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# Design, Fabrication and Testing of Improved Traditional Rice Parboiler

**Gbabo, Agidi, Abdullahi, Lukman and A. M. Kuku.**

***Abstract*— This study focused on the design, fabrication and testing of improved traditional rice parboiler. The parboiling methods adopted in rural areas in Nigeria need to be modernized to improve their performances. This led to the development of an improved traditional rice parboiler at the National Cereals Research Institute Badeggi (NCRI). The parboiler has a capacity of 70kg with soaking chamber volume of 0.3269 $m^3$ and a steaming chamber volume of 0.0759 $m^3$. The steaming chamber is located directly below the soaking chamber and it is provided with two drain plugs to drain water off from the paddy and the steaming chamber. The parboiler is mounted on a frame which is insulated with bricks blocks to minimize heat loss during parboiling. Firewood was used as the source of fuel. Tests results using three rice varieties FARO44, FARO 28 and FARO 40showed that the improved traditional rice parboiler, parboiled 70kg of paddy rice in 1hr 50mins, 1hr 57mins and 2hr 5mins for FARO 44 (long grain), FARO 28 (medium grain)and FARO 40 (short grain). The parboiler consumed 3.6 kg, 3.6kg and 5.0kg of fuel for FARO 44(long grain), FARO 28 (medium grain) and FARO 40 (short grain) respectively at a soaking temperature of 75$^o$C and steaming temperature of about 100°C. Water absorption test showed that FARO 28 (medium grain) recorded highest water absorption compared to FARO 44 (long gain) and FARO 40 (short grain) which is the basses on which the points are not closely distributed. This confirms that there is significant difference in water absorption of the three varieties of paddy rice parboiled using the local improved rice parboiler. The local improved rice parboiler, parboiled 70kg of paddy rice in 1hr 50mins, 1hr 57mins and 2hr 5mins for FARO 44 (long grain), FARO 28 (medium grain)and FARO 40 (short grain). local improved rice parboiler consumed 3.6 kg, 3.6kg and 5.0kg of fuel for FARO 44(long grain), FARO 28 (medium grain) and FARO 40 (short grain) at a soaking temperature of 75$^o$C and steaming temperature of about 100°C. Water absorption test showed that FARO 28 (medium grain) recorded highest water absorption compared to FARO 44 (long gain) and FARO 40 (short grain) which is the basses on which the points are not closely distributed. With a production cost of N22, 500:00 (twenty thousand, five hundred naira only) local improved rice parboiler parboiled average 0.224 tons/day, 0.75tons/month and 84.375ton/year for 8-9 working hours.***

***Index Terms*— paddy rice, parboiler, Performance assessment, soaked and steamed.**

## I. INTRODUCTION

Rice (Oryza sativa) has been in use as an important food since ancient times and today, more than half of the world's populations consume rice as the in main food. It is well known for its hygroscopic behavior. However, it has been observed that the degree of swelling varies with varieties, raw and parboiled rice and processing methods (Juliano 1985). Rice being the second largest consumed cereal after wheat shapes the lives of millions of people; more than half the world's population depends on rice for about 80 percent of its food calorie requirements. Rice has been a good partner to mankind. The adaptations in terms of ecological, economical and technological changes around rice facilitated this "partnership between man and rice" (Braun, 2006).

Presently in Nigeria, rural farmers who are the major producers of rice still parboil rice using the traditional methods of parboiling by soaking paddy in cold water in mud pot, aluminum pot or half drum for two or three days after which the paddy is steamed for hours and later dried and milled. These traditional parboiling processes commonly results in improper gelatinization, discoloring and low market acceptability of the milled rice, due to defects and inadequacies in the parboiling processes. The method is also time consuming and highly laborious. Parboiling operations within a short period of time and to get better quality output with good market acceptability. This necessitates the need to develop a local improved rice perboiler to increase efficiency of an existing traditional method of parboiling in order to carry out. Paddy rice parboiling was originated in India. It is now widely used all over the world. (Ali .N. and ojha, T.P; 1970).

Rice parboiling involves a hydration conditioning of the paddy before milling by removing the husk and polishing the final product. Parboiling also results in higher milling recovery, more translucent kernels and increased swelling when cooked to the desired softness (Ali and Ojha, 1976). Parboiling also reduces milling breakage, facilitates disintegration of protein bodies, impacts hardness to the grains and makes them more resistant to pest [Raghavendra, R. And Juliano, B.O. 1970). In addition Parboiling is important in reducing the losses of starch, vitamins, and minerals in cooking, destruction of infestation molds and insects, and inactivation of lipases to improve the shelf life of rice bran (USDA, 2010). Parboiled rice has a characteristic texture, flavor, Color, taste, and cooking behaviour. As at 1972, about 25 to 30 % of the world paddy was parboiled (Gariboldi, .F. 1984). Consumers in most African countries favour parboiler rice grain qualities traits to while or review rice (Sakarai *et at*, 2006). Therefore, this paper presents the Design, Fabrication and Testing of Improved traditional rice perboiler.

### *Description of improved traditional rice parboiler*

The improved traditional rice parboiler is consists of the following basic components shown in fig. 1-2 and plate1.

***i. Soaking Chamber*:** The soaking chamber is a circular tank which is made up of galvanized sheet. It has a diameter of

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80cm and 80cm in height with two outlet valves, and a pressure relief valve. The 'bottom' outlet valve to drains out the water inside the steaming chamber while the steaming level indicator valve drains the water to it's level for steaming operation. The pressure relief valve reduces steam pressure during steaming in other to overcome the hazardous effect of explosion of the tank.

***ii. Steam Generation Chamber:*** This is circular in shape made from galvanized sheet. It is located below the soaking chamber and has a diameter of 80cm and height of 18cm. This chamber generates steam.

***iii. False Bottom (Circular Screen):*** This is an inner circular screen incorporated inside the parboiler to prevent the paddy rice from falling into the steaming chamber. It is constructed with a flat bar.

***iv. Parboiler Cover:*** The parboiler cover is also made from galvanized sheet which has a diameter of 81cm used to cover the top of the system to prevent of unnecessary escape of steam.

***v. Free space*:** This is a 10cm gap between the soaking and steaming chamber which disallows the water from touching the grain.

***vi. Stand*:** This consists of four legs of 54cm height each which is made from 5cm ×5cm angle iron. They hold the parboiler in upright position at the base.

***vii. Frame chamber*:** It's made from silicon (Si) sand and clay used to insulate the heat generated by the firewood.

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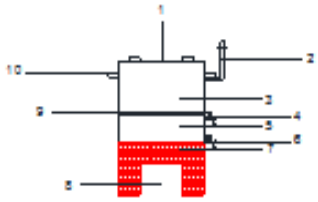

Fig 1. sectional view of improved traditional rice parboiler

1=cover 2=pressure release valve 3=soaking chamber 4=soaking tap 5= steaming chamber 6=steaming tap 7=bricks 8=source of heat 9= false bottom 10= handle

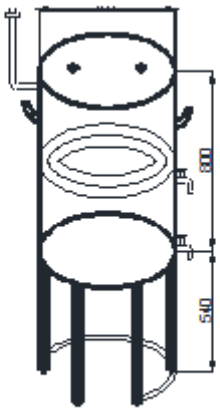


Fig 2. pictorial view of improved traditional rice parboiler

**Plate 1. Constructed Improved traditional rice Parboiler**

**Plate 2. Testing of improved traditional parboiler**

**Plate 3. Parboiled rice evacuation**

## II. DESIGN ANALYSIS

The design analysis was carried out with a view to evaluating the necessary designs parameters, strength of the materials for consideration in the selection of the various parboiler components in order for it to performance efficiently.

***i. Evaluation of the volume of rice parboiling drum***

The volume of the boiler is estimated as follow:

$V_w = \frac{Mw}{\rho w}$, $(m^3)$……..1

Where:
$V_w$ is the volume of rice parboiler ($m^3$)
$M_w$ is the mass water required to soak paddy rice (kg)
$\rho w$ is the density of water ($kg/m^3$)

***ii. Heat requirement***

The amount of heat required to accomplish the parboiling operation was calculated using the equation:

$qu = MCpdTdt, (kg/min)$----------2

Where:
qu= useful heat required for a parboiling operation.
M = mass of paddy, kg.
Cp = specific heat capacity of water. (KJ/kg$^O$C)
$\delta T$ = temperature $^O$C
$\delta t$ = time taken for parboiling (mins).

***iii. Thickness of the parboiler***

$K_U = f + m, (m)$……..3

Where:
***f*** is the heat flux (joules/$m^2$)
$K_U$ is the parboiler thickness
***m*** is the representing material constant

Thick plate (3-D)

$T - T_0 = \frac{q/v}{2\pi\lambda t} \exp\left(\frac{r2}{4at}\right), (m)$.....4

For thin plate (2 – D)

$T - T_0 = \frac{q/v}{d(4\pi\lambda pct)\,1/2} \exp\left(-\frac{r2}{4at}\right), (m)$.....5

Where:
T is the material thickness before reflux
$T_O$ is the material thickness after reflux
t is the temperature of heat (°C)
r is the radius of rice parboiler (m)
d is the diameter of the rice parboiler (m)
a is the height of the rice parboiler (m)

***iv. Volume of steam flow***

The volume of steam flowing from the lower chamber to the upper chamber was determined by using this equation:

$Q=AV, (m^3/sec)$ ----------6

Where:
Q = volume of steam flowing in the pipe for a period of time, $m^3$/ sec.
A= cross - sectional area of the pipe, $m^2$.
V = the average velocity of flow in a pipe. ($ms^{-1}$)
However, the following was assumed:

i) The flow is steady and internal and one dimensional flow
ii) The steam is incompressible and frictionless.

***v. Velocity of flow***

The velocity at which steam travelled within the pipe to ensure equal distribution of steam for effective steaming is given by:

$V = {}^1/_4\left[\frac{P_1 - P_2}{UL}\right](D^2 - 4r^2), (ms^{-1})$ ------7

## MATERIALS AND MATHODS

**Design Consideration**

In design of the parboiler, the following factors were considered.

**a. Gsrain characteristics**

The sizes of the paddy rice to be parboiled were considered because the grain size determines the depth at which the water penetrates into the grain. The grain caryopsis was also considered to be entirely coved by the husks, because the shape and colour of the paddy grain will be distorted if the caryopsis is exposed. FARO 44, (long grain), FARO 28 (medium grain) and FARO 40 (short grain) were used in evaluating the parboiler.

**b. Materials for construction**

The major materials for the construction of the parboiler were 2mm mild steel, the galvanized pipes, 5×5 cm angle iron, and valves were chosed based on availabity and in operational requirements of the equipment.

**c. Testing of improved traditional rice parboiler**

70kg of paddy rice each of FARO 44 (long grain), FARO 28 (medium grain) and FARO 40 (short grain) which had been pre-cleaned and washed were soaked in hot water at a

temperature of 75$^{O}$C. At 50min interval of time, the weights of the paddy rice were taken to know the water absorption rate of the paddy and temperature drop for four specific periods before the paddy was left in the hot water for 12hrs overnight. The paddy was then drained and weighed for each samples. The paddy rice was placed on the false bottom of the parboiler and steamed until over 98% of the husk split open. The duration taken for each variety, FARO 44 (long grain), FARO 28 (medium grain) and FARO 40 (short grain) to split were taken. The paddy was sun- dried for 2hrs and later shade dried for one day. They were then analyzed for the following qualities:

**i. Water uptake**

***Water Uptake*:** The levels of water uptake for the samples were determined by taken the difference between the final weights of paddy from the initial weight as shown below:

$$UW = Wf - Wi, \text{(kg)}\text{----------8}$$

Where:

$U_W$ is water uptake of paddy samples (kg)

$W_f$ is Final weight of paddy samples

$W_i$ is Initial weight of paddy (kg)

***ii, Physical quality***

***a. Total milled rice yield:*** 5,000g of parboiled rice was weighed and milled. The total milled rice which contains head rice and broken rice was calculated

$$\text{TRM (\%)} = \frac{\text{milled rice (head rice broken)}}{\text{500g of parboiled rice}} \times 100 \text{.....9}$$

***b. Head rice recovery*:** From a 2000g sample of cleaned rice, the head rice was manually separated and weighed by manual grader and weighing balance respectively. Milled rice grains with lengths greater than three-quarters that of complete the grains were referred to as head rice while the remaining ones were considered as broken rice.

$$\text{HRR (\%)} = \frac{\text{Weight of head rice}}{\text{weight of measured sample (2000g)}} \times 100 \text{....10}$$

**c) Broken rice:** 2000g of the milled samples each were measured separated and weighed using manual grader and weighing balance. The broken rice is regarded as rice that is less than three quarters of the total length of the grain were evaluated as follow:

$$\text{BR (\%)} \frac{\text{Weight of broken rice}}{\text{weight of measured sample (2000g)}} \times 100 \text{---11}$$

## III. RESULTS

From the results obtained in table 2, the improved traditional rice parboiler parboiled rice in 3hrs, 3hrs-2minutes and 3hrs-10minutes. 3.6kg, 3.6kg and 5.0kg of fuel were used for FARO 44 (long grain), FARO 28 (medium grain) and FARO 40 (short grains) respectively.

The water absorption of local improved rice parboiler at decreasing temperatures as determined at an interval of 50minutes is shown in table 3.

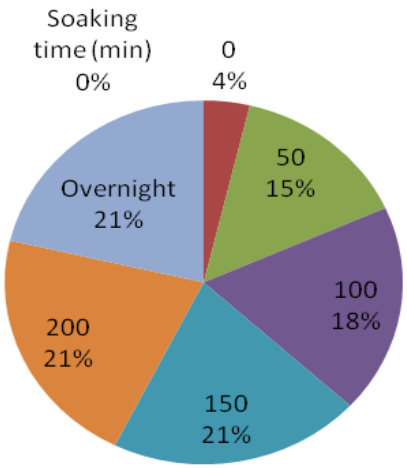


**Fig.3, Water absorption with time variance for grains varieties.**

Figure 3; also show the results of water absorption tests for local improved rice parboiler at 50 minute interval of time. The result obtained from the water absorption test showed that FARO 28 (medium grain) recorded highest water absorption at all water temperature compared to FARO 44 (long gain) and FARO 40 (short grain) which is the basses on which the points are not closely distributed. This confirms that there is significant difference in water absorption of the three varieties of paddy rice parboiled using the local improved rice parboier.

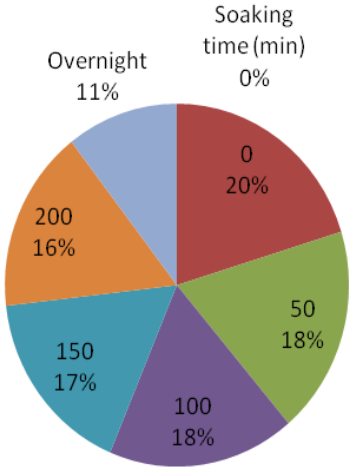


**Fig. 4, temperature drop with time varience for grains varieties.**

Figure 4; show the results of temperature drop at different temperature change for local improved rice parboiler. The results showed that FARO 40 (short grain) retained heat and absorbed less amount of water at all temperature variance compared to FARO 44 (long grain) and FARO 28 ( medium grain) which showed that point of heat are closely distributed. There is no significant difference in temperature variance of the paddy rice.

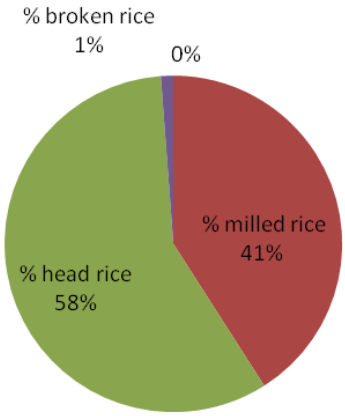


**Fig.5; physical charasterities of the grains**

***Total milled rice, head rice recovery and broken rice*:** figure 5, show results of total milling yield, head rice recovery and broken rice tests for the three varieties tested at 12-13% moisture content. The results obtained show that there was no significant difference in total milling rice recovery, head rice recovery and broken rice for three varieties tested.

## IV. CONCLUSION

In conclusion the improved traditional rice parboiler has following merits compared to the local method of parboiling:
i) Has high head rice recovery, high milled rice yield and less percentage of broken rice compared to local way of parboiling
ii) The parboiled rice has golden yellow color in appearance, good smell test and odorless.
iii) The improved traditional rice parboiler gave better results for all FARO rice varieties tested
iv) The improved traditional rice parboiler parboiled faster, taken 3hours 20min to parboil the paddy rice compared to local way of parboiling that taken 40-48hour to parboil the paddy rice
v) It can parboil paddy averagely 0.224tons/day, 6.75tons/month and 84.375tons/years
vi) The improved traditional rice parboiler also has higher economic benefits in term of energy lost, water wastage after soaking and also required small amount of water for steaming.

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## APPENDIX

| Parameters | Quantity |
|---|---|
| Volume of soaking chamber ($m^3$) | 0.3269 |
| Volume of steaming chamber ($m^3$) | 0.0754 |
| Total volume of parboiler ($m^3$) | 0.4023 |
| Amount of heat required (kj/min) | 441000 |
| Parboiler water capacity (litre) | 402 |
| Velocity of flow ($m^3$/sec) | 0.1499 |

Table 2. Heat treatment for various rice varieties

| S/N | Parameters | Rice varieties | | |
|---|---|---|---|---|
| | | FARO 44 | FARO 28 | FARO 40 |
| 1. | Mass of paddy rice (kg) | 70 | 70 | 70 |
| 2. | Time taken for soaking (min) | 3-4 | 3-4 | 3-4 |
| 3. | Soaking temperature (°C) | 75 | 75 | 75 |
| 4. | Water temperature after 50min (°C) | 68.5 | 68.2 | 70 |
| 5. | Time taken for steaming (min) | 30 | 32 | 45 |
| 6. | Paddy temperature after steaming (°C) | 85.3 | 88.4 | 90 |
| 7. | Quantity of water used for soaking (litre) | 100 | 100 | 100 |
| 8. | Quantity of water used for steaming (litre) | 25 | 25 | 25 |
| 9. | Quantity of fuel used (kg) | 3.6 | 3.6 | 5.2 |

| Grain varieties | | | | | | |
|---|---|---|---|---|---|---|
| Soaking time (min) | FARO 44 (long grain ) | | FARO 28 (medium grain) | | FARO 40 (short grain) | |
| | Temperature (°C) | Water absorption (kg) | Temperature (°C) | Water absorption (kg) | Temperature (°C) | Water absorption (kg) |
| 0 | 75 | 2 | 75 | 2 | 75 | 2 |
| 50 | 68.5 | 7.8 | 68.2 | 9 | 70 | 5.2 |
| 100 | 65.3 | 9.9 | 65.8 | 11 | 68.2 | 7 |
| 150 | 62.3 | 11 | 63.5 | 12 | 65.5 | 9 |
| 200 | 60.3 | 11.4 | 62 | 12.5 | 63 | 10.5 |
| Over night | 39 | 11.4 | 37.7 | 12.5 | 32.8 | 11 |

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**ACADEMIC QUALIFICATION**

. Doctor of Philosophy (Ph. D.) Degree Agricultural Engineering
. Master of Science (M. Sc.) Degree Agricultural Engineering
. Bachelor of Technology (B.Tech). Degree Agricultural Engineering
. School Certificate / General Certificate of Education (GCE)
. First School Leaving Certificate

**JOURNAL PUBLICATIONS**

**1) Gbabo Agidi (2013).** Emerging Technological Developments Suitable for Viable Sugar Production in Developing Countries.International Journal of Scienc, Engineering and Technological Research. Volume 2 Issue 5 (2013).

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**- Gbabo,Agidi and Abdullahi,Lukman (2014)**. Performance Assessment of NCRI Parboiling System with Local Improved Parboiling International Journal of Engineering and Innovative Technology (IJEIT) Volume 3, Issue 12.

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