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A mini rice processing machine for Nigerian farmers

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The rice milling plant is developed to solve the problem associated with the manual processing of locally produced rice (OFADA RICE), particularly the removal of pebbles and other impurities from the rice. The machine consists majorly of two stages: dehulling and sieving. The dehuller consists of rotary cylindrical sieve which separates the chaff from the rice grains via the shaft and blade. Impact method was adopted for the removal of husk from the rice paddy. After milling the paddy rice, it passes through a vibrating sieve machine where a crank mechanism converts rotary motion into a reciprocating movement of the sieve bed. The vibrating sieve removes the chaffs and the pebbles from the rice grains. The performance tests conducted on the machine showed that the dehuller effectiveness reduced with increase in number of paddy rice fed into it, while the sieve shaker optimum yield occurs at a maximum stroke of 40. It was discovered that a minimum output shaft speed of 900 rpm transmitted by a v-belt drove by an electric motor of 3.5 hp which is required for the effective performance of the vibrating sieve. Mild steel was used majorly for the fabrication of component parts for ease of machining, assembling, maintenance and affordability. The plant would reduce the hazardous health implication currently experienced when eating locally produced rice. It would reduce the cost of labour and also enhance the economic status of the peasant farmers in Nigeria.

Key words: dehuller, impact method, o*ryza sativa,* paddy, pebbles, sieving

Introduction

Rice (*Oryza Sativa)* is one of the most staple foods in Nigeria. Rice is very popular because of its high carbohydrate content which is an essential element for energy, human development and body growth (Encyclopedia Americana, 1980). Many cultures have evidence of early rice cultivation, including China, India, and the civilizations of Southeast Asia. However, the earliest archaeological evidence comes from central and eastern China and dates to 7000–5000 BC (Encyclopædia Britannica, 2010). It was made known by Omotola and Ikechukwu (Omotola and Ikechukwu, 2006) the intention of

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Federal Government of Nigeria to cultivate about 3million of hectares of rice by 2007; this is an indication that government was committed to rice production. In the report, lack of access to improved technology was seen as one of the problems militating against effective cultivation and processing of rice in Nigeria. Rebecca (2006) in her thesis characterized data from laboratory pilot and industrial scale rice milling machine. A bivariate analysis of factors affecting rice processing in Igbemo-Ekiti, Nigeria was carried out by Basorun (2008). Comparison of different rice milling methods to determine the best milling method in Fars a province of Iran was conducted by Sadegh and Mohammed (2002); Zossou *et al*. (2010) presented a paper on how to strengthen local innovation in rice processing through the use of video.

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. As a result of this, the authors were motivated to design a simple machine that can be used to produce Ofada rice that is saved 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 wastage, improve the quality of locally produce rice (OFADA rice), increase its demand, enhance mass production and make operational processes more convenient.

To be able to meet the above requirements, the separation process must include sieving, cleaning, winnowing, screening and the use of aspiration machine (Encyclopedia Americana, 1980; Kaul *et al.,* 1985; Henderson and Perry, 1976; Klenin, 1983). Literature has shown the existence of rice - stone specific gravity separator which works on a principle that makes use of the densities variation between sand and rice (Chang, 1997). There is another specific gravity separation method adopted by Adekoya and Koya (1994). The system involves movement of grains on an oscillating conveyor and the application of aerodynamic force. Another machine for the separation of dust and stone from rice is the stoner separator (Chackravery, 1981). Multi crop cleaner has been developed by Ademosun (1993). Ozormba described rice destoner as a machine, which takes advantage of the difference in axial velocities of rice and stone. The rice is fed via a hopper into a rotating cylindrical sieve, which separate the rice from the stone. The rice passes through the sieve and leaves the stone in the cylinder to roll down to the stone collector while rice is being collected in the rice collector (Ozormba, 1997; Adegun, 2006) in his paper used sieve shaker to separate guinea corn from rice. A method of separation similar to this is adopted in the current research work.

Materials and methods

Material Selection

Of the various factors that ensure the viability of an engineering project, material selection was one of the most important; but engineering practice generally involves utilizing scientific principles to design components and systems that perform reliably and satisfactorily (William and Callister, 1980). The criteria for design of the machine component parts were adopted from (Osborne, 1977; Khurmi and Gupta, 2005; Keter, 1980; Ryder, 1977). The factors that determined the selected materials for this work were involved in the mechanical properties such as toughness, strength and hardness. Surface finish, density, interaction with environment, fabrication cost, maintenance cost and availability of materials; ease of fabrication and safety of materials were also considered.

Mild steel with carbon content 0.15% to 0.3% and of various thicknesses were used. However, galvanized steel was used for the blades of the blower and for the hopper.

Preliminary Investigation

The physical properties such as density, specific gravity, weight, size of the impurities and rice grains were considered. These properties form the basic information for the design of the machine. Parameters such as capacity (quantity of feed), axial dimension of rice grain, coefficient of friction and sphericity of the rice were determined in other to have a comprehensive and effective design of the machine. For the sample of rice considered the dynamic coefficient of friction μ and angle of inclination of the sieve bed θ were determined experimentally to be 0.414 and 23^o respectively. The moisture content for effective milling was 12.8% wet basis while the density of the Ofada rice was 1336 kg/m^3.

Design and Fabrication Requirements

In the design of the machine, several factors were considered to make the design workable. These include: The Separation of the rice from chaffs and pebbles based on the size and shape of rice (1.0 mm to 5 mm), the use of blower to remove all light impurities and dirt in the rice, the development of centrifugal force as a result of the sieve motion which rolls down the rice grain on the sieve bed and passes it through the oblong shaped holes of the sieve, the sieve which was made of light material to facilitate easy separation.

Using the above factors and some relevant equations, the authors were able to estimate for the dehuller: the average rotational speed of the detachable sieve (159 rpm), pulley weight (19.45 N), relative centrifugal force (2.42), torque transmitted from electric motor Pulley to machine pulley (245 NM), speed of the belt (2.83 m/sec), length of the belt (380 mm), belt tension (Tight side, T_1 =86.21 N; Loose side, T_2= 9.01 N), the power transmitted by the belt(.218kW), maximum bending moment = 28.67 Nm , maximum Torsional moment = 5.018 Nm, diameter of the loading shaft (18 mm), volume of hopper **(**12.27 x 10^6 mm^3**)** and total power required to operate the plant (3.85 hp) For the slider crank mechanism: radius of the disk (500 mm), radius of the connecting rod (2.5 mm), length of connecting rod (340 mm), the total reciprocating mass (5.88 kg), the maximum dynamic force (613.01 N). For the sieve shaker: the sieve box (615x330x50 mm), the depression of the spring by application of load, suspend the sieve from 20^0 to 45^0 for easy sliding of the rice, diameter of small pulley (130 mm), diameter of large pulley (250 mm), belt length (200 mm). The fabrication was carried out in stages for convenience and ease of execution. This includes fabrication of the hopper, machining of the shaft and blade, work on the vibrating sieve box, Exposit diagram showing all the details of the component parts of the machine is shown in Fig.1 and 2.

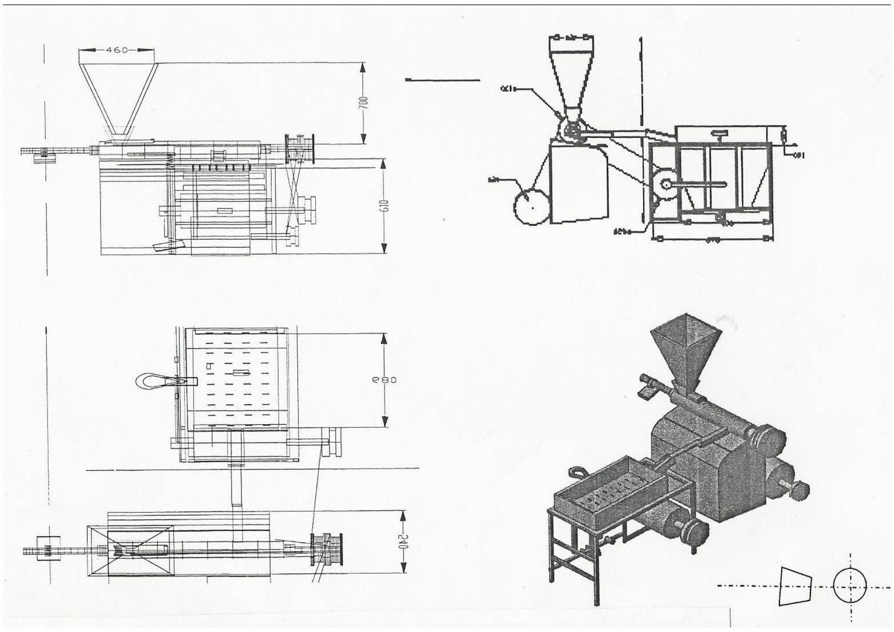

Fig. 1. Orthographic projection of the plant.

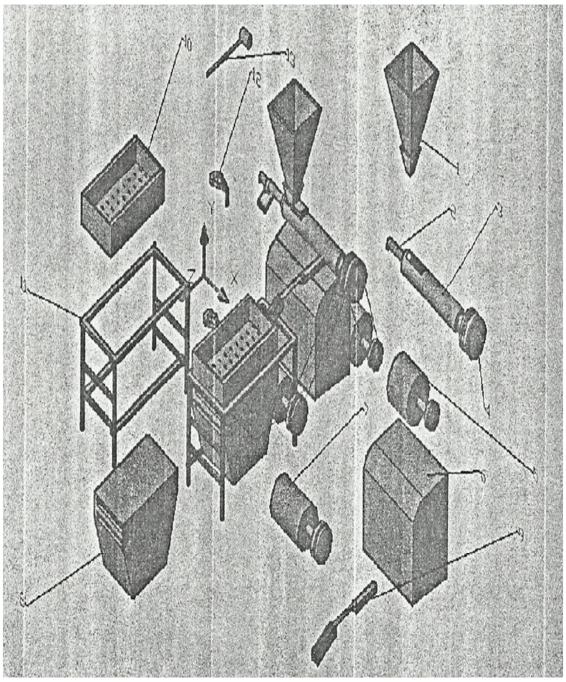

Fig. 2. Component parts of the machine.

Principle of Operation of the Machine

The paddy rice is parboiled before the milling process. When the paddy is fed into the hopper of the dehuller, the blade is adjusted to the diameter of the paddy. The impaction led to the removal of husks and the blower separates the shaft from the rice. The rice and other impurities enter into the sieving bed of the vibrating sieve where the pebbles are separated from the rice. Fig. 3 is the picture showing assembly drawing of the machine.

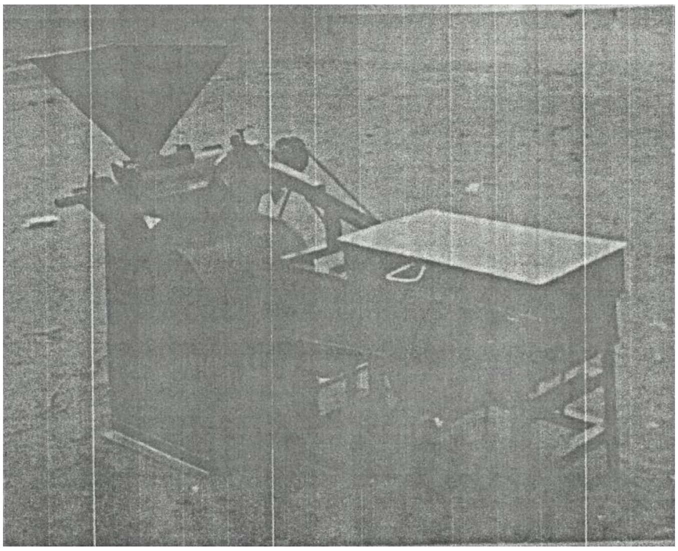

Fig. 3. Photograph of the machine

Results

The tests were conducted using locally produced rice where 500 grains weighed 200 g.

Performance Test on the dehuller

The test was carried out by feeding 500, 1000, 1500 and 2000 grains into the dehuller. The result of different feeding rates is given in Table 1.

Performance Test on the Sieve shaker

500 grains were mixed with 100 small stones of various sizes and the mixture fed into the sieving machine and measurements were taken for various numbers of strokes (a stroke is to and fro movement of the sieving bed by the crank mechanism). The results are presented in Fig.4 for machine for separation. The results are shown in Fig.4 for different number of strokes.

Table 1. Feeding rate and the percentage milled

Paddy rice grains	Milled grains	Unmilled grains	Broken grains	Percentage milled
500	400	30	70	80
1000	650	100	250	65
1500	850	150	500	56.7
2000	900	300	800	45
Average	700	145	405	61.7

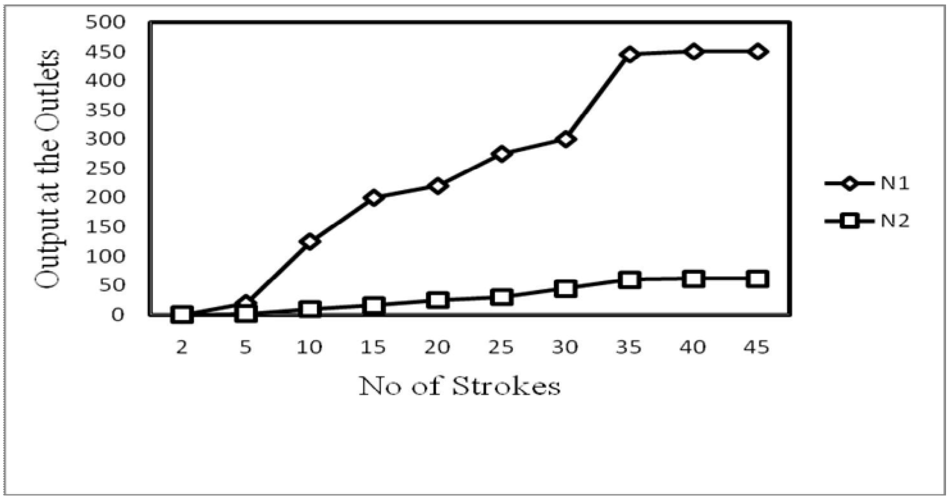

Fig. 4. Plots of output at the outlets against number of strokes

N1= Number of rice grains at rice outlet, N2= Number of stones at stone outlet.

Discussion

Experiments were conducted on the rice milling machine developed to ascertain its suitability and functionability in Nigeria. The model machine comprises 13 components which are shown in Fig. 2 while their descriptions (names) are given in Table 2.

Table 2. Component Parts as numbered in Fig. 2

Component Part Number	Component's name	Component Part Number	Component's name
1	Hopper	8	Sieving box
2	Shaft	9	Rice output
3	Housing	10	Sieve
4	Pulley	11	Sieve frame
5	Electric Motor	12	Spring
6	Dehuller's frame	13	Connection rod
7	Blower		

The feeding rate, the percent milled, un-milled and the broken rice as shown in Table 1. One could infer from the table that, for the range of feeding rate considered, the percentage milled ranges from 80 to 45, percentage un-milled ranges from 6 to 15 while the broken is between 14 and 40 percent. For the broken, the range is somehow wide and there is an ongoing effort to reduce it. The range is believed to be somehow wide when compare with that of steel huller which is between 15 and 25% (Henderson and Perry, 1976).

A graph showed the relationship between the rice collected at rice outlet of the sieving machine and the number of strokes of the connection rod of the crank mechanism (Fig. 4). It is discovered from the plot that between 2 and 35 strokes, the number of rice grains at the outlet increases with the number of strokes; there is a slight increase between 35 and 40 strokes. Beyond 40, the number of grains collectable at the outlet is invariant with increasing strokes. This is an indication that the maximum number of strokes required for the best performance of the Sieve shaker is 40. When the number of strokes is more than 40, it is a waste of time and energy. It did not showed that the machine produce a complete stone free rice, though the percentage of stone in the mixture is negligible.

But when rice paddy was winnowed before parboiling and milling, it was discovered that the rice grains at the rice outlet of the sieving machine was stone free. This is an indication that clean environment and pre-treatment of paddy rice are necessary to achieve stone free rice. This is in line with references of Kaul and Egbo (1985), Henderson and Perry (1976) and Klenin (1983) who presented the processes required to achieve rice that is fit for human consumption; this is also in agreement with the presentation of Bashorun who saw poor operational technique as a major problem with the domestic output of rice in Nigeria.

The current research effort has proffered solution to the problem identified by Omotola and Ikechukwu (2006) that identified unavailability of affordable technology as the major problem militating against effective processing of local rice in Nigeria.

Part of the initial experiments conducted on the rice gave a moisture content of 12.8% wet basis for effective milling of the local rice, this falls within the range of 12 and 14 % which postulated by Sadegh and Mohamed (2002) for their local rice milling. The rice density of 1336 kg/m^3 in the present work is very close to that of Adegun (2006), this is due to the species of rice used for the performance evaluation of the machine is the same Ofada obtained from the same locality.

Conclusion

It is concluded that the quality of locally produced rice is improved with little effort and reduced labour cost. The use of sieve shaker in this project has reduced the harzardous health implication associated with eating of locally produced rice and therefore make it safe for human consumption.

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