Development of Low Cost Rice De-Stoning Machine

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ABSTRACT: In Nigeria, Local rice processing has suffered a lot of setback, such as problem of stones and other foreign materials in processed rice. In an attempt to develop capacity to meet the ever increasing demand, this study designed, constructed, and evaluated performance of a rice de-stoning machine. The study is divided into five major tasks namely: (1) determination of the engineering characteristics of five commonly cultivated local rice varieties in Nigeria that are relevant to design of the de-stoning machine, (2) design of basic components of rice destoner (3) engineering drafting of the components, (4) construction of de-stoning machine using local technology and sourced materials (5) performance evaluation of the fabricated machine. Relevant engineering procedures and standards were applied to the determination of the properties and design of the machine components. The machine with a design capacity of 3 tons per day was constructed in the Faculty of Engineering workshop, Niger Delta University. It's consists of centrifugal blower, reciprocating sieves, screw conveyor, separating cylinder, transmission shaft with rotating speed of 360 rpm, powered by a 5 hp electric motor. The total cost of constructing the machine is estimated at ₦196,050. The performance evaluation revealed a de-stoning efficiency of 78%. This research work has developed a local, cost effective and efficient rice de-stoning machine, thus improving the quality and the market value of locally produced rice in Nigeria.

***Index Terms*; Local rice, processing, engineering property, de-stoning machine, Research and development. Centrifugal blower, reciprocating sieves, transmission shaft.**

I. INTRODUCTION

Rice is a staple food crop that is cultivated and eating in most part of the world. Rice plant is monocotyledonous with fibrous root system, which belongs to the family gramiceae (grass family), genus Oryza and the specie sativa [9]. The botanical name of rice is; *Oryzasativa*. It is grown as an annual crop with average height of between 1-1.8m at maturity; it has slender leaves of about 50- 100 cm long and 2.0-2.5 cm wide. Harvested rice are called paddy, which are processed to obtain finished rice. Rice is popularly cooked and eaten with stew in Nigeria, however, in the northern parts of Nigeria it is milled, moulded and fried into cakes called "gurasa", or pounded and eating with soup known as "Tou Shinkafi". Commercially, rice can be processed into flour, for making pastry (bread, macaroni, nodules, and biscuits) as well as confectionaries (infant meals, flakes and cakes). Also rice bran which is one of the by-products is an important livestock feed ingredient and a good source of calcium for crops.

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Globally, rice production is estimated at about 600 million metric tonnes per annum [8]. The world five leading producers of rice are; China (193,354,175 metric tonnes/ yr), India (148,260,000 metric tonnes/yr), Indonesia (60,251,072 metric tonnes/yr), Bangladesh (46,905,000 million metric tonnes/yr), and Viet Nam (38,725,100 million metric tonnes/yr). The World rice consumption is estimated at 500 million metric tonnes annually, with a population of 6.93 billion,[14]. Across the globe, about 300 million metric tonnes of rice is imported annually. Japan is world leading rice importer, with an annual import of about 11.89 million metric tonnes per year, [16]-[8].

In Africa, rice production for the past 50 years has increased from about 3.14 million metric tonnes, to about 14.60 million metric tonnes per year, while rice consumption is estimated at about 24.3 million metric tonnes/yr [8] and about 9.7 million metric tonnes of rice is imported into Africa annually.

Specifically, in Nigeria, rice production is currently estimated at about 3.0 million tonnes per year. Nigeria has ecologies that are suitable for different rice varieties which can be harnessed to boost rice production to meet domestic demands and produce a surplus for export [1]. Nigeria has a potential land area for rice production of between 4.6 million and 4.9 million hectares. However, only 1.9 million hectares representing about 40 percent of Nigeria's total cultivable land mass is cropped with rice. Notwithstanding, this great rice potential, rice production has not kept pace with the rapid growth in population [4].

Rice plants are classified according to ecological requirements of where they are best grown. The cultivable land for rice is spread over five major ecologies; upland, inland/shallow swamp, irrigated rice, deep water/floating rice, and tidal mangrove/swamp. The latter is not fully developed because there is a lack of appropriate technology [13]. Nigeria is the largest producer of rice in West Africa; she produces about 50% of the total quantity of rice grown in the sub-region.

The history of Cereal cleaning is as old as man himself. Cereals like maize, rice, sorghum and millet etc are principal grain crops grown in Nigeria [12]. Foreign materials get into cereals during harvesting and transportation. These unwanted materials are imposed constraints on grains and must be significantly reduced for good market value of grains and their product. In Nigeria, demand for locally produced rice is low, this has been attributed to poor harvesting and post-harvest handling methods which bring about contaminants such as stones, stick, chaff and leave stalk [11]. Many types of processing equipment have been developed, which are used in many parts of the world to clean seeds, grains and beans. In the pre-civilization days, grain cleaning was undertaken by manual means, which involves throwing grains upward against wind direction. This traditional method of winnowing still being employed by the peasant farmers usually cannot effectively handle the increased grain production and also laborious as well.

The poor acceptance of local rice in Nigeria has to do with its processing which introduces stone particles and pebbles and medical analysts had reiterated so many times the danger inherent in its consumption [2]. As a result of this, there had been several attempts to design a low cost, efficient and simple machine that can be used to remove stones/pebbles and extraneous materials from our local rice to make it safe and attractive for human consumption. The machine will reduce the labour and efforts involved in the manual method of separation of the impurities from rice grains, minimize wastages and improve the quality of locally produce rice (OFADA rice), increase its demand, enhance large scale production and make operational processes more convenient. However, despite the huge resources, time and efforts that Nigerian government and individuals have invested results got so far is still below expectation rice consumers.

II. NECESSITY OF THIS RESEARCH

i. Locally processed rice is not attractive to most Nigerian consumers, due to its high extraneous materials content, which either results in out-right rejection, low demand and low pricing compared to imported rice.

ii. In Nigeria presently rice processing is still being manually carried out which makes the business unattractive to most farmers.

iii. Imported rice de-stoning machines are very expensive which is usually beyond the reach of an average Nigerian farmer.

iv. Foreign rice processing machines are not efficient in processing local rice varieties cultivated in Nigeria, thereby necessitating design of a local model.

III. OBJECTIVES

The objectives of this research are as follows:

1. To determine the physio-mechanical properties of locally produced rice varieties that are relevant to the design of an efficient rice de-stoning machine.

2. To design an efficient rice de-stoning machine, using the physio-mechanical properties determined in 1 above as design input, specifically for locally produced rice in Nigeria.

3. To employ local technology and sourced materials in constructing a cost effective rice de-stoning machine which is affordable to an average Nigerian peasant farmer.

4. To determine the efficiency of the fabricated machine using local rice varieties cultivated in Nigeria.

IV. METHODOLOGY

The methodology used for this research included five major tasks namely:

i. Determination of the engineering characteristics of five commonly cultivated local rice varieties that are relevant to design of rice de-stoning machine.
ii. Design of basic components of rice de-stoning machine.
iii. Engineering drafting of the components and sourcing of required materials using 3D AutoCAD Software.
iv. Construction of rice de-stoning machine using local technology and sourced materials.
v. Performance evaluation of the fabricated rice de-stoning machine.

V. DETERMINATION OF THE ENGINEERING PROPERTIES OF RICE

In order to design an efficient and cost effective rice de-stoning machine, engineering properties was determined for five locally cultivated rice varieties these include; length, width and thickness, effective diameter, Sphericity and Surface area, Bulk density, true density, Angle of repose, Coefficient of Static Friction and Terminal Velocity of the rice grains. This investigation was done in Biological material Laboratory of Agricultural Engineering department, Niger Delta University. The American Society of Agricultural Engineers (ASAE) standard of 1993 was applied in the determination of physio-mechanical properties of rice [5].

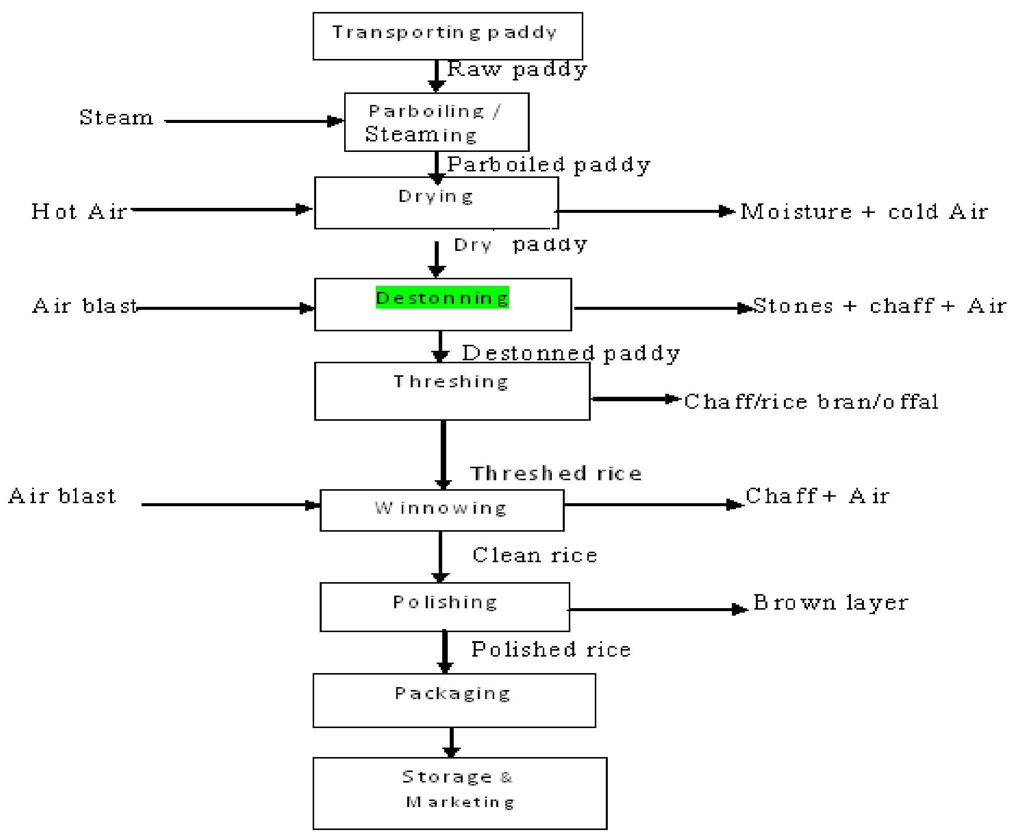

Fig. 1. Rice Processing Flow Chart

VI. DESIGN CONSIDERATIONS

The design considerations include:

- The machine should be safe and simple to operate such that local farmers can use it without difficulty.
- The machine should be affordable in terms of purchase and maintenance cost.
- The machine should be durable.
- The machine should be able to remove stones and other extraneous materials from

rice efficiently, without damage to rice grains.

- The machine should be such that its spare parts will be readily available to farmers without having to travel long distances.
- The energy requirement of the machine should be minimal.
- The machine should be such that it can be easily moved from one place to another (should be portable)
- Material selection: materials for construction should be selected based on strength, safety (anti-corrosion characteristics) and durability.

VII. DESIGN OF SHAKER MECHANISM SHAFT DIAMETER

The shaker mechanism and fan shaft diameter was designed using the ASME (American Society of Mechanical Engineers) code equation for solid shaft [6] is given

$$D^{=}\ 16/\pi S_s \sqrt{(K_b M_b)^2 + (K_t M_t)^2} \qquad \textbf{(1)}$$

D = diameter of shaft (mm)

M_b = maximum bending moment Nm

$M_{t\,=}$ Torsional moment Nm

Ss = allowable shear stress MN/m^2

Kb = combined shock and fatigue factor applied to bending which is 1.5 for gradually applied load [10].

K_t = combined shock and fatigue factor applied to a torsional moment, which is 1.0 for gradually applied on rotating shaft [10].

D = 0.029.9m = 29. 9mm

Use standard commercial shaft of 30mm

VIII. BELT AND PULLEY DESIGN FOR SHAKER MECHANISM

The belt and pulley was designed in accordance with Fenner industrial Belt Drives manual [7];

Motor power: 2hp= 1.5kw

Motor speed: 1440 rpm

Speed ratio: 1:4

Belt type: V- belt (A belt section)

- Service Factor = 1.0 (the machine will run for less than 10 hours per day)
- Belt Designed power= 1.0x 1.5 kw =1.5kw
- Section: 80mm and One Step Pulley
- Driven Speed: At 1:4 speeds gives 360 rpm obtainable with the stock pulleys.
- Pulley Diameter: the diameter of small pulley (driver) and large pulley (driven) are :

  d= 100mm

  D= 400m

- Centre Distance: is Found using the formula

$$C = 2 \text{ x } \sqrt{D + dxd} \qquad \textbf{(2)}$$

$$C = 2 \text{ x } \sqrt{(400+100)X}\ 100$$

C= 447.2mm

(a) Correction factor = 0.89
(b) Number of belt

$$= \frac{\text{corrected designed power}}{\text{Correction factor}}$$

$$= \frac{1.5}{0.89} = 1.68 \text{ kW}$$

One belt will supply 1.68 kW power which is greater than the corrected designed power (1.5kw); hence a single belt will be sufficient for the shaker Mechanism. Using the belt catalog, a belt so selected has the following characteristics;

Belt Characteristics;

- Belt description = A1750
- Shaker mechanism pulley (driven) = 400mm
- Motor pulley (driver) = 100mm

IX. SHAKER MECHANISM SHAFT KEY DESIGN

i. Steady torque = 1.5 factor of safety [10].
ii. Square key required

Iii. Shaft diameter = 30mm, radius = 15mm
Tangential force Torque T= F x r = 1500 x 0.2 = 300Nm using pulley.

$$Ts = \frac{Ss}{N} \text{ x W x L x r} = 300\text{Nm} \qquad \textbf{(3)}$$

Where Ts = shearing Stress

Ss =allowable shear stress of 100mpa for mild steel

N = factor of safety = 1.5 for steady torque

W = Width of Key

L = length of hub on Pulley = 0.05m

$55 \times 10^6/1.5 \times W \times 0.05 \times 0.015 = 300$

$= 27500 \times W = 300$

$$W = \frac{300}{27500} = 0.0109m = 10.9mm$$

Use standard square key of 11mm X 11mm

Sieve Design

The sieve design consists basically of the determination of diameter of the sieves using the formula:

$$d = \sqrt{\frac{D2(D\pi - 2Co}{Co}} \qquad \textbf{(4)}$$

Where, $D \rightarrow$ average effective diameter of rice grains =3.8 mm; and Co = coefficient of opening (3.5).
Therefore,
Upper Screen diameter $d = 3.162 \cong 3$ mm
Middle screen diameter = 2.5 mm
Lower screen diameter = 2.0 mm

X. DRAFTING

The graphical details of the rice de-stoning machine were drawn using 3D AutoCAD software; as shown in Figures 2 to 5.

Plate.1. Picture of fabricated rice destining machine

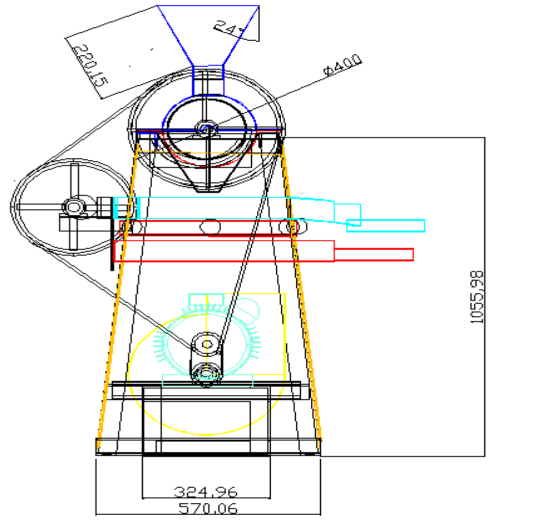

Fig. 2. Orthographic View of Rice destining machine

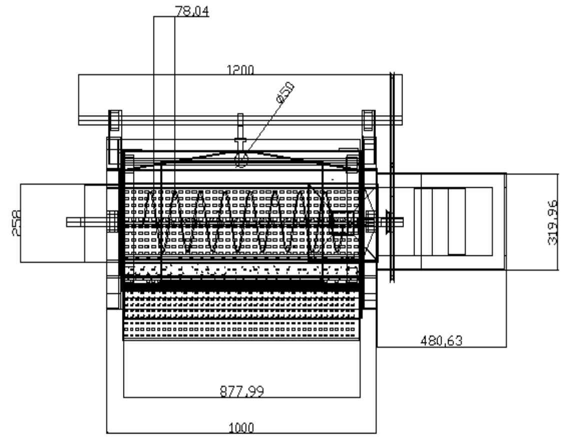

Fig.3. Plan of Rice Destoner

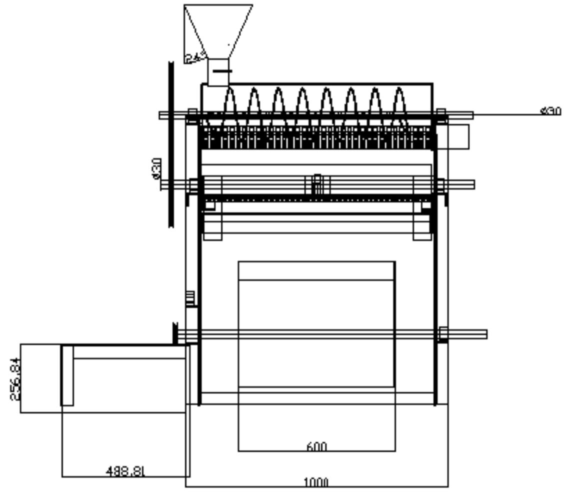

Fig. 4. Front View

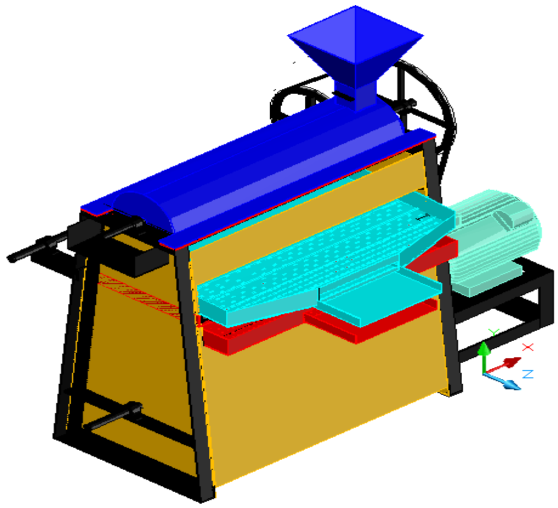

Fig.5. SE Isometric view of rice destining machine

Tab.5. Bill of Engineering Measurement and Evaluation

S/N	Items	Qty	Price (N)
(1)	Angle Iron	3 full length	4,750
(2)	v-belt	2	4,500
(3)	Friction bearing	6	7800
(4)	4mm thick sheet metal	1 full length	8,900
(5)	ø40mm mild steel rod	3000mm length	4,000
(6)	2mmthick stainless Steel plate	1full length	9,500
(7)	Ø500mm mild steel rod	200mm length	6,000
(8)	Grinding disk	8	6,000
(9)	Hack saw cutting blade	5	2,000
(10)	Pre-design investigation	---------	35,000
(11)	Drafting & printing	----------	15,000
(12)	Field trips Kwara,Ogun, and EkitiStates	-----------	10,000
(13)	Labour	----------	40,000
(14)	Spraying/painting	-----------	7,000
(15)	Turning of shaft	-----------	5,000
(16)	Slotting of keyway	------------	5,000
(17)	Transportation	------------	10,600
(18)	miscellaneous	--------------	15,000
	Total Expenditure		196,050

Note; total cost was as at June 2017

XI. FABRICATION OF RICE DE-STONING MACHINE

The Main operations that were used the fabrication included;

i. Purchase of Construction materials from, metal market, Yenagoa.
ii. Marking out and cutting of construction material.
iii. Machining/machine tool processes.
iv. Assembly of fabricated and purchased components.
v. Surface finishing.
vi. Painting/Spray painting/ Coating/ Metal treatment.
vii. Testing, evaluation, installation and marketing of product(machine)

Table.6. Component part list of designed rice De-stoning machine

S/N	Item	Quantity	Material
1	Auger	1	Steel plate
2	Hopper	1	Steel plate
3	Cylinder	1	Steel plate
4	Electric motor	1	5 hp
5	Motor seat	1	2 by 2 angle iron
6	Frame	1	2 by 2 angle iron
7	Key	6	Mild steel
8	Fan	1	Centrifugal fan
9	Bearing	7	418
10	Screen	3	Stainless steel plate
11	Pulley	4	Cast Iron
12	Belt	2	Leather

XII. TESTING

In order to test the machine, 10 kg of rice paddy, was put into the hopper of the machine at 360 rpm, data were collected to evaluate its performance.

Specification of fabricated machine

The Specification of fabricated machine

are as follows;

- Model: NDU-Mtech-x
- Height: 1050 mm
- Length: 900 mm
- Width: 375 mm
- Overall weight: 235 kg
- Hopper Capacity: 0.600 m^3 (10kg)
- De-stoning capacity: 300kg/hr (3 tons per day)
- Power transmission: belt drives, pulleys and shafts
- Colour: green
- Prime mover required: Electric motor or petrol engines
- Power requirement: 2hp (1.5Kw)
- Motor speed: 1440 rpm
- Fan: Centrifugal fan
- Bearing type: No; P206, 30mm diameter
- Belt: A1250, & A1750 belts

XIII. DISCUSSION

The determined mean terminal velocity for the five varieties is 7.4 m/s, which is slightly different from a range of between 5.06 to 5.19 m/s, which Adewuni got in 1996 [3] when he determined the terminal velocities of some rice varieties grown in the South West of Nigeria.

The imported rice destining machines only remove stones from rice paddy at one stage with one sieve, this imply that the broken/smaller grains are discharged as waste which is a disadvantage to the Farmer. however, this local model destones at three stages with three sieves, which also separate the rice grains into different grades base on sizes of grains, by this every grain is de-stonned and collected as good product, whether small or big which are graded into different sizes. This is major improvement on the local model of rice de-stoning machine.

XIV. CONCLUSION

A local, cost effective and efficient rice de-stoning machine was designed, constructed and evaluated to determine its performance. The machine has a de-stoning efficiency of 78 %, at a speed of 360 rpm and a capacity of 300 kg/hr (3 tons per day), the total cost of the project is ₦196,050 (one Hundred and Ninety six Thousand, Fifty Naira only). The machine can be sold up to ₦300,000 (Three Hundred Thousand Naira) or more in the market, as against the imported model of similar capacity and efficiency which costs several millions of naira, and this is the significance of the research.

Conclusively, the objectives of this research which is to "develop a local, cost effective and efficient rice de-stoning machine " being a local need in Nigeria, have been fully achieved.

XV. RECOMMENDATIONS

In order to ensure optimum de-stoning efficiency of the machine, the following routine maintenance must be carried out;

i. To undertake all required adjustments regularly.
ii. Ensure proper belt tension at all time.
iii. Ensure that friction bearings are properly lubricated on regular basis.
iv. Check moving parts for defect and replace as and when due.
v. Remove chaffs and stones from the converger before starting fresh de-stoning session.
vi. Ensure proper feed rate of materials into the separating cylinder, by using the feed gate which is located inside the hopper as a control mechanism.

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