. carry out performance evaluation of the machine developed in order to determine its functional requirements

4. JUSTIFICATION

The limitations of using traditional ways of winnowing include:

- A lot of effort is required in the lifting of the basket containing the cereals
- The wind winnowing process highly depends on the wind to blow away the light particles and chaff, so it will be more effective on a windy day, but on a non-windy day, the wind winnowing process is not very effective
- Few amounts of grains can be winnowed in one instant, since a person can't carry a large amount of cereals, only a machine can perform winnowing of large quantities of cereals.
- Wind winnowing requires the use of both hands which is very tiresome.

Due to the above-stated limitations of traditional winnowing processes, there is a need to come up with a grain winnower that requires less effort to operate, has a fan incorporated in its design that provides the wind that blows away the light particles and has enough space that holds a large amount of cereals to be cleaned.

5. METHODOLOGY

An extensive review of literature on the different types of cereals, methods of threshing and winnowing plus existing machines was also carried out. Literature on cereal grinding machines was read and used. Some experimental grinding processes were done and literature on construction and fabrication techniques was also consulted so as to get a good development that is cheap, made from local materials, and with good aesthetics.

The assembly of the machine was also researched and the materials selection software (GRANTA) was adequately used. Evaluation and testing of the project work was carried out under a controlled environment of the institute's workshop so that the behaviour of the machine was properly ascertained and its behaviour under other conditions could be predicted.

Vast knowledge of various CAD software (ProEngineer, AutoCAD and Autodesk Inventor) was adequately used in the Modeling and Simulation of this machine and the force analysis was carried out to know its performance under different loading conditions.

Table 1. Materials Selection Procedure

S/N	Machine Component	Criteria for Selection	Most Suitable Materials	Materials Selected	Reason for Selection
1.	Hopper	Weight, good wearing property, availability	Mild Steel, Galvanised Steel, and stainless.	Stainless Steel	Cost, Usage, corrosion resistance and availability
2.	Base Frame and machine frame	Strength, Ability to withstand impact load/stress, availability	Mild Steel, Galvanised Steel, Stainless Steel	Stainless Steel	Strength, Ability to withstand impact load/stress, and availability
3.	Gate	Strength, Ability to withstand impact load/stress, availability	Mild Steel, Galvanised Steel, Stainless Steel	Stainless Steel	Strength, Ability to withstand impact load/stress, and availability

6. SIGNIFICANCE OF THE PROJECT

The manual method of winnowing is very slow and burdensome which apparently led to the wastage of resources, low output, and time consumption. This work aims at increased productivity, optimal performance of the machine, and affordability by the Small and Medium scale industries in the country.

7. MATERIALS SELECTION PROCEDURE

The considerations contained in this work are based on the logical necessity of design parameters. The selection of materials for various parts of machine is based on the following factors. The design of the machine was based on the following consideration [8]:

a. Choice of materials and Properties of material to be processed
b. Choice of design for specific parts and selection of some standard parts of the machine
c. Strength of the material and rigidity of the machine,
d. Availability of the material locally and ease in obtaining them
e. Durability
f. Corrosion and its effect under various uses and weather condition to which its exposed,
g. Ease of fabrication.

8. MACHINE DESCRIPTION

The machine is being driven by an electric blower with a rated power output of 65W and a speed of 1350RPM. The Blower is installed at one end of the Machine and in such a way that when the sorghum is poured into the hopper, the gate is first closed to ensure that the air from the blower has more impact with the sorghum that wants to be winnowed. The machine comprises of different parts namely; the hopper sub-assembly, machine frame sub-assembly and the blower sub-assembly. The Sorghum is fed into the hopper, with the feed control locked. An amount of the threshed grains is fed into the winnower through the hopper. It flows down by gravity and pass through the hopper outlet and drops across the fan air stream unto the sieve. The non – grain materials being lighter than the grains are blown out of the machine through the out end of the machine. The clean grain material passes through the sieve on to the grain collecting pan and subsequently, flows down still by gravity towards the grain outlet where it is collected.

9. BLOWER

The Blower was selected based on the required wind and power output for the smooth and efficient operation of the machine. The specifications of the diesel engine as available on its tag are:

Table 2. Blower Specifications

DESCRIPTION	DATA
Power Rating	65W, 230V
Speed	1350rpm

Fig. 3. Picture of the sorghum winnowing machine

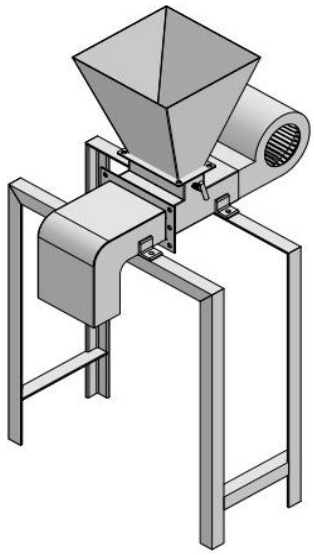

Fig. 4. Model of the sorghum winnowing machine

10. PERFORMANCE EVALUATION

"Performance Evaluation of the winnower was carried out to observe the workability under controlled conditions, so as to detect the specific conditions or parameters that may affect the operation of the machine. This was done in addition to ascertain whether or not the machine performs the intended task for which it was designed. This was also important so as to establish the rate and efficiency at which the task was achieved" [10,11].

11. PERFORMANCE VARIABLE

The underlisted were put into consideration during the Performance Evaluation of the machine so as to ensure that the optimum performance of the machine was considered [12].

- The feeder speed: This is the speed of the feeder and it affects the feed rate and the cleaning efficiency.
- Nature of the mixture: The nature of physical properties of the mixture need to do with whether the sorghum mixture resulting in a reduction in the cleaning efficiency of the winnower. This determines the nature of the final product and plays a pivotal role during cleaning.
- Moisture content: The weight of agricultural material reduces as it is dried. This is because drying reduces the amount of moisture (water in agricultural products or materials). This relates to the moisture that is found in the grain at the time of winnowing. It is expected that the grain be dry for ease of cleaning
- We must also note that the speed of rotation of the fan can also affect the velocity of the air stream.
- Angle of attack: The angle at which mixture is introduced into the air stream affect the cleaning efficiency.
- The distribution of the mixture into the air stream, whether uniformly dispersed will not also affect the cleaning efficiency.
- Based on the scope of this work, the capacity and the cleaning efficiency of the sorghum winnower will be examined under one heading. That is, speed of feeder.

12. CALCULATION OF THE PARA-METERS

1. Cleaning Efficiency (CE): This is the percentage mass of separated chaff after winnowing, relative to the total mass of the chaff in the mixture before winnowing
2. $$CE = \frac{Y_i}{Y_2} X100\%$$

$$CE = \frac{Total\ weight\ of\ the\ cleaned\ grain}{Total\ weight\ of\ impure\ grain} X100\%$$

Where;

$Y_i\ is\ the\ Total\ weight\ of\ the\ cleaned\ grain$
$Y_2\ is\ the\ Total\ weight\ of\ impure\ grain$

Table 3. Analysis of the Performance Evaluation considering the Machine Capacity and Cleaning Efficiency

Trial No.	Machine Capacity (kg/hr)	Total weight of impure grain (Y_2) in kg	Total weight of the cleaned grain (Y_i) in kg	Cleaning Efficiency $CE = \frac{Y_1}{Y_2} X100\%$
1.	530	10	9.6	96%
2.	620	10	9.1	91%
2.	700	10	8.4	84%

3. Machine Capacity (CP): This is the rate at which the machine achieves its given task. It is rated in kilogram per hour for a processing machine, like the winnower. The unit is $^{kg}/_{hr}$

$$CP = {}^{R}/_{t}$$

Where
R is weight of mixture (kg); and
T is the winnowing time (hr)

To determine the Machine Capacity, this was done by dividing the weight of total mixture by the time it took to winnow the mixtures under proper time documentation. During this process, three (3) different time Machine Capacities based on our results was used as seen Table 3.

It was found that by increasing feed rate from 530kg/h to 720kg/h, purity decreased from 96% to 84% respectively. It was found that purity was affected by feed rate. The machine obtained the highest cleaning efficiency (CE) of 96% at a federate of 530kg/h. For the rural farmers, having a machine that feeds 530kg/hr with an efficiency of 96% or 620kg/hr at a cleaning efficiency of 91% has done a very good job considering its cost comparison to the imported ones or existing locally fabricated machines [16-18].

13. CONCLUSION

The sorghum winnowing machine that was designed and fabricated in this work is aimed at reducing the time spent in the cleaning of sorghum to make it clean and healthy for cereal production. The performance evaluation of the produced machine showed it works at an efficiency of 96%, thereby making the fabricated winnowing machine efficient. The materials selected for the development of the machine are locally available which is one of the advantages of the fabricated machine thereby making the machine easy to maintain and affordable. The nutritional hazards associated with the use of conventional means of cleaning sorghum and other grains is eliminated in this newly fabricated machine. Thus, there is no health hazard experienced by the operation of the new machine. Furthermore, the newly developed winnowing machine would reduce working losses, reduce production downtime, give nutritional advantages, enhances greater consumer choice and it reflects a more effective response to changing market requirements and increases better working capability of the Machine.

The machine has been found to be highly useful for the winnowing of sorghum during the post-harvesting process. After testing the winnowing machine, it has been concluded that the machine reduces human participation and effort for winnowing and hence the spare time can be utilized for other socio-economic purposes. Farmers can take advantage of this machine as good winnowing process and achieve a highly efficient final product from the farm or storage homes.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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