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Full-Length Research Paper

Development of a multi-layer sieving machine

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ABSTRACT: This research focused on developing a three-layer motorized sieving machine for separating agricultural produce that are unintentionally mixed, also to sieve out coarse particles to enhance suitable soil structure for plant growth. The developed machine can be easily assembled, modified, transported to different locations and the parts can be easily maintained or replaced. The study therefore considers separating a mixture of rice, beans and flour and also, sieving out excessive coarse materials in a sieving analysis for suitable soil structure using this machine. The machine was able to perform the specific function of separation; it was able to separate food materials of different sizes and also soil samples of varying sizes It was able to function as a multi-purpose machine; it could sieve particles of different shapes and sizes in a record time when compared to crude methods of sieving. The rate of sieving of 15kg of mixed food materials showed that replicate 1 had the highest sieving rate of 1.5kg/m while the overall replicates had an average of 1.32 kg/m, while the different samples had the highest sieving rate of 1.67kg/m on replicate 5, and an average of 1.49kg/m. Except for replicate 1, the comparison of the rate of sieving for food materials showed that the rate of sieving for soil samples were higher than those of food materials except for replicate 1.

Keywords: Sieving, separate, throughput, rate

INTRODUCTION

Separation techniques are used to separate mixtures into its constituent elements and/or compounds. Recall that a mixture is contains elements and/or compounds which are not chemically combined together. By separating the constituents of the mixtures, we are able to find out the properties of the known/unknown substances from mixtures and possibly use them for the production of useful substances such as medicines. Depending on the physical and chemical properties of the substances in the mixture, we can choose the most appropriate separation technique to isolate them from the mixture (Atkins, *2009).* The word "sift" derives from "sieve". In cooking, a sifter is used to separate and break up clumps in dry ingredients such as flour, as well as to aerate and combine them. A strainer is a form of sieve used to separate suspended solids from a liquid by filtration (Zainal et al., 2017). The issue of environmental threat in the country due to the relevant economic activities has received considerable critical attention (Lee et al., 2018). Raw materials are often mixed with impurities, hence the need to input undergo sieving in post-harvest operations. Sieving process is the process to separate larger particles from a mixture (Liu, 2009). While sieve is a piece of equipment that has holes punched in it or made of crossed wires for the use of separating larger particles from a mixture. The size of particles allowed to pass through depends on the sieve sizes which are the area of a single hole on the sieve screen, while the trapped particles are usually the unwanted residue in which they are too large to pass through the holes. Sieve is generally used in many fields such as agriculture, medicine, gardening, cooking, building construction, industry, and it also uses to separate fibre. The traditional sieving method is hand sieving, due to its non-consistency, low accuracy and

precision before the development of modern sieve that is more practical. However, there is no much attention paid to the research about sieve (Leschonski, 1979). The introduction of machine sieve significantly reduces the users' workload as well as time consumption because the machine takes over the repetition of the sieving process with high precision, unlike the uncontrollable traditional method variables. A sieving machine is designed to separate the particle according to their mesh size. We need to separate these pure substances from the mixture in order to use them individually (Simolowo and Adeniji, 2011).

General objective

The general objective of this work was to develop three-layer motorized sieving

Specific objectives

(i) To fabricate an electrical sieving machine
(ii) To evaluate the machine by sieving selected mixed agricultural food produce

Physical parameters of some selected agricultural food produce

Table 1 shows some physical parameters of some agricultural produce

MATERIALS AND METHOD

Methodology

The machine was designed to enhance the separation of agricultural produce both for commercial and non-commercial purposes. It would help to avoid the use of human labor, reduce the use of crude method in sieving or separating agricultural or food produce when they are unintentionally mixed.

Materials and equipment used for fabrication

Some of the materials used for the construction of this machine include;

Welding machine	Drilling machine
Grinding machine	Metal sheet
Angle iron	Cutting machine
Electrode	Electric motor
Iron mesh	Pulley

Design consideration for parts

The design considerations for the different parts of the machine were classified into two; design criteria and functional requirement.

Design criteria

1. The components were designed to ensure easy assemblage.
2. The machine was designed for easy maintenance
3. The machine was fabricated with easily accessible materials to ensure low cost

Determination of belt tension

Belt tension: $T_1/T_2 = e^{\mu\theta}$

Where T_1 is the tension of the tight side
T_2 = tension of the slack side
μ = coefficient of friction between the belt and pulley
θ = angle of wrap (3.07 rad)

Power transmitted by belt: this was determined using the formula below;

$P = (T_1 - T_2) \times V$

Where P = power transmitted by belt (KW)
V = velocity of the belt (m/s)

Functional requirement

1. The mesh should be able to sieve or separate small sized food particles and soil samples.
2. Skilled and unskilled operators should be able to operate it.
3. It should be more efficient than available manual methods.

Description of the machine

We generally use sieve plates for the separation of flour from the bran particles or other impurities. These sieve plates allow the fine flour particles to pass through the holes of the sieve plate while the bigger impurities are unable to pass through it and remain on the sieve. This method of separation of particles from a mixture based on the difference in size of particles is known as sieving. Sieve plates have meshed or perforated bottoms which allow only particles of a specific size to pass through it. The size of mesh can vary from one place to another depending upon its application. The sieving/separating

Table 1: Physical features of selected agricultural crops.

Food crop	Colour	Shapes/size
Rice	Rice is naturally brown after harvesting	Longer grain rice will have longer cylindrical shapes.
Beans	Beans are naturally dark red in colour	It has roughly kidney shape, with the ends lobed on either side of the hilum
Flour	The major, normal and general colour for flour is whitish in color. Other colors are creamy yellow, brownish grey. e.t.c.	The mean particle size for HRW and SW flour is 110.98gm and 570.29gm respectively.

Table 2: Electric motor specification

S/no	Specification	Unit
1	Voltage	230 volts
2	Frequency	50/60Hz
3	Speed	600rpm
4	Power	0.5H.P

machine is made up of the following components;

Mesh assembly: high surface finish mild metal sheets were used as mesh to allow the passage of materials. The meshes were arranged in layers such that the topmost layer has meshes with the larger holes, the second layer with a smaller holes and the last layer was sealed to trap materials as the final destination.

Pulley and belt: pulley and belt mechanism was used to transfer torque from the motor to the frame carrying the bearings that mobilizes the mesh assembly. The belt was ensured to be the suitable size for the pulleys.The diameter of the pulley on the motor was 75mm, a pulley of diameter 100mm on the device mechanism was used to transmit torque from the motor, and the largest pulley on the device mechanism was used to transmit same torque to the bearings.

Main frame: is the part of the machine that gives shape, supports and encloses the machine. The total weights carried by the main frame are: Weight of the electric motor, weight of the mesh layers, weight of the bearings and pulleys. The two design factors considered in determining the material required for the frame are weight and strength; angle steel bar was used to give the required rigidity. Electric motor … this is connected to an electric source; it transmits electrical energy into rotational force or torque and transmits it through its pulley. A suitable 3-phase motor was placed on a motor plate belt for motor pulley. **Table 2** gives a summary of the electric motor specification.

Principle of operation

Operation of the machine is easy and requires only one individual to operate it easily. Separation by sieving mechanically is accomplished by powering the electric motor which has a pulley; a rubber is attached to the pulley of the motor and then to the bearings which makes up the drive mechanism that goes to and fro along the frame. The motion of the bearings to and fro subjects the mesh assembly to the same, thereby unsettling the materials on the mesh. The constant random motion of these materials and the effect of gravity forces smaller particles that can pass through the mesh to fall through to the lower layer. The particles with the smallest sizes end up at the lowest layer, while those with the largest particle sizes remain on the utmost layer. **Figure 1** below is the pictorial view of the fabricated machine.

Performance test

A performance test was carried out in the Federal College of Forestry, Jericho, Ibadan. The electrical sieving machine was used to carry out separation operations on different mixtures of food crop materials, and soil sample with excessive coarse particles. For this study, a mixture of rice, beans and yam flour was separated and a soil sample. This mixed food materials were poured in the first layer of the mesh assembly and sieved. The time to completely separate the mixture into the three different layers was recorded and the respective weight of each layer was finally measured. Similarly, the soil sample was weighed before sieving and each soil collection from respective layers were weighed after sieving with the electrical machine.

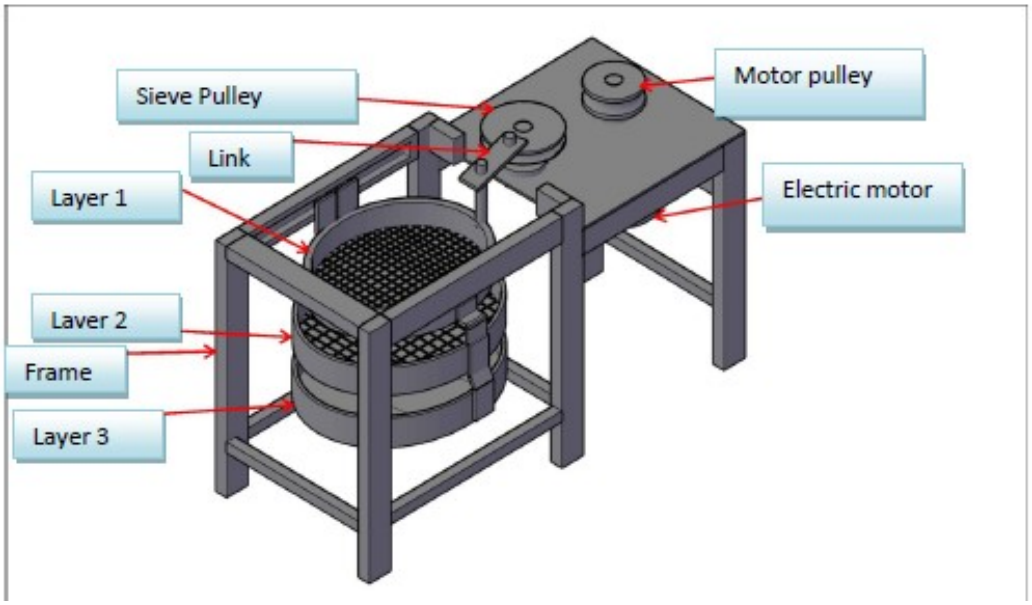

Figure 1: Isometric view of the fabricated machine.

Table 3: Rate of sieving for mixed food materials using the fabricated machine.

S/N	Weight (kg)	Time (m)	Rate (kg/m)
1	15	10	1.5
2	15	12	1.25
3	15	11	1.36
4	15	12	1.25
5	15	12	1.25
Mean		57	1.32

Evaluation parameters

The fabricated machine was evaluated considering the following factors; workability, rate of sieving and cost of fabrication.

Workability: this ascertains if the machine works and separates food materials of different sizes successfully.

Rate of sieving: this is the ratio of the quantity of food particles sieved successfully to time.
Mathematically

$$Rate\left(\frac{kg}{s}\right) = weight\ /\ time$$

RESULTS AND DISCUSSION

Workability: the machine was able to perform the specific function of separation; it was able to separate food materials of different sizes and was also used to sieves oil samples with varying sizes into three different layers. It was able to sieve particles of different shapes and sizes in a record time when compared to crude methods of sieving. It can be easily assembled, modified, transported to different locations and the parts can be easily maintained or replaced.

Rate of sieving: Table 3 shows the rate of sieving of the fabricated machine; 15kg of mixed food materials were sieved with the sieving machine and replicated five (5) times. Replicate 1 had the highest sieving rate of 1.5kg/m while the overall replicates had an average of 1.32kg/m. Table 4 shows the rate of sieving a soil sample of 15kg, made up of different particle and dirt sizes. Different samples of but from same source were sieved replicated five (5) times. Replicate 5 had the highest sieving rate of 1.67kg/m while the overall replicates had an average of 1.49kg/m. Figure 2 is a chart to compare the rate of sieving for food materials and soil samples; it shows that the rate of sieving for soil samples were higher than those of food materials except for replicate 1.

Table 4: Rate of sieving for soil samples using the fabricated machine.

S/N	Weight (kg)	Time (m)	Rate (kg/m)
1	15	12	1.25
2	15	10	1.5
3	15	10	1.5
4	15	10	1.5
5	15	9	1.67
Mean		51	1.49

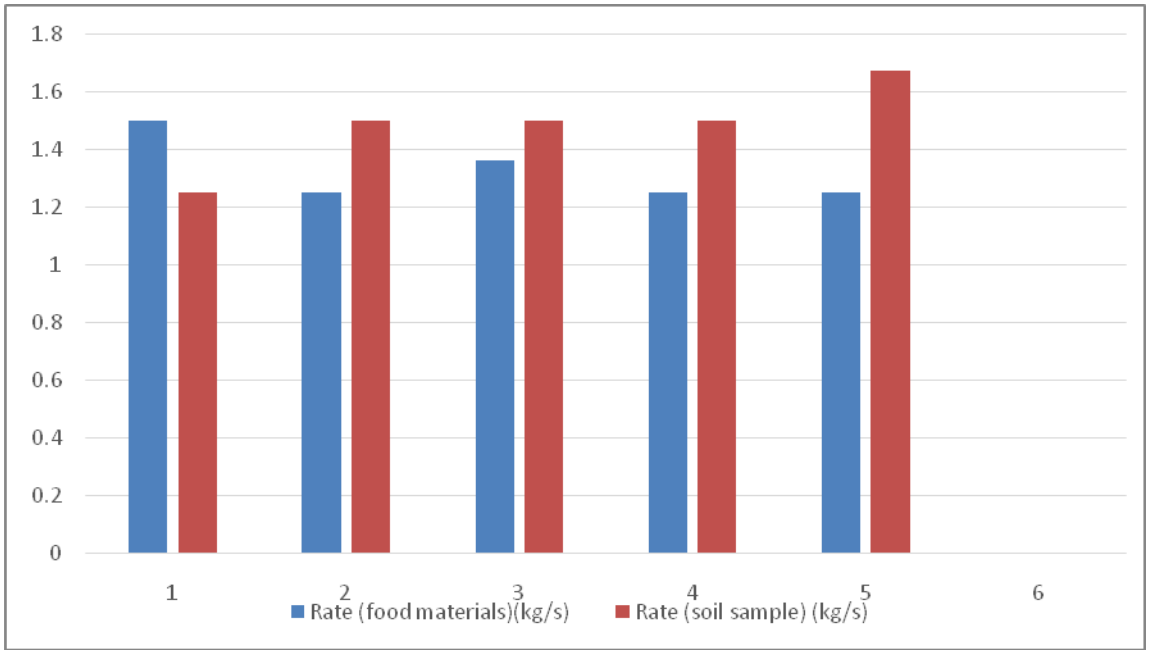

Figure 2: Chart to compare the rate of sieving for food materials and soil samples.

Table 5: Bill of engineering and evaluation.

S/N	Component	Cost (₦)
1	Electric motor	12,000
2	Mesh	1,000
3	Frame angle	500
4	Belt	500
5	Pulley's stainless steel	4,000
6	Bolts & nuts	1,000
7	Paint &transmission oil	1,500
8	Wiring	2,500
9	Transportation	1,500
10	Workmanship	5,500
Total		30,000

Cost: this considers the cost of the materials used for fabrication and the total cost expended on fabrication. Table 5 is a breakdown of the cost of materials for the fabrication of the electrical sieving machine.

Conclusion

The machine was successfully constructed and tested. Locally sourced materials were used and it can be easily assembled or modified. The machine was able to perform the specific function of separating food materials of varying sizes and could conveniently sieve soil sample into three different layers. The machine passed the test of workability. Test result when the machine was used to sieve 15kg of mixed food materials and replicated five (5) times showed that replicate 1 had the highest sieving rate. Comparison of the two samples showed that the rate of sieving for soil samples was higher than those of food materials except for replicate 1. This suggests that the machine performed better when used to sieve soil samples than when used to separate food produce. The overall cost of fabrication was #30, 000 and this cost could be lower when produced in bulk.

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