DEVELOPMENT OF A LOW COST RICE MILLING MACHINE

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ABSTRACT

Rice is generally considered as semi aquatic annual plant that survives as perennial in the tropics or subtropics. The high cost of the available rice milling machine affects the production of rice in large quantity. Therefore, there is need for a low cost rice milling machine with high efficiency and reduced operating noise. A rice milling machine was developed consisting of the feeding unit, milling unit, cleaning unit, separating unit delivery unit and the frame. The rice milling machine has a capacity of 12 kg/hr and powered by a 3hp electric motor. The process of milling involves the interaction of machine and seed for the release of grains through blown air from impeller. The performance parameters include, percentage of broken rice, milling efficiency of paddy varieties, wholeness and machine efficiency which were evaluated at five different moisture content groups namely; A, 11.00-12.99%, B, 13.00-14.99%, C, 15.00-16.99%, D, 17.00-18.99% and E, 19.00-20.99%. Four varieties of paddy, NEL-42, NE 2, F55 and OFADA were used. The highest milling efficiency of 64 % was obtained for all varieties of paddy at A. The low percentage of broken rice and milling efficiency of 64% for paddy variety NEL-42 proved the effectiveness of the machine.

Keywords: Rice, Milling machine, Efficiency, Moisture content

INTRODUCTION

Rice is generally considered as a semi aquatic annual plant, although it could survive as a perennial in the tropics or subtropics. It grows widely in the tropics where rainfall is abundant because it is a cereal that requires plenty of sunshine and water. It remains article of food for many countries and it is a basic food for world population. Rice is the seed of the monocot plants oryza (Asian rice) sativa or *oryza glaberrima* (African rice). As a cereal grain, it is the most widely consumed staple food for a large part of the world's human population, especially in Asia. It is the grain with the second highest worldwide production after corn.

Rice cultivation is well suited to countries and regions with low labour costs and high rainfall, as it is labour intensive to cultivate and requires ample water. However, rice can be grown practically anywhere, even on a steep hill or mountain area with the use of water controlling terrace systems. Although its parent species are native to Asia and certain parts of Africa, centuries of trade and exportation have made it common place in many cultures worldwide (Koya and Adekoya, 1994). The traditional method for cultivating rice is flooding the fields while, or after, setting the young seedlings (Popoola, 2007).

Rice processing involves harvesting, drying, threshing and milling. Each grain of rice is encased in an easily removed protective hull. Rice is milled to remove the hull, bran and other unwanted materials (Matz, 1970).

In the rice industry, milling is referred to as overall operations in rice mill-cleaning, shelling, bran removal and size separation. The purpose of rice milling is to remove the chaffs (Luh, 1980). Traditionally, after harvest, in some rice growing areas, rice milling is accomplished by very primitive methods such as pounding the rough rice in a wooden mortar with pestle and then winnowed to remove the chaff from the grain. This practice make local production of rice very low with poor quality(Ibukun, 2008). The country depends largely on foreign importation. The rice milling machine is an improvement of traditional rice winnower. It consists of hopper, sheller, cleaner, separator (sieve) delivery unit and the frame. Most locally available machines are beyond the reach of farmers due to high cost (Oni, 1988).

Since rice will most likely remain the basic food of the ever increasing world population, efforts have to be made to increase its production by developing a low cost milling machine. Winnowing of the grains after shelling to remove chaffs and Rice is generally considered as a semi aquatic annual plant, although it could survive as a perennial in the tropics or subtropics (Garial and O'Callaghan, 1990). It grows widely in the tropics where rainfall is abundant because it is a cereal that requires plenty of sunshine and water (Douglas and Glenn, 1982). It remains article of food for many countries and it is a basic food for world population. Therefore, this research work focussed on the development of low cost rice milling machine.

MATERIALS AND METHODS

Different manufacturing processes are involved in the fabrication of rice milling machine. The machine consists of so many components which must be put together appropriately that their interaction with one another would produce the desired output called rice milling machine. Some of the processes include: cutting, drilling, turning welding and forming.

Materials

In the design and fabrication of a rice milling machine, it is very important to carefully select the material and method. This is to ensure that the final product meets its specification and work as intended. In the selection of suitable material that will satisfy this design and product requirement, it is necessary to look at many aspects so that the components and assembly are fabricated within the resources available. The materials employed are contained in Table 1.

Table 1: List of Materials for construction and Fabrication

S/No	Name	Material Used
1	Hopper	Mild steel
2.	Hopper shelling drum	Mild steel
3.	Drum shaft	Mild steel
4.	Magnet	Magnet
5.	Transmission belt	Rubber/Leather
6	Pulley	Mild steel
7	Shaft	Mild steel sheet metal
8	Impeller	Stainless sheet metal
9	Perspex	Plastic
10	Tube/Hose	Rubber
11	Prime Mover	Electric Motor
12	Body frame assembly	Angle iron mild steel

Design Consideration

In the design of rice milling machine, the following factors are considered:
The production cost of the equipment must be cheap. It must be affordable. The equipment should be portable. Maintenance cost must be bearable. The design concepts listed below are also considered. Cleaning and separation should be accomplished in the minimum possible space. The grain should move in a direction different from the motion of chaff to separate the grain from chaff
The knowledge of aerodynamic properties of rice such as drag coefficient and terminal velocity are necessary in the design since air will be used as a carrier for separating the rice from the unwanted materials.
When a particle (like rice) is immersed in a flowing fluid (air), the resultant force acting on it is resolved into two components. These are:

(i) The lift force (F_L)

(ii) Drag force (F_D)

The equation for calculating the drag and lift force can be derived by dimensional analysis on the assumption that the object has a projected area A_P moving through a fluid of density ℓ_F, and velocity V.
Therefore,

$$F_D = \frac{C_D A_P \lambda_F V^2}{2} \quad (1)$$

and

$$F_L = \frac{C_L A_P \lambda_F V^2}{2} \quad (2)$$

where C_D = the coefficient of drag force, C_L = the coefficient of lift force
Most of the grains are free to assume any random orientation. The net resistance force F_r will be given in terms of overall drag coefficient C as

$$F_r = \frac{C A_P \lambda_F V^2}{2} \quad (3)$$

where Fr = resistance drag force (N)
C = dimensionless overall drag coefficient
ℓ_F = density of the fluid (kg/m^3)
V = relative velocity between the main body of fluid and object (m/s)

If sphere is placed in a fluid flow, the frictional drag is usually neglected because of the small surface area on which the frictional effects can act. Thus, for a sphere of diameter d_p, moving at a velocity V, through a fluid of viscosity μ, Stokes' law gives drag force as (Ahrajahpour, 2006)

$$F_D = 3\pi\mu V d_p$$

and this can be equated to

$$F_D = \frac{C_D A_P \lambda_F V^2}{2}$$

The projected area A_p can be taken as the frontal area which is equal to

$$A_p = \frac{\pi d_p^2}{4}$$

The drag coefficient is found to be

$$C_D = \frac{24}{N_R}$$

Where N_R = Reynolds number

However, the use of the above formula for calculating C_D is restricted to N_R less than unity since flow clashes behind sphere-like object and the profile drag is composed primarily of frictional drag section since the inertia forces may be neglected.

and $$N_R = \frac{\lambda_F dV}{\mu}$$

where d = the effective dimension of the object such as diameter of a sphere μ = absolute viscosity of fluid.

When air is used for separation of a product such as rice, from foreign materials associated with it such as chaff, the knowledge of terminal velocity of the particles involved would be useful to define the range of air velocities effecting good separation of the grain. (Olorunnisola, 2005)

The forces involved by a falling particle are given as:

$$M\frac{dV}{dt} = F_g - F_r \qquad (4)$$

but $$Fg = \frac{M_r g(\gamma_p - \gamma_F)}{\gamma_r}$$

and

$$F_r = CA_p\gamma_F\left(V^2/2g\right)$$

therefore,

$$\frac{dV}{dt} = \frac{g(\gamma_p - \gamma_F)}{\gamma_p} - \frac{C(V^2\gamma_F A)}{2gM}$$

The sign of the g (gravity) term is positive for a particle starting from rest or having an initial downward velocity. The sign is negative for an initial upward velocity. If γ_p is larger than γ_F, the particle motion will be downward when steady-state has been reached. If the fluid is denser than the particle, that is, γ_F is larger than γ_p, the particle will rise during the steady-state condition.

$M\frac{dV}{dt}$ = net accelerational force in the fluid flowing direction

For constant velocity, steady state conditions, dV/dt = 0, and the terminal velocity can be derived by setting the gravitational force Fg equal to the resisting drag force F_r and putting V as V_t

Thus, Fg = F_r, when $V=V_t$ then

$$M_p g\left(\frac{\gamma_p - \gamma_F}{\gamma_p}\right) = CA_p\gamma_F\left(V^2/2g\right)$$

so that

$$V_t = \left(\frac{2M_p g^2(\gamma_p - \gamma_F}{CA_p\gamma_p\gamma_F}\right)^{1/2} \qquad (5)$$

Where g = acceleration due to gravity

M_p = mass of particle

γ_p = specific weight of particle

γ_p = specific weight of fluid

A_p = projected area of the particle normal to the motion

C = particle aerodynamic drag coefficient, dimensionless

V = relative velocity

t = time

F = force

The overall drag force coefficient $C = C_F + C_D$.

When the flow is laminar, C_F is generally negligible. For turbulent flow, C_F is usually negligibly small except for streamlined bodies (Olorunnisola, 2005).

The formula for escape velocity can be derived from conservation of energy, in order to escape, an object must have at least as much kinetic energy as the increase of potential energy required to move to infinite height. To escape from a single body, the escape velocity is the kinetic energy equivalent to minus gravitational potential energy (Gariboldi, 1988)

$$\frac{1}{2}mV_e^2 = \frac{GMm}{r}$$

$$V_e = \sqrt{\frac{2GM}{r}} = \sqrt{\frac{2\mu}{r}} \qquad (6)$$

where

V_e = escape velocity, G = gravitational constant, M = mass of the body being escaped from m = mass of the escaping body, r = distance between the center of the body and the point at which escape velocity is being calculated μ = standard gravitational parameter.

The orthographic projection of the designed machine is presented in Fig 1.

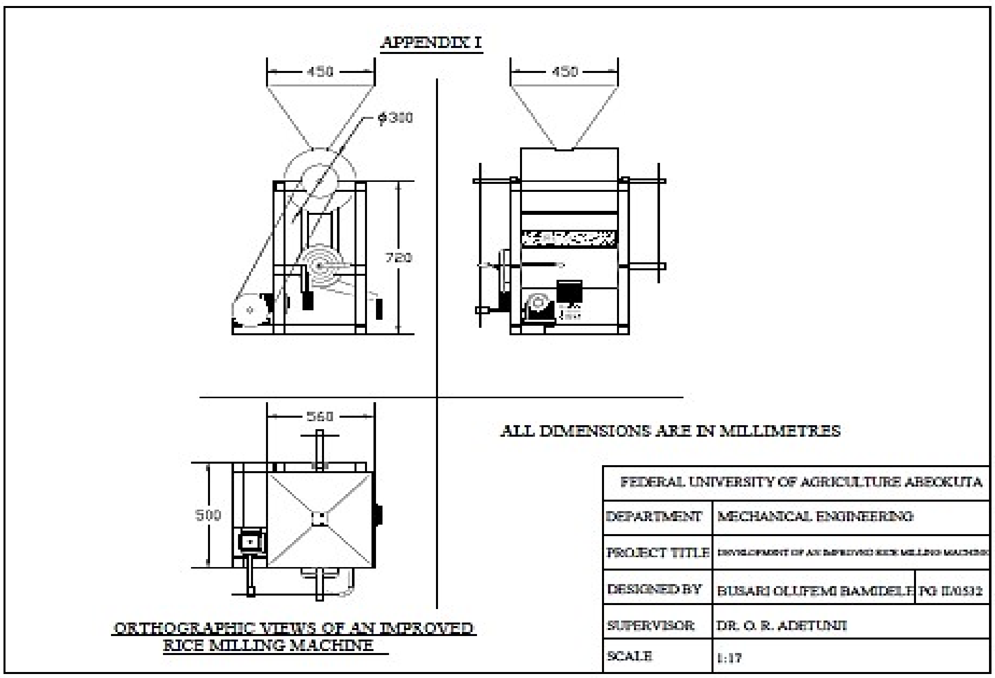
The Hopper

The machine was designed for small and medium scale users, so the hopper was designed for a capacity of about 35,100cm^3. This was achieved by making the upper part of the hopper to be 45cm in length and breadth 45cm, while the lower part of the hopper has length and breadth 7cm each with the height 30cm.

The capacity of the hopper is calculated as the area of its side multiplied by the length of the hopper.

$$\text{Volume} = \tfrac{1}{2}(7+45) \times 30 \times 45 = 35{,}100 \text{ cm}^3$$

Fig.1: Orthographic views of the developed Rice Milling Machine



The Shelling Unit

(a) Shelling Drum

This unit is made of a spiked tooth shelling drum and perforated concave. The shelling drum consists of studs that will cause the shelling action when the drum rotates. The drum is housed in the concave and drum cover made from a horizontal cylinder. The concave is the lower half of the cylinder, perforated to serve as discharge holes for the shelled materials while the upper half is the cover and carries the hopper.

The parameters of the shelling drum are, the drum diameter, the drum length, the drum speed and number of beaters on the drum (Koya and Adekoya, 1994).

The drum length was obtained from the equation below as it was reported by Douglas and Glenn, 1982.

$$q = q_o LM$$

where L = drum length, M = number of (row of) beaters, q = feed rate of sheller (kg/s), q_o = permissible feed rate (kg/s).

According to Resnikov (1991), permissible feed rate of sheller is 0.4 – 0.6kg/s.

(b) Criteria for the Performance Evaluation of the Rice Milling Machine

Operating time was used as one of the criteria for my performance.

Four varieties of paddy at five levels of moisture content groups viz:

A(11.00 – 12.99)%, B(13.00 – 14.99)%, C(15.00 – 16.99)%, D(17.00 – 18.99)%, E(19.00 – 20.99)% was also used.
Data were analyzed to obtain the mean, chart and graph. Minitab 16 was used for the analysis of variance at 5% level of significant.
The low cost machine was evaluated using established performance coefficients shown below. Moisture content wet basis was determined. Coefficient of shelling, Coefficient of wholeness, Shelling efficiency, Cleaning efficiency, Broken rice (%) ,. Head rice (%), Shelling capacity, H_C=shelling capacity, H_O = total shelling output kg, Es = shelling efficiency, T_O = operating time, hr

Shelling recovery

RESULTS AND DISCUSSION

The developed rice milling machine is shown in Figure 1. The four varieties of paddy at five levels of moisture content groups viz: A(11.00 – 12.99)%, B(13.00 – 14.99)%, C(15.00 – 16.99)%, D(17.00 – 18.99)%, E(19.00 – 20.99)% was also used.

Moisture content had significant effect on shelling recovery where group A & B MC w.b were more significant than group C & D while the group E had the least significant effect on shelling recovery as shown on Table 2. The results of the machine evaluation are shown in Tables 3 and 4, and illustrated in Figures 2 to 4.

Table 2**:** Shelling recovery of paddy at different moisture content in %

MCw.b.(%)	Group	NE L-42	NE 2	F 55	OFADA
11.00 – 12.99%	A	76	75	72	70
13.00 – 14.99%	B	71	73	68	61
15.00 – 16.99%	C	66	53	55	57
17.00 – 18.99%	D	58	53	46	47
19.00 – 20.99%	E	43	42	46	36

Table 3: Shelling Efficiency of paddy at different moisture content in %

MCw.b.(%)	**NE L-42**	**NE 2**	**F 55**	**OFADA**
11.99%	64	66	64	61
13.99%	62	60	57	53
15.99%	58	41	47	45
17.99%	46	41	37	33
19.99%	34	31	37	24

Table 4: Whole kernel percentage of paddy at different moisture content in %

MCw.b.(%)	**NE L-42**	**NE 2**	**F 55**	**OFADA**
11.99%	0.84	0.86	0.86	0.85
13.99%	0.88	0.8	0.81	0.82
15.99%	0.85	0.75	0.76	0.75
17.99%	0.77	0.75	0.72	0.58
19.99%	0.72	0.68	0.67	0.55

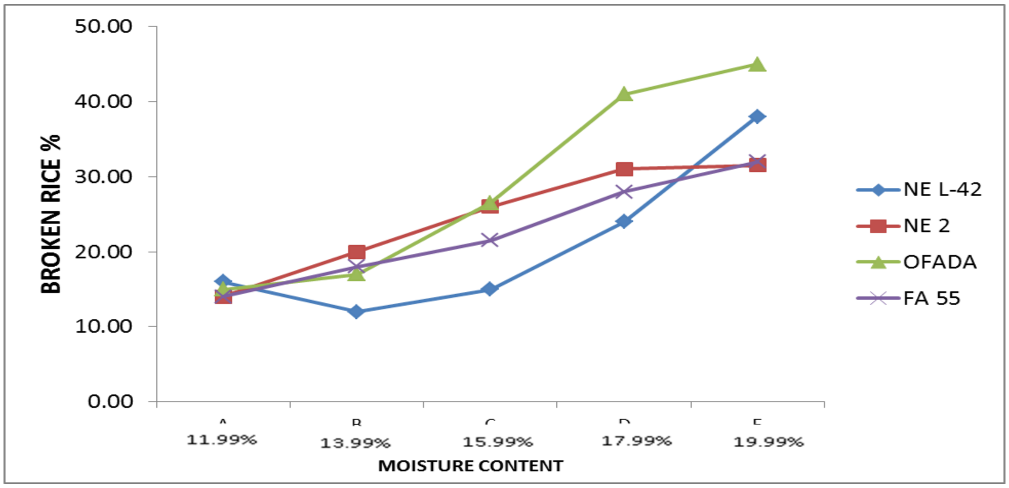


Fig.2 Plot of Broken Rice percentage versus Moisture content of Paddy

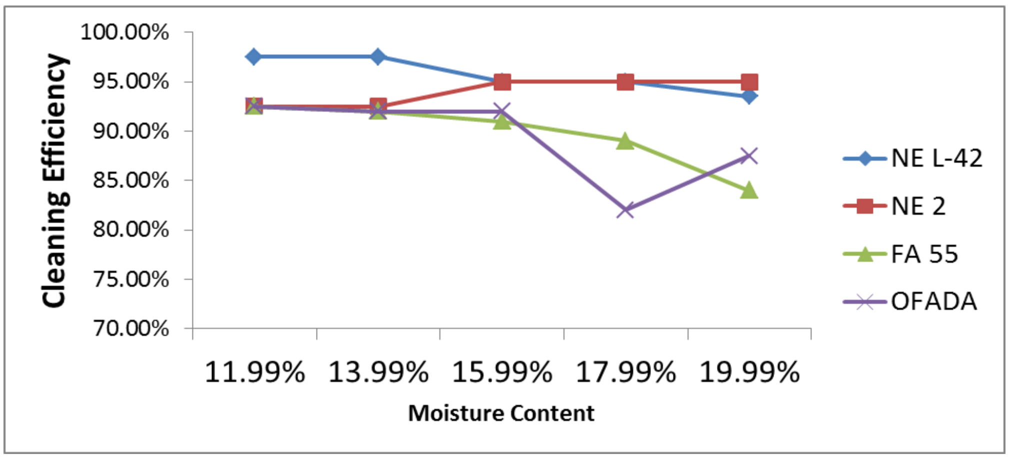


Fig.3: Plot of Cleaning Efficiency versus Moisture content of Paddy

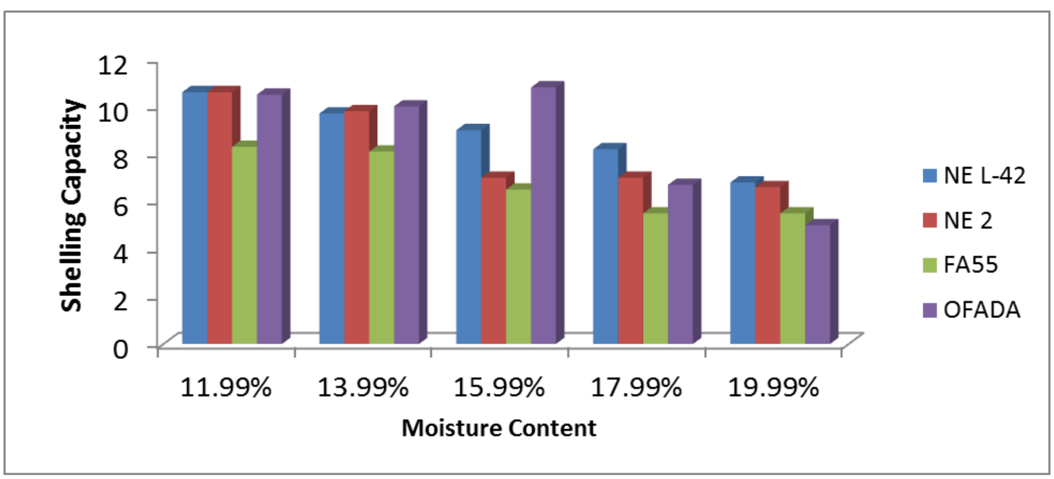


Fig.4: Plot of Shelling Capacity of machine versus Moisture content of Paddy

The highest shelling efficiency was obtained for all varieties of paddy at 11.00 – 12.99% moisture content. The shelling efficiency at 11.00 – 12.99% for NEL-42 was 64%. For all varieties of paddy, as moisture content increased, the shelling efficiency decreased.The percentage of whole kernel decreased as moisture content increased. Moisture content had significant effect on shelling recovery. 11.00 – 12.99% and 13.00 – 14.99% moisture content had more significant effect than 15.00 – 16.99% and 17.00 – 18.99% while 19.00 – 20.99% had the least significant effect on shelling recovery as shown on Table 2

There was an increase in broken rice percentage as moisture content increased for all paddy varieties. The maximum head rice 80% was recovered at a single pass within 11.00 – 12.99% and 15.00 – 16.99% moisture content ranges as shown on fig. 1.It was observed that shelling capacity decreased from 11 as moisture content increased except for Ofada variety which increased at 15.00 -16.99% before finally decreased with increased moisture content.The maximum capacity utilization was observed at 11.00 – 12.99% and 13.00 – 14.99% moisture content wet basis, while, the least 86% was observed at 19.00 – 20.99% for all paddy varieties except for Nerica L-42. These results were in agreement with earlier researchers(Adewumi *et al*.,2007 and Akintunde, *et al.*, 2005)

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CONCLUSION

A low cost rice milling machine was developee and tested, results showed that the moisture content of the paddy significantly affected the performance of the machine. The machine efficiency increased as the moisture content of the paddy decreased. The breakage percentahe increased with increased moisture content of rice for all varieties.

At 11.00 – 12.99% range of moisture content, the shelling efficiency of NEL-42 variety of paddy was 64% while the percentage whole kernel for all paddy varieties decreased as moisture content increased.

The maximum capacity utilization was observed at 11.00 – 12.99% and 13.00 – 14.99% moisture content wet basis for all varieties except Nerica L-42.

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References

Adewumi, J.K., Olayanju, T.M.A. and Adewuyi, S.A. (2007). Support for small rice threshers in Nigeria. A-DFID/PROPCOM, Nigeria project 68pp.

Ahrajahpour, O. (2006). Effect of Moisture on Terminal Velocity of Wheat Varieties. *International Journal of Agriculture and Biology, 10-13.*

Akintunde, B.O., Oyawale, F.A. and Tunde-Akintunde, T.Y.(2005). Design and Fabrication of a Cassava Peeling Machine. *Nigerian Food Journal. 23(231-238).*

Douglas, M.C. and Glenn, D. (1982). Foods and Food Production Encyclopedia. VanReinho. D., New York.

Gariboldi, F. 1988. Rice Milling Equipment Operation and Maintenance. FAO Agricultural Service Bulletin 22.

Gorial, B.Y., and O'Callaghan, J.R. (1990). Aerodynamic properties of grain/straw materials. *Journal of Agricultural Engineering Research, 4,27-290.*

Ibukun, E.O. 2008. Effect of prolonged parboiling duration on proximate composition of rice. *Academic Journals Vol.3 (7),* pp. 323-325, July.

Koya, O.A. and Adekoya, L.O. (1994). Some Physical and Aerodynamic Properties Relevant in Destining some Grain Crops. Journal of Technology.

Luh, B.S. (1980).Rice Production and Utilization. AVI Publishing Company Inc, Westport.

Matz, S.A. (1970).Cereal Technology. AVI Publishing Company Inc, Westport.

Olorunnisola, A.O. (2005). Improvement of an Existing Low Cost Wooden Groundnut Sheller. *Journal of Applied Science. Engineering Technology.5(71-74).*

Oni, E.I. (1988). Design and Construction of Rice Blowing Machine. Unpublished B.Sc Thesis, Department of Mechanical Engineering, University of Ibadan.

Popoola, C.A. (2007). Design, Fabrication and Evaluation of a Rice Milling Machine. Unpublished M.Sc Thesis, Department of Industrial and Production Engineering, University of Ibadan.