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Full Length Research Paper

Development of a Continuous Process Multi-crop Washing Machine

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Abstract

Agricultural products undergo washing operation before they can be processed into their various end products. Different washing machines have been developed for washing some Agricultural products such as potato, melon seeds, cassava root and coffee by centres like the National Centre for Agricultural Mechanization, (NCAM), Ilorin, the International Potato Centre, (CIP), Peru and others. These machines which use batch process methods incorporating different processes of washing agricultural products such as soaking in still or moving water or in other fluid, water spraying, use of rotary drum cleaner, brush and shuffle or shaker washing. Continuous process washers that can be used to handle different agricultural products are yet to be developed. Hence, a continuous process multi-crop seeds washing machine was designed and fabricated at the NCAM, Ilorin. The machine is an improvement on the existing batch process melon washer develops by NCAM. The washer is capable of washing out melon seeds, locust bean seeds, coffee, cocoa and other seeds from their pulpy media. The washing machine is powered by a 5.5hp petrol engine and is composed of five major components, namely; the frame, the hopper, washing chamber, water trough and discharge outlets. A preliminary test was carried out on the washer using melon and locust bean seeds in their pulpy media. Results obtained gave cleaning efficiencies of 80% and 89% for melon seeds and locust bean seeds respectively.

Keywords: *Development, Design, Performance, Multi-crop, Washer.*

Introduction

Agricultural processing is any activity that maintains, raises the quality or changes the form or characteristics of an agricultural product. The processing activities are undertaken to increase the yield from a raw farm product by either increasing the amount of the finished product, the number of finished product or both and to improve the net economic value of a product, Onwualu, et.al (2006).
Many processes are involved in converting a raw product to the final product that is consumed by the end users and each of these processes is referred to as a unit operation. The major unit operations in processing of agricultural products include; cleaning, size reduction, drying, separation, mixing, packaging, etc., and for each of these unit operations, some machines exist that can be used for mass production and improvement of the agricultural product. Separation operation can be classified into cleaning, sorting and grading. However, cleaning separates contaminants or unwanted material from the raw material. There are two basic methods of cleaning which are dry and wet cleaning, Onwualu, et.al,(2006). Washing operation is basically a wet cleaning process.

The washing operation is very important in the removal of soil contaminants or unwanted materials from crops and it ensures less damage to the crop. The effectiveness of washing is determined by the availability of water as the cleaning liquid, which helps in the removal of foreign matter (dirt, dust, lighter particles etc.) from the crops. Some crop seeds are in a pulpy media after they have been fermented or soaked in water and must be separated from their pulpy media before they can be further processed into consumable products. Such operation is accomplished by washing. Among these crops are melon seed and locust bean seeds. The different principles used in the washing of agricultural products according to Henderson and Perry (1980), are soaking in still, moving water or other fluid; water sprayers, rotary drum cleaner, brush washing and shuffle or shaker washer. Akande,(2001) described some washing machines that had been developed for washing agricultural products by the National centre for Agricultural Mechanization, (NCAM), Ilorin (for melon washer); the International Potato Centre, (CIP), Peru (for potato washer); and the Department of Agricultural Engineering, Federal University Technology,(FUT), Minna.(for cassava root washer).

Objectives

The objectives of this project therefore were to design and develop a highly efficient, continuous process seeds washer capable of washing many crop seeds, to modify and improve on the existing NCAM manually operated batch process melon washer and to evaluate the performance of the developed washer for adoption and use by the end users on commercial scale.

Description of continuous process multi-crop seed washer

Machine Main Features

The washing machine is powered by a 5.5hp petrol engine and is composed of five other major components, namely, the frame, hopper, washing chamber, water trough and discharge outlets

Principle of operation

The main function of the continuous process washer is to separate the seeds from the fermented or softened pulp. The fermented and pulpy material is poured into the machine through the hopper, and then as the shaft and brushes rotate, the materials are moved along the length of the washing chamber. The shaft and brushes rub the materials against the wall of the drum, thereby separating the seeds from the pulp as the materials move along the length of the washing chamber. The pulpy slurry first pass through the perforated holes of the drum in the washing chamber to the outlet, while the seeds progress to their outlet and then discharge into a collector.

Development of the multi-crop washer

Design considerations

In the design of the washer, an effective means of washing the seeds was considered. A mechanism of washing the seeds involving a rubbing action with the aid of brushes or other abrasive materials in a washing chamber was selected due to its effectiveness for removing soils and sticky residue adhering to the seeds. The following factors were then considered in the design of this continuous multi-crop seeds washing machine:

1. The crop seeds that were considered in this design were those that can be washed in their pulpy media, such as melon, locust bean, cocoa, coffee etc.
2. The strength and stability of the materials to be used in the fabrication of the washer.
3. The need for the washer to be a continuous process machine, so that it could be used for a large-scale commercial operation with little water and be suitable for areas where water supply is scarce.
4. The use of available local materials in the fabrication of the machine components. Consideration was given to the cost of local items and materials to be used for fabrication with selection of the cheapest available materials that can meet the strength requirements.
5. The relevant physical and mechanical properties of the crop seed that are basic for design were determined and obtained from the literature.
6. The size/dimension, speed, and capacity of the machine.

The Volumetric Capacity of the Washing Chamber and Speed of the Washer were determined as well as the diameter of the washer shaft using a machine design textbook written by Khurmi and Gupta, (2005). The isometric, orthographic, exploded and workshop drawings of washer were drawn using AUTOCAD software and the machine was fabricated. The detailed isometric and orthographic drawings of the washer are shown in figure 1 and 2.

Construction/Fabrication of the washer

The continuous process multi-crop seed washer consists of six major components as follows;

Hopper: This is a wide chute made from 1.5mm galvanized sheet; it is situated at the top left of the washer and serve as inlet for the material to be washed.

Washing Chamber: This is main component of the washer and it's made from 1.5mm thick galvanized sheet. It comprises of two cylinders; the small and big cylinders which are horizontally attached to each other and were segmented into two equal halves, with one of segments perforated .The small cylinder has the overall dimension of 148.8mm diameter and length 525mm while the big cylinder has the overall dimension of 234mm diameter and length 544.5mm. Spikes on which the brushes are fixed are spirally arranged on a shaft that passes through the length of cylinders for easy conveying of the material.

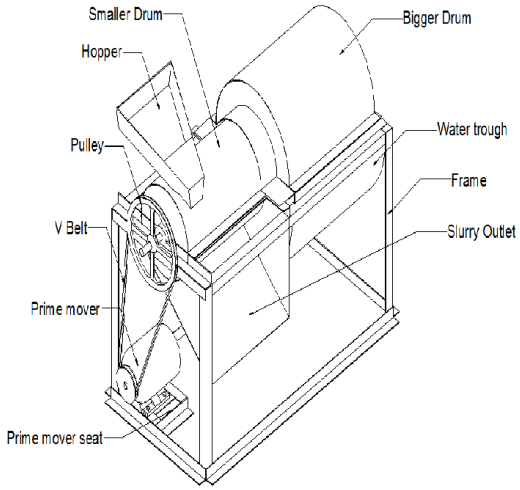
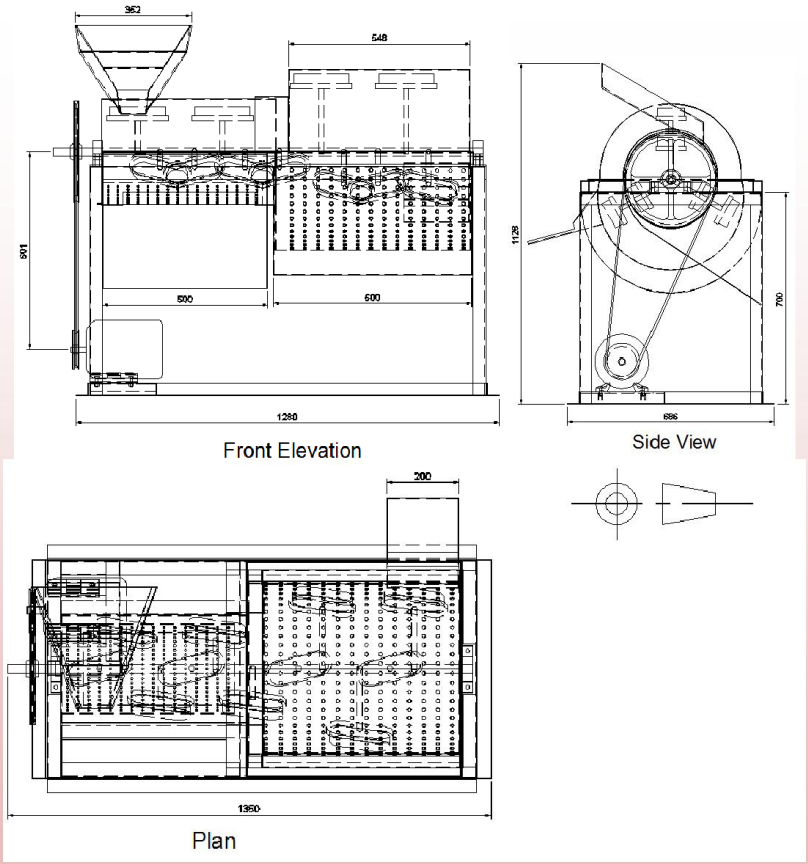


Fig 1: The isometric view of a continuous process multi-crop seed washer



Scale 1:10
All Dimensions in mm

Fig. 2: Orthographic view of multi-crop seed washer

Discharge Outlets: The washer has two outlets; the first outlet is beneath the small cylinder and serves as the waste material (slurry) outlet while the second one is at the extreme end of the big cylinder and use for discharge of the washed seeds.

Water Trough: It is semi-cylindrical shaped and made from 1.5mm galvanize sheet with overall dimension of 255mm diameter and length 600mm. It serves the purpose of holding water for final cleaning of the seeds an it's situated beneath the big cylinder.

Frame: The frame is made from 45mmx45mmx45mm angle iron and serves the purpose of holding the whole system in a rigid position.

Power Source: The washer is powered by 5.5hp petrol engine and can also be powered by an electric motor depending on predominant power source in the location where it will be used.

Preliminary test

Test Methodology

A preliminary test was conducted on the washer at operating speed of 125rpm using locust bean and melon seeds in their pulpy media and 5.5hp petrol engine as power source. 5 samples of 15kg each for each material in their pulpy media were weighed to test the washer. The weight of washed seeds, weight of unwashed seed, weights of the materials at each outlets, time taken to feed the materials and time taken to discharged were collated for analysis and determination of the performance parameters.

Performance Parameters

The data collated were used to determine the performance parameters of the machine as follows:

a) Cleaning Efficiency, (E_C)% - this determines how efficiently the machine is cleaning, it is expressed as

$$E_{C\,(\%)} = \frac{W_2}{W_4} x100 \quad \text{.....(5)}$$

Where

W_2= weight of the washed seeds collected at seed outlet, kg

W_4 = weight of the material at the seed outlet, kg

b) Percentage Recovery (R_P) % - This determines the fraction of the seeds that is recovered at the seeds outlets. This is expressed as:

$$R_p(\%) = \frac{W_4}{W_0} x100 \quad \text{.....(6)}$$

Where

W_0 = Total weight of the seeds in the pulpy media, kg.

W_4 as defined above

c) Throughput, (Ic),,kg/hr:- This determines the input capacity of the washer. It is expressed as:

$$Ic\ (kg/hr) = \frac{W_1}{T_1} \quad \text{.....(7)}$$

Where,

W_1 = Original weight of pulp containing the seeds fed into the washer, kg

T_1 = time taken to feed in the material, hr

d) Output Capacity, (O_c) kg/hr:- This determines the quantity of seeds discharged at the seeds outlet per unit time.

$$Oc\ (kg/hr) = \frac{W_4}{T_2} \quad \text{.....(8)}$$

Where, T_2 = time taken to discharge the seeds at the seeds outlet, hr

Results and Discussion

The results of the preliminary test carried out on the washer at 125rpm operating speed using melon and locust bean seeds in pulpy media are presented in Tables 1-2. Table 1 is the result of the test using melon seeds in pulpy medium. The results showed that the washer has throughput capacity ranged between 473.68kg/hr and 545.45kg/hr while output capacity ranged between 275.48kg/hr and 318.06kg/hr. It has the highest recovery percentage of 97.33% and the lowest recovery percentage of 94.00%, while its highest cleaning efficiency was 96.94% and the lowest cleaning efficiency was 87.25%.

Table 1: Summary of the Performance the Washer Using Melon Seeds in Pulpy Medium

S/N	$W_{1(kg)}$	$W_{2(kg)}$	$W_{3(kg)}$	$W_{4(kg)}$	$W_{5(kg)}$	$T_{1(sec)}$	$T_{2(sec)}$	Ic(kg/hr)	Oc(kg/hr)	R_p (%)	C_E(%)
1	15	8.8	1.1	9.9	4.7	102	115	529.42	275.48	97.33	88.88
2	15	9.1	0.8	9.9	4.3	99	103	545.45	318.06	94.67	91.92
3	15	9.4	0.6	10.0	4.1	111	116	486.47	291.72	94.00	94.00
4	15	8.9	1.3	10.2	4.6	106	110	509.43	291.27	98.67	87.25
5	15	9.5	0.3	9.8	4.9	114	118	473.68	289.83	98.00	96.94

Locust bean in pulpy medium as shown in table 2 indicated that the throughput capacity ranged between 545.45kg/hr and 580.65kg/hr while output capacity ranged between 221.54kg/hr and 241.17kg/hr. It has the highest recovery percentage of 98.00% and the lowest recovery percentage of 95.33%, while its highest cleaning efficiency was 94.52% and the lowest cleaning efficiency was 86.49%. The results, so far show that almost all the material fed into the washer were recovered and they were efficiently washed.

Table 2: Summary of Performance the Washer Using Locust Bean Seeds in Pulpy Medium

S/N	$W_{1(kg)}$	$W_{2(kg)}$	$W_{3(kg)}$	$W_{4(kg)}$	$W_{5(kg)}$	$T_{1(sec)}$	$T_{2(sec)}$	Ic(kg/hr)	Oc(kg/hr)	R_p (%)	C_E(%)
1	15	6.4	1.0	7.4	6.9	96	104	562.50	221.54	95.33	86.49
2	15	6.7	0.4	7.1	7.2	100	107	540.00	225.42	95.35	94.37
3	15	6.8	0.4	7.2	7.3	97	105	486.47	233.14	96.67	94.44
4	15	6.7	0.7	7.4	7.1	93	101	509.43	238.81	96.67	90.54
5	15	6.9	0.6	7.3	7.4	98	103	473.68	241.17	98.00	94.52

Conclusion and Recommendation

A Continuous process multi-crop seed washer was designed and fabricated at the National Centre for Agricultural Mechanization, (NCAM), Ilorin. The machine is an improvement on the existing batch process and manually operated melon washer and was designed to handle many crop seeds including locust bean, coffee and cocoa. Preliminary test carried out on the washer using melon and locust bean seeds showed a performance of cleaning efficiencies range between 87.25% and 96.94% for melon seeds and between 86.49% and 94.52% for locust bean seeds. Since, the washer can wash crop seeds in pulpy media; it is recommended that a comprehensive performance test should be carried out on the washer at different operating speeds using different crop seeds such as cocoa, coffee, etc to evaluate its performance for further adjustment and commercial use.

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