



DEVELOPMENT OF A DOMESTIC WATER MEDIUM RICE DE-STONING MACHINE

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Abstract

It has become critical to build a de-stoning machine that can be used in our homes whenever we need it. As a result, the goal of this research was to develop and build a wet-method household rice destoning equipment. The design was built utilizing locally accessible materials and was based on the notion of material separation using water as a medium of separation. A reservoir, hopper, de-stoning chamber, washing chamber, impeller, water filter, and brush drum make up the machine. The produced machine was powered by a 1 horsepower variable electric motor that communicated the rotating motion of the driving pulley to the driven pulley, which was supported by bearings, through a V-belt. The machine was built and tested, and it was discovered that 2kg/10minutes and 20.04kg/hour of processed rice were destoned at a de-stoning speed of 400rpm, which is the optimal speed for maximum speed separation. The destoning machine's effectiveness in terms of stone removal is approximately approaching 100 percent free of impurities, making it ideal for residential usage. This discovery elucidates the potential to deal with the challenges of stone removal from locally produced rice using hand and manual method, which are inefficient, time and energy wastage, it acts as a rice processing industry innovation.

Keywords: Rice, domestic rice-destoning, water medium.

Introduction

Rice, (*Oryza sativa*) is a monocot crop, is generally farmed for a year but may persist as a perennial crop in tropical places. Rice is among the three major crops in the world, and it contributed greatly to satisfy the food needs in the world. The role of rice crop is necessary in the present and future extensive food security (Bhagirath, 2017).

Rice is a food that makes up the dominant part of a population's diet and is highly competitive in international trade. It is very nutritious and has high calorie contents, accounting for more than one-fifth of all calories ingested by people globally. Rice farming in Nigeria is one of the great important agricultural growth for more than a decade (Terungwa and Yuguda, 2014). In Nigeria today, rice is sold on the major road of the towns and villages, for many households; it is their daily ingredient.

Rice production worldwide in 2021/22 study, analyze and have a record of about 513.0 million tons down to 1.0 million tons, with 4.2 million tons greater than the previous year. According to annual record countries like India, China, Pakistan, Australia, Bangladesh, Cote

d'Ivoire, Nigeria, South Korea, Senegal, and Thailand recorded a high rate increase for rice production in the year 2021/2022 countries like Australia, Bangladesh, China, India, and Thailand recorded the highest increase rate annually. The two largest production countries in the world are China and India with production rate of 149 million tons and 129 million tons count for more than half of the rice production annually worldwide (Nathan and Bonnie, 2022).

In Africa, rice producing has increase from 3.14 million tons, to 14.60 million tons annually, while the demand of rice is about 24.3 million tons per year (FAO 2010) and the rice import into Africa is about 9.7 million metric tons yearly. In Nigeria the demand for rice is about 32kg per capita indicating 4.7% increase in the past years which makes the total demand to be 6.4 million tons in 2017 as against 3.7 million tons yield per year (Erhie *et al.*, 2018).

Rice is use for different varieties in the northern part in Nigeria which include; 'Masa', 'Kunun shinkafa', and 'Tuwon shinkafa' and the most familiar class of food make with rice include parboiled rice eaten with stew, popped/puffed rice and brew process (Oludare *et al.*,

2014). Rice bran is used for producing paper, animals graze and as a source of fuel. Rice bran oil is used in soap making and rice bran wax, a byproduct of rice bran oil is used in industries (Mohammed *et al.*, 2016).

However, stones, sand particles, dirt, chaffs, and other contaminants have been discovered in locally produced rice in Nigeria, contributing to its low quality and poor market appeal. One of the reasons limiting local rice's demand and potential for export to produce foreign cash for the country is its poor quality. These foreign elements or contaminants are frequently introduced into rice during harvesting, threshing, handling, packing, and other processes (Usman *et al.*, 1999).

De-stoning is the process of removing stones or contamination from various crops of different sizes and colors. It is a post harvesting process for the value addition of harvested crops. Mud usually is attached to the stem of rice when uprooted from the soil and thereafter, it dries up to become sand and stones which can only be removed by cleaning. Also, after parboiling, drying is usually carried out under the sun on bare floor, platforms or slabs which could also result in stones and other dry impurities being introduced into the rice. Hence, cleaning, as a preliminary operation, must be carried out to remove the unwanted materials or impurities from rice to increase the quality of locally produced rice and make it more attractive to the consumers (Ogunlowo and Adesuyi, 1999). In order to completely remove all the stones/sand and impurities from the seeds the use of de-stoners is of great significance. Many researchers have developed machines for the separation of stones, sands and other contaminants from refined rice to satisfy public demand (Henderson and Perry, 1987; Adejuyigbe *et al.*, 2005; Simonya *et al.*, 2010; Adigun *et al.*, 2012; and Okunola *et al.*, 2015). This has impart many new innovations and technique of eliminating contaminants from rice (Adejuyigbe and Bolaji, 2005), developed and fabricated a rice de-stoner using a vibrating sieves and achieved a great destoning efficiency. Okunola *et al.* (2015) developed a cereal cleaner capable mostly for uses in refined rice cleanse contaminants. Henderson and Perry, (1987) developed a gravity-based and floating separator. Yet, using a separator in removing impurities from the rice is stressful and sufficient drying will be required to avoid the possibility of fungi or mold growth on the rice during storage (Fadeyibi *et al.*, 2012). Ojediran *et al.* (2019) work on developed motorized rice de-stoner. The technical definitions in the design machine, nevertheless, are very complex and hard to reveal (Ogunlowo *et al.*, 2014; Simonyan *et al.*, 2010; Adegun *et al.*, 2012; Agidi *et al.*, 2015).

A lot of rice de-stoning machine (imported) are very costly. The ones being developed in Nigeria uses dried method and non-of these machines that have not recorded breakage, tray loses and stones that are

relatively of the size of rice were not separated. The wet method uses water as a medium of separation and as a result of bulk density difference of stone/sand (irregular shape) and rice, the stone density is 1.33 g/cm³ while 0.51 g/cm³ for rice. Large quantity of rice float with the water while the stones settled down at the bottom of the container and be collected at the coarse surface. The water pass through a screen and be re-circulated to the reservoir to avoid water wastage. There is no breakage of rice and tray losses due to vibration from the machine. Stone that are relatively the same size of the rice were separated and the rice is properly clean. This provide a good efficiency in solving the traditional method of removing stone from our locally produced rice in our domestic households.

The paper introduced a brief overview of the technology of de-stoning and rice farming. Thereafter, the methodology examines the process of identifying the design concepts and parameters of the rice de-stoning machine. The de-stoner using wet medium was picked with detailed design parameters discussed. The machine performance was evaluated to ascertain real life application. This study will encourage rice farming globally especially in developing countries by virtue of the affordability and efficiency of this machine. Locally made rice free of stones and nutritional will be common in place.

Materials and Method

Design Consideration

The machine was developed from first principle approach. A review of existing methods and principle of de-stoning was carried out. The design study is completely accomplish to find the important design measurable factors and material strength for thought in choosing of the various rice de-stoner parts for the machine to carry out efficiently and to stop non-performance of the machine during the time for which is expected to operate. Thereafter, a final concept was picked from the lot and the wet method was adopted. The machine was designed and simulated using computer aided machine tool such as Autodesk Inventor for students. The analysis discovered that toughness, ductility, strength, hardness, and malleability were some of the mechanical properties that affected the materials utilized in this project. Surface polish, density, interaction with the environment, fabrication cost, maintenance cost, and material availability, as well as manufacturing simplicity and material safety, were all considered. The final machine was manufactured on a shop floor using conventional machines such as Lathe, grinder, drilling machine and CNC Lathe. The assembling and finishing were done using electrical welding machine. The finishing and quality assurance was performed. The manufactured machine was evaluated to ascertain the performance and the data discussed.

Description and Principle of Operation of the Machine

The domestic rice de-stoning machine developed is made up of the reservoir, de-stoning chamber, washing chamber, and outlet. The de-stoning chamber is made up of the hopper and impeller blade, it is supported with the aid of a frame. The washing chamber unit which consists of a brush drum is position parallel to the de-stoning chamber unit.

The machine was switch on and allowed to run at no load to ascertain its condition. The sample prepared which contains 2kg of rice grain mixed with 20 pieces stone of different sizes was fed through the hopper to the de-stoning chamber which happens to be 1/3 of the volume of de-stoning chamber. Water was displaced from a reservoir tank to the de-stoning chamber. Variable speed electric motor with speed rating from 1400 rpm to 10 rpm was used which provide the motion of the shafts and rotate the impeller blade to stir the infested rice at a considerable speed and at given time.

As a result of bulk density difference of stone/sand which is 1.33 g/cm^3 (irregular in shape) while 0.51 g/cm^3 for rice large quantity of rice float into the washing chamber for proper cleaning with the aid of brush drum and be collected at the rice outlet, while the stones settled down at the bottom of the de-stoning chamber and be collected at the coarse surface. The water passes through a screen and be re-circulated to the reservoir to avoid water wastage.

The Machine Design and Drawings

The detailed conceptual drawing of the proposed rice destoning machine using water medium was done using Inventor application software (version 2018) because for the provision of features such as: automatic drawing view creation and update, modelling and simulation and complex assembly design.

The isometric view and parts list of the rice destoning machine is shown in Figure 1. While the orthographic view of the design machine showing the Front, Top and Side views of the machine is shown in Figure 2 and, the 3D drawing shown in Figure 3.

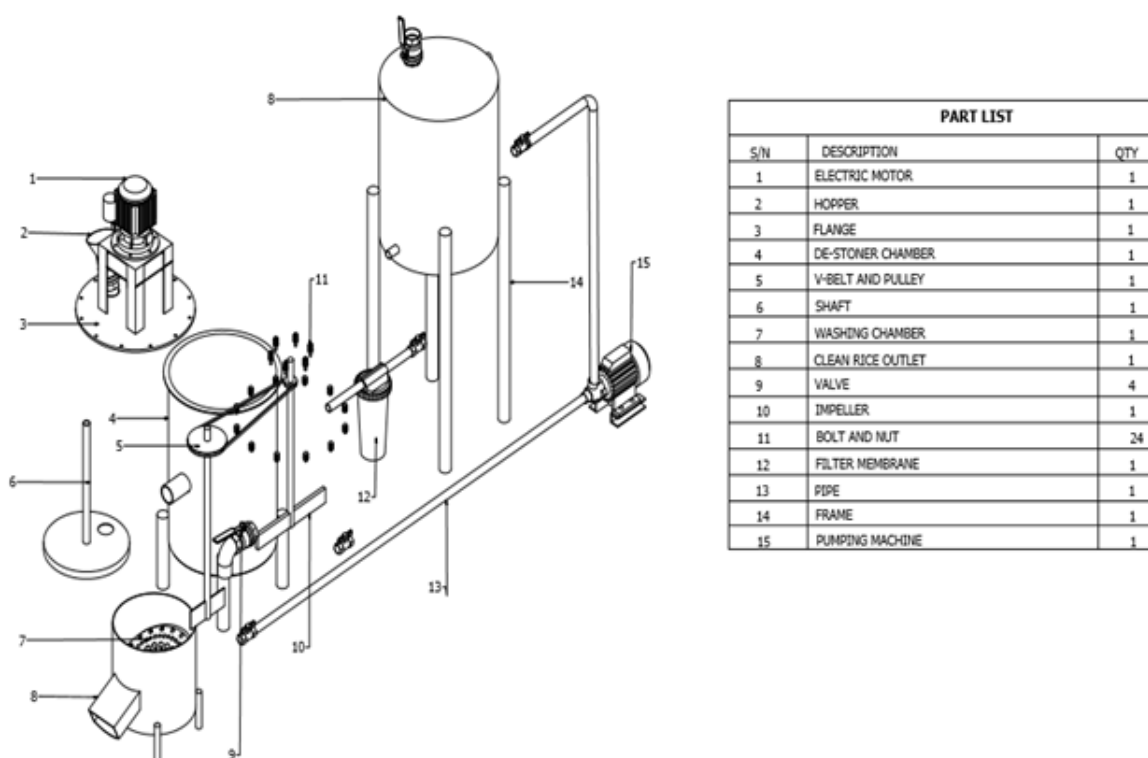


Figure 1: The isometric view of the rice destoning machine

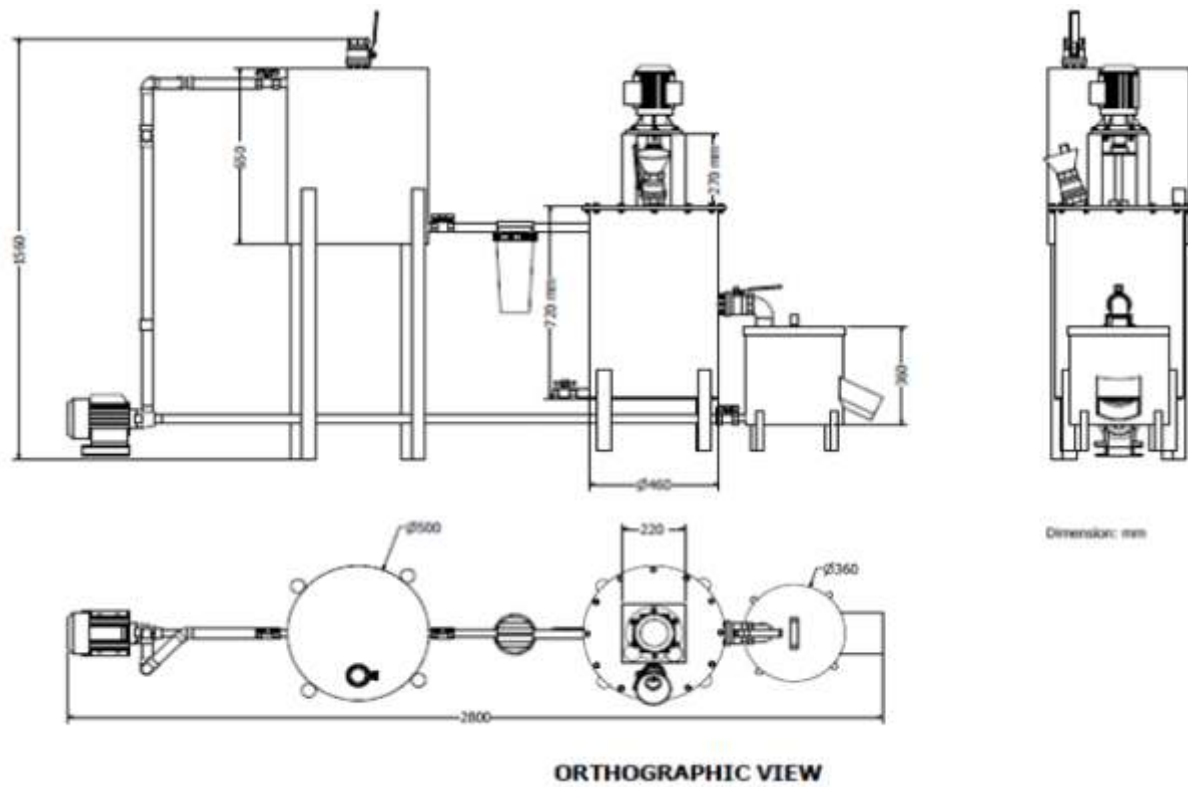


Figure 2: The orthographic view of the rice destoning machine

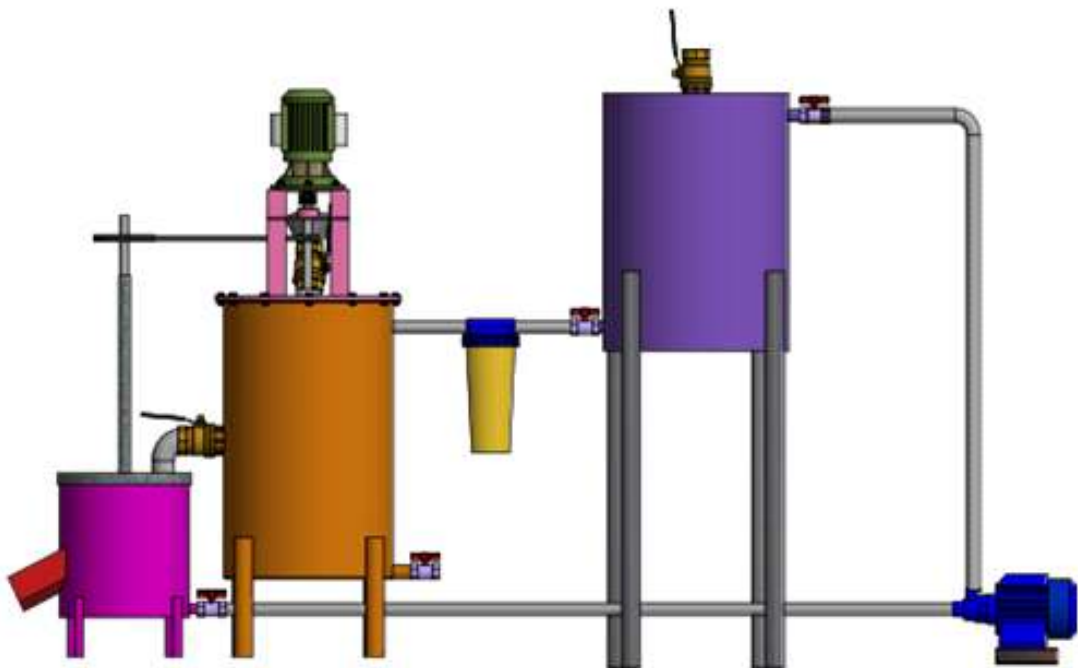


Figure 3: The main view of the rice destoning machine

Machine Component Design Calculation

The design components of some of the machine parts are presented in Equations 1 to 12.

Hopper Capacity

The volume of the hopper is a function of the dimension of the rice which also depends on the volume of the rice to be fed into the de-stoning chamber per batch.

$$\text{Volume of Frustum of a cone} = \frac{1}{3} \pi r^2 h \quad (1)$$

where; h is the height of the cone and r is the radius of the cone.

Volume of the De-stoning Chamber

The volume of the de-stoning chamber (V_{des}) is given by equation

$$V_{des} = \pi r^2 h \quad (2)$$

where; d is the diameter of the destoning chamber, r is radius of the destoning chamber and, h is the height of destoning chamber .

Total mass of the De-stoning Chamber

$$\text{Total Mass}_{dsc} = M_R + M_{RI} + M_{water} \quad (3)$$

where; M_R - mass of rice, M_{RI} - mass of rotating impeller and, M_{water} - mass of water

Speed of the Impeller (Agitator)

$$V = \frac{Ds}{D_L} = \frac{N_L}{N_s} \quad (4)$$

where; V - speed of the impeller (agitator), D_s - diameter of smaller (driving) pulley, D_L - diameter of larger (driven) pulley, N_s - speed of smaller (driving) pulley in r.p.m and, N_L - speed of driven pulley in r.p.m

Shaft Design

Loads acting on the shafts are three impeller blade, brush drum and pulley. Dimensions of components on the shafts was based on the shape and size of the impeller.

Impeller Blade

The number of the blade is a function of the maximum volume of the rice in the destoning chamber during operation. Length of blade is chosen based on the distance between the wall of the destoning chamber and the clearance. The function of the beater is to complete the destoning processes by causing the turbulent of the rice and water. Material is stainless steel.

$$\text{Volume of blade} = \text{length} \times \text{width} \times \text{thickness} \quad (5)$$

Shaft of the Impeller Blade

The function of the shaft of the impeller blade is to provide rotational motion the blade that aid in destoning of the rice from stones.

Main Shaft Design

The purpose for the design of shaft is to ensure the appropriate firmness and rigidness needed to transfer a useful force is ensured. The firmness in the twisting force of shafts made of ductile materials are usually calculated on the fundamental of the maximum shear theory.

Determination of Power Required to Drive the Pulley and Shaft

$$\text{Power transmitted by the belt} = (T_1 - T_2) \times v \quad (6)$$

where; T_1 is the belt tight side tension in Newton, T_2 is the belt slack side tension in Newton and v is the belt velocity in meter per second. The efficient rotational force at the perimeter of the driven pulley is the distinction between the tension at the slack side and the tight side of the belt (T_1 and T_2).

Determination of Shaft Diameter

For a solid shaft made from malleable material having no axial loading, the shaft diameter is obtained from

$$\frac{T}{J} = \frac{\tau}{r} \quad (7)$$

where; T - Applied Torque in Nm, J - Polar moment, τ - Maximum shear stress at the outer surface and, r - Perpendicular distance between the rotational axis= $d/2$

$$T = \frac{\pi}{32} \times d^4 \quad (8)$$

and

$$T = \frac{\pi}{16} \times \tau \times d^3 \quad (9)$$

To determine the twisting moment transfer by the shaft,

$$T = \frac{P \times 60}{2\pi N} \quad (10)$$

where; P - Power required to run the shaft and

N - Output Speed of the transmission shaft

Belt Design and Selection**Center Distance, x , between Driving and Driven pulleys**

Note that the center distance, x , between the two pulleys is twice the diameter of the larger pulley. Thus, distance between the centers: Khurmi and Gupta (2005)

where; d_1 is the diameter of driving pulley and d_2 is the diameter of driven pulley

$$x = 2d_2 = 2(0.175) = 0.35 \text{ m}$$

Length of the Belt

$$L_p = \frac{\pi}{2} (D_1 + D_2) + 2C + \frac{(D_2 - D_1)^2}{4C} \quad (11)$$

where; L_p is the total length of belt and,
 C is the centre to centre distance,
 D_1 is the Diameter of larger pulley and,
 D_2 is the Diameter of Smaller Pulley

The Flow Rate

The flow rate of a liquid is how much fluid passes through an area in a particular time. Flow rate can be articulated in either terms of velocity and cross-sectional area, or time and volume. It is proportional to both the magnitude of the average velocity and the size of a pipe or conduit. To ensure continuity flow, the cross sectional area of the pipe decreases, the velocity necessarily increases.

Flow rate of the machine

$$Q = AV \quad (12)$$

where; Q - flow rate, A - Area of the pipe and, V - Velocity of the fluid

Design Factor	Design Equation	Design Value
Volume of a hopper	Volume of Frustum of a cone = $\frac{1}{3} \pi r^2 h$	$2.597 \times 10^{-3} \text{ m}^3$
Volume of the de-stoning chamber	$V_{des} = \pi r^2 h$	$1.0054 \times 10^{-3} \text{ m}^3$
Volume of rice and stone in the De-stoning chamber	$V_R = 1/3 V_{DES}$	$3.352 \times 10^{-3} \text{ m}^3$
Mass of water in the destoning chamber	$M_{water} = \rho \times v$	6.7029 kg
Power of electric motor	$P = T \times \omega$	1.452 kW
Peripheral belt speed	$V = \frac{2\pi N_s}{60} \times \frac{D_1}{2}$	5.28 m/s
Length of the belt	$L_p = \frac{\pi}{2} (D_1 + D_2) + 2C + \frac{(D_2 - D_1)^2}{4C}$	42.59"
Power transmitted by belt	$P = (T_1 - T_2)v$	1.6166 kW
Required number of belt	Number of Belts = $\frac{\text{Total power transmitted}}{\text{Power transmitted per belt}}$	1 belt
Volume of the washing chamber	$V_{was} = \pi r^2 h$	$3.4222 \times 10^{-3} \text{ m}^3$
The flow rate	$Q = V/T$ or $Q = AV$	3.57 L/S
Torque transmitted by the shaft	$T = \frac{P \times 60}{2\pi N}$	$33.15 \times 10^3 \text{ Nmm}$
Shaft diameter	$T = \frac{\pi}{16} \times \tau \times d^3$	14 mm

Performance Evaluation of the Designed Rice De-stoning Machine at Different Speeds

In order to achieve the objective of this study a rice de-stoning machine using wet medium was fabricated to evaluate its capability. In each run base on the experiments, 2 kilogram of rice and 20 pieces of stones of different sizes was used. The de-stoning was carried out at variable speed of 1400 rpm - 10 rpm. A variable

electric motor was chosen to determine the functioning of the developed machine at a constant time of 10 minutes. The machine was run without load using a single phase, 1440 and a 1.8 kW petrol engine whereas the shaft was run at a speed of 10 rpm. The separation effectiveness of the rice and stone obtained at different speeds are presented in Table 2, Figure 4 and Figure 5, respectively.

Table 2: Machine Performance Evaluation

Speed (r p m)	Rice (g)	Number of Stones	Rice in Washing Chamber (g)	Stone in Washing Chamber	Rice in De-stoning Chamber (g)	Stone in De-stoning Chamber
1400	2000	20	2000	20	0	0
1200	2000	20	1950	17	50	3
1000	2000	20	1940	15	60	5
800	2000	20	1935	10	65	10
600	2000	20	1930	4	70	16
400	2000	20	1928	0	72	20
200	2000	20	1800	1	200	19
100	2000	20	1500	2	500	18
50	2000	20	750	0	1250	16
30	2000	20	300	0	1700	20
20	2000	20	0	0	2000	20
10	2000	20	0	0	2000	20

Discussion of Results

Results from experimental investigations carried out under the workshop conditions are discussed. The effect of different operational parameters like percentage of stone separation, rice cleaning efficiency and de-stoning machine are presented and discussed.

Percentage of Stone Separation

The results of test analysis on the rice de-stoning machine using wet medium confirms that, at a very high speed of 1400 rpm both the rice and the stone flow together as a result of high torque and there was no separation of stone from the rice. At a speed of

1200rpm, 3 pieces of stone were recovered whereas the remaining flow with the rice to the washing chamber which gives only 15% of stone removed. At 1000 rpm, 800 rpm, 600 rpm, and 400 rpm gives 25%, 50%, 80% and 100% stone removal.

At a very low speed of 200 rpm and 100 rpm gives 5% and 10% stone removal while at 50 rpm, 30 rpm, 20 rpm and 10 rpm gives 0% as there was no de-stoning of stone as a result of very low torque, it settled at the coarse surface of the de-stoning chamber and was collected through the stone outlet. This shows that the speed of 400 rpm is the best speed for the stone removal from the rice.

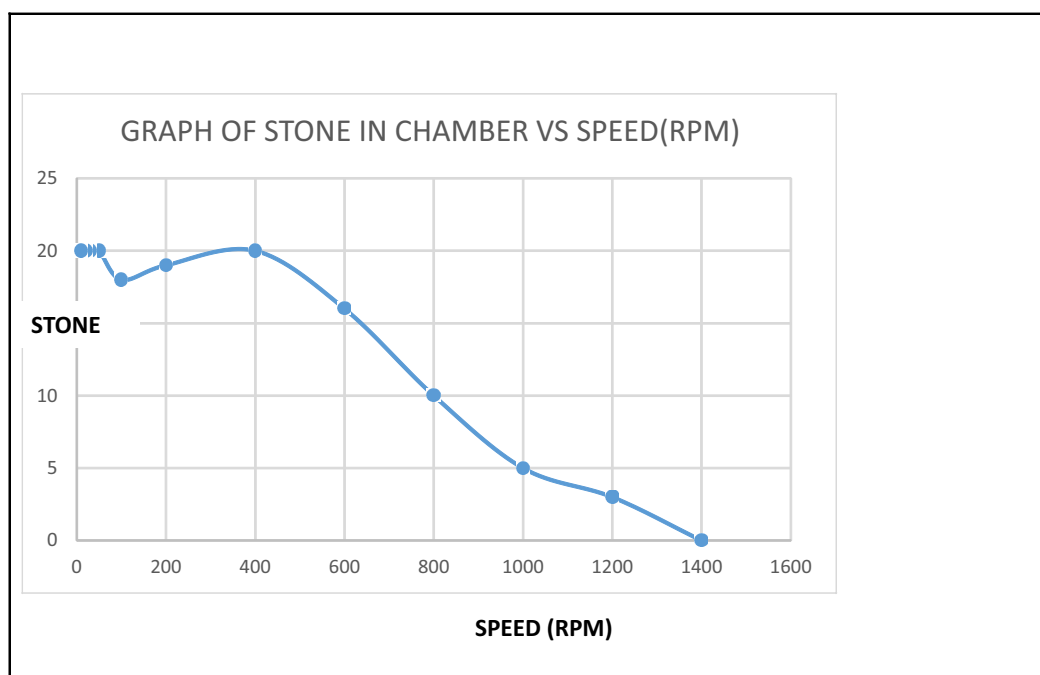


Figure 4: The Graph of Stone Separation

Rice Cleaning Efficiency

The cleaning effectiveness of the machine increase as a result of resultant increase in speed of the impeller blade. Evaluation result as seen in Figure 5 revealed that cleaning efficiency recorded for machine at a very high speed of 1400 rpm, there was no rice destoning as both the rice and stone flow together to the washing chamber as a result of high torque. At 1200 rpm, 1000 rpm, 800 rpm and 600 rpm which gives 97.5%, 97%, 96.75% and 96.5% of the rice that flow to the washing

chamber but still contains stones which make it not favorable but at 400 rpm gives 96.4% of the clean rice separated without a stone.

At a very low speed of 200 rpm and 100 rpm gives 90%, 75% but contain some pieces of stone, at 50 rpm and 30 rpm gives 37.5% and 15% only small quantity of rice without stones was separated while at 20 rpm and 10 rpm there was no de-stoning of rice and stone as a result of very low torque both the rice and stone settled at the bottom of the de-stoning chamber.

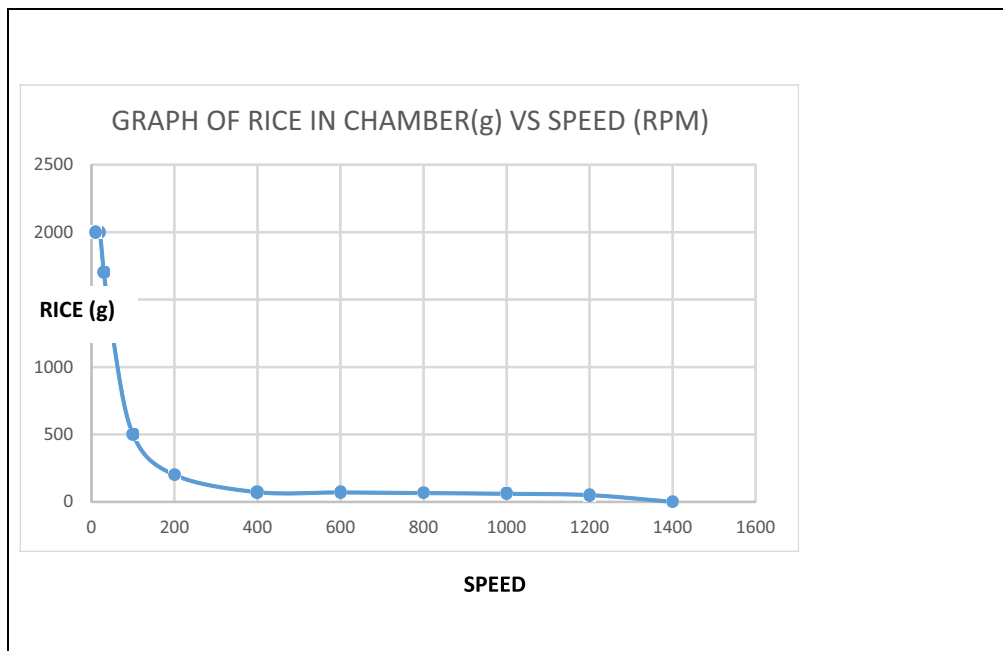


Figure 5: The Graph of Rice Separation

Conclusion

The performance on developing and testing a rice destoning machine that uses wet medium and works with one type and the same amount of rice was accomplished. The equipment performed admirably in tests, according to the results. The following are some of the work's particular conclusions:

The machine's stone separation rose as the impeller's speed grew, and decreased as the impeller's speed decreased. Rice separation rises with increasing speed and reduces with decreasing speed, with no rice loss or breaking. After separation, the impurity was extensively cleaned in the washing chamber. For simplicity of maintenance, the domestic rice de-stoning machine may be simply manufactured with locally accessible components. The Federal Government of Nigeria may encourage domestic, medium, and small-scale enterprises to create clean rice from domestically grown rice that contains sand/stones and other impurities, lowering unemployment and our reliance on rice imports in Nigeria. With these findings, more work will be done to increase the machine's overall performance indices, such as stone separation, rice

separation, and rice retention efficiency. Following the testing of the machine, it was ascertained to efficiently de-stone several varieties of locally process rice.

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