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Performance Assessment of NCRI Parboiling System with Local Improved Parboiling

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Abstract*— The need to improve on parboiling techniques by rural farmers in Nigeria has led to the development of a parboiling device at the National Cereals Research Institute Badeggi (NCRI). The local improved rice parboiler has a soaking chamber of 0.3269 m^3 and a steaming chamber of 0.0759 m^3. The steaming chamber is 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. The performance Assessment of the improved (NCRI) parboiler was compared with the local improved method of parboiling. The improved NCRI parboiler, parboiled 40 kg of rice in 2hr 5mins, 2hr 7mins and 2hr 15mins for FARO 44(long grain), FARO 28(medium) and FARO 40 (short grain) respectively. The local improved rice parboiler, parboiled 40kg of paddy rice in 1hr 50mins, 1hr 57mins and 2hr 5mins for FAEO 44 (long grain), FARO 28 (medium grain)and FARO 40(short grain). The quantity of fuel used in parboiling using NCRI method were 4.8kg, 4.8kg and 5.2kg for FARO 44 (long grain), FARO 28(medium grain) and FARO 40 (short grain) while local improved method consumed 3.6 kg, 3.6kg and 5.0kg for FARO 44(long grain), FARO 28 (medium grain) and FARO 40 (short grain) at a soaking temperature of 75°C and steaming temperature of about 100°C. Overall results show a significant improvement, less time of operation and a cheaper cost using the developed parboiler. There was no significant difference in the water uptake of the rice parboiled using the Improved and local improved parboiler at varying temperatures.

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

I. INTRODUCTION

Rice parboiling is a significant procedure in rice processing, it includes a hydration conditioning of the paddy before removing the hulls and polishing the final product. Rice is parboiled in National Cereals Research Institute (NCRI) Badeggi for research, domestic consumption and to a limited extent for commercial purposes. Parboiling results in higher milling recovery, more translucent kernels and increased swelling when cooked to the desired softness (Ali and Ojha, 1976). Consumers in most African countries favour parboiler rice grain qualities traits (Sakarai *et at*, 2006). Presently in Nigeria, rural farmers who are the major producers of rice still parboil rice using the traditional methods of soaking paddy in cold water in a mud pot or half drum for two or three days after which the paddy is steamed for hours and later dried and milled. This traditional parboiling process commonly results in improper gelatinization, discoloring and low market acceptability of the milled rice, due to defects and inadequacies in parboiling process. The method is also time consuming and highly laborious. This necessitates the need to develop a paddy rice parboiler to improve upon the existing traditional method of parboiling in order to carry out parboiling operations within a short period of time and to get better quality rice with good market acceptability. The parboiling techniques for paddy originated in India. It is now widely employed all over the world. (Ali .N. and ojha, T.P; 1970). It involves a hydrothermal treatment by soaking, steaming and drying before milling. Basically, this is done to gelatinize the starch, remove air voids from the kernel and heal the cracks. This process 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). Parboiling is also 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 behavior. As at 1972, about 25 to 30 % of the world paddy was parboiled (Gariboldi, .F. 1984). Parboiling was been used merely for hygienic treatment to clean the threshed grain, or because of its hardening effect and consequent improvement of quality or a combination of these (Khush, G.S., Paule, C.M. and De la Cruz, N. M. 1979).Therefore, this paper presentation is Performance Assessment of Improved parboiling system Developed at National Cereals Research Institute with an Improved Local Rice Parboiling Method.

A. Description of National Cereals Research Institute rice parboiler

The NCRI rice parboiler consists of the following: (plate 2)

1. Boiler: The boiler is a cylindrical tank which is made up of mild steel. It has a diameter of 120cm with five outlet valves; three at the top while two at the side of the casing in other to allow the outflow of water from the tank to the steamer.

2. Steamer: The steamer is a rectangular tank in shape which is made from galvanized sheet. It has a height of

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60cm, base of 123cm and length of 123cm with four valves; two valves take water from boiler while other two valves drain water away from the steamer after soaking.

3. False Bottom (Rectangular Screen): This is an inner rectangular screen of 15cm height fixed inside the steamer to prevent the paddy rice from getting contact with the steamer base.

B. Description of a local improved rice parboiler

This consists of the following parts (fig. 1-2 and plate1-3):

***i. Soaking Chamber*:** The soaking chamber is a circular tank which is made up of galvanized sheet. It has a diameter of 80cm and 80cm in height and it consists of two outlet valves, and a pressure relief valve. The 'bottom' outlet valve functions to drain out the water inside the steaming chamber while the steaming level indicator valve drains the water 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: The steamer is circular in shape made from galvanized sheet which is inside the boiler. It has a diameter of 80cm and height of 18cm which generate steam.

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

iv. 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.

v. Parboiler Cover: The parboiler cover also made from galvanized sheet which has a diameter of 81cm used to cover the top of the system.

vi. Stand: It consists of four legs of 54cm height each which is made from 2inches angle iron with 80cm in diameter used to hold the parboiler from the base.

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

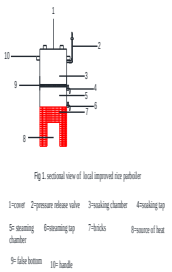

Fig 1. sectional view of local improved rice parboiler

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

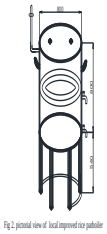

Fig 2. pictorial view of local improved rice parboiler

Plate 1. Constructed Local Improved rice Parboiler

Plate 2. Parboiling of paddy by the two processes

Plate 3. Parking of the parboiled rice

DESIGN THOREMS

i. Heat requirement

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

$$qu = MCp\delta T\ \delta t(\ KJ/min) \quad (1)$$

Where:
qu= useful heat required for a parboiling operation.
M = mass of paddy, kg.
Cp = specific heat capacity of water. (KJ/kg^{O}C)
δT = temperature ^{O}C
δt = time taken for parboiling (mins).

ii. Volume of steam flow

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

$$Q = AV\ (m3/sec) \quad (2)$$

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. (m/s)
However, the following was assumed:
i) The flow is steady and internal and one dimensional flow
ii) The steam is incompressible and frictionless.

iii. Velocity of flow

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

$$V = {}^{1}/_{4}\left[\frac{P_1 - P_2}{UL}\right]\ (D^2 - 4r^2)\ {}^{m}/_{s} \quad (3)$$

II. MATERIALS AND METHODS

A. National Cereals Research Institute Method of Rice Parboiling

40kg of paddy rice which had been pre-cleaned and washed was measured and soaked in hot water at 75^{O}C for 4hr. At 50mins interval of time, the weight of the paddy rice was taken to know the water uptake of the paddy rice. Also, the temperatures of the soak water for four specific periods were noted before the samples were left overnight for 12hrs. The water was drained and the wet paddy weighed. The paddy was placed on a false bottom incorporated in the steamer and steamed for 45min, 47min and 55min for FARO 44 (long grain), FARO 28 (medium grain) and FARO 40 (short grain). The paddy rice was sun dried for 2hrs and later dried in the shade for three days.

B. Local/Traditional Improved Method of the Rice Parboiler

40kg of paddy rice which had been pre-cleaned and washed was soaked in hot water at temperature of 75^{O}C for 3hr-20min. At 50min interval of time, the weight of the paddy rice was taken to know the water absorption of the paddy and temperature drop for four specific periods before the paddy was left in the hot water for 12hrs overnight to cool at ambient temperature. The paddy was then drained and weighed. The paddy rice was placed on the false bottom of the parboiler and steamed until over 95% 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 three days. The samples were analyzed for the following qualities:

***a. Water Uptake*:** The level of water uptake was determined by taken the difference between the final weight of paddy with the initial weight as shown:

$$UW = Wf - Wi \quad (4)$$

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)

b.Physical quality

i.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

$$TMR\% = \frac{milled\ rice\ (head\ rice + broken)}{5000g\ of\ parboiled\ rice} \times 100 \quad (5)$$

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

$$HRR\ \% = \frac{Weight\ of\ head\ rice\ (g)}{Weight\ of\ measured\ sample\ (2000g)} \times 100 \quad (6)$$

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

$$BR\ \% = \frac{weight\ of\ broken\ rice\ (g)}{Weight\ of\ measured\ sample\ (2000g)} \times 100 \quad (7)$$

III. RESULTS AND DISCUSSIONS

From the results obtained in table 1, the local improved rice parboiling system parboiled rice in 3hrs,

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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 while NCRI parboiler parboiled paddy rice in 3hrs-10minutes, 3hr- 12minutes and 3hr-25minute and 4.8kg, 4.8kg and 5.2kg of fuel were consumed for FARO 44 (long grain), FARO 28 (medium grain) and FARO 28 (short grain). This indicates that the time taken and quantity of fuel used to parboil paddy rice using the local improved rice parboiling system was less compared to the improved NCRI method of parboiling. The water absorption of rice parboiled using the local improved method of parboiling at decreasing temperatures as determined at an interval of 50minutes is shown in table 2.

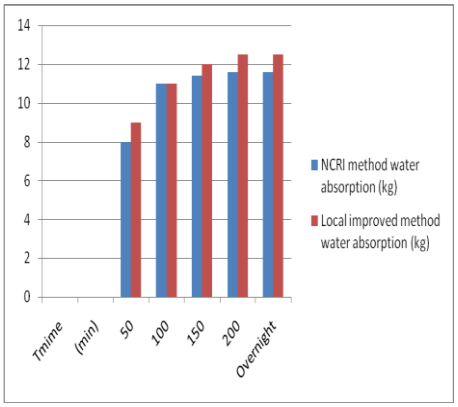

Fig. 3. FARO 44 (long grain) grain water absorption with time variance.

Figure 3, 4 and 5 also show the results of water absorption tests for both parboiling systems at different temperature drop. The result obtained from the water absorption test of the rice parboiled using NCRI and local improved rice parboiler show that the points are closely distributed. This confirms that there is no significant difference in water absorption of the paddy rice parboiled using both the parboiling systems.

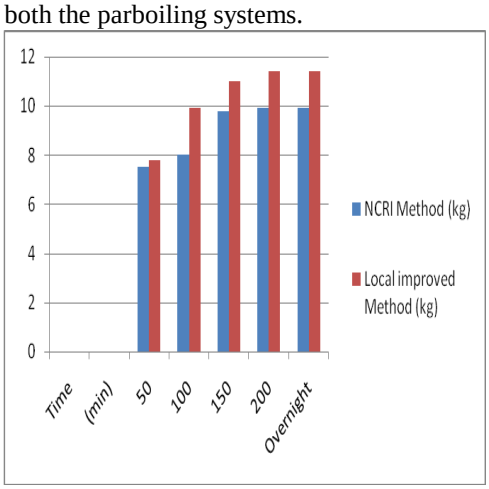

Fig. 4 FARO 28 (medium grain) Water absorption With time variance.

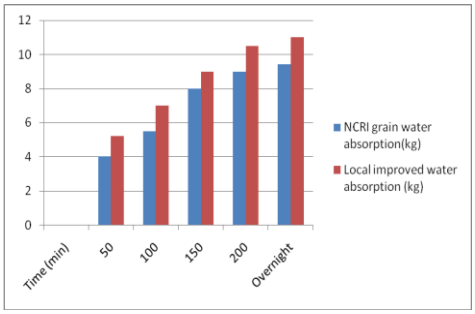

***Fig. 5* FARO 40 grain (sort grain) water absorption with time variance**

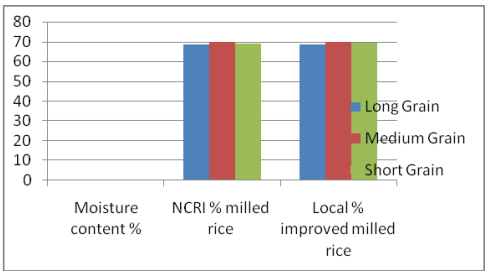

Fig. 6. Milled rice recovery of NCRI and improved parboiling method at 12-13% moisture content.

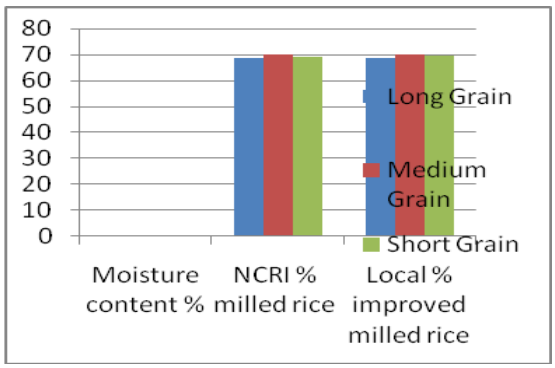

Fig. 7 Head rice recovering of NCRI and local improved method

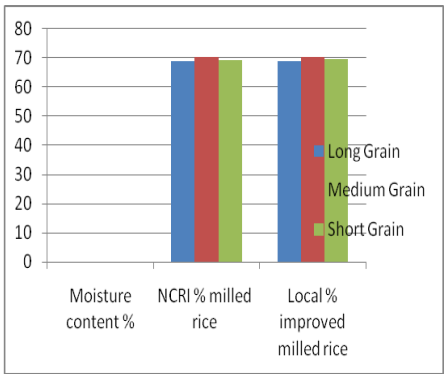

***Fig. 8* Broken rice of NCRI and local improved parboiling method at 12-13% moisture content.**

Total milled rice, head rice recovery and broken rice: From table 3, interpreted in figure 6, 7 and 8 also show results of total milling yield, head rice recovery and broken rice tests for NCRI parboiling method and local improved parboiling method at 12-13% moisture content. The results obtained show that there was no significant difference in total milling rice recovery, head rice

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recovery and broken rice for both NCRI and local improved method of parboiling.

IV. CONCLUSION

The local improved rice parboiler gave better results for FARO 44 (long grain), FARO 28 (medium grain) and FARO 40 (short grain) and parboiled averagely 0.224tons/day, 6.75tons/month and 84.375tons/years for 8-9 working hours. The local improved rice parboiler also have higher economic benefits over the NCRI method of rice parboiling in term of time saving and energy lost, water wastage after soaking and also required small amount of water for steaming

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APPENDIX

Table 1. Heat treatment for various rice varieties

		Rice Varieties					
		FARO 44(Long grain)		FARO 28(Medium grain)		FARO 40(Short grain)	
	Parameters	**NCRI**	**LIPM**	**NCRI**	**LIPM**	**NCRI**	**LIPM**
1	Mass of paddy (kg)	40	40	40	40	40	40
2	Time taken for soaking (min)	180-240	180-240	180-240	180-240	180-240	180-250
3	Soaking temperature (°C)	75	75	75	75	75	75
4	Water temperature after50min (°C)	65.5	68.5	64.8	68.2	65.4	70
5	Time taken for steaming (min)	30	45	32	47	55	45
6	Paddy temperature after steaming (°C)	78.2	85.3	88.3	88.4	83	90
7	Quantity of water used for soaking (l)	100	100	100	100	100	100
8	Quantity of water used for steaming (l)	25	25	25	25	25	25
9	Quantity of fuel used (kg)	4.8	3.6	4.8	3.6	5.2	5

NCRI PM is National Cereals Research Institute parboiling method
LIPM is Local Improved parboiling method

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Table 2. Water absorption of the grains with temperature variance

	Rice varieties											
	FARO 44 (Long grain)				FARO 28 (Medium grain)				FARO 40 (Short grain)			
min	NICI PM	LIPM	NCRI PM	LIPM	NCRI PM	LIPM	NCRI PM	LIPM	NCRI PM	LIPM	NCRI PM	LIPM
0	75	75	42	42	75	75	42	42	75	75	42	42
50	65.5	68.5	7.5	7.8	64.8	68.2	8	9	65.4	70	4	5.2
100	62.3	65.3	8	9.9	63	65.8	11	11	63.2	68.2	5.5	7
150	59.1	62.3	0.8	11	60.9	63.5	11.4	12	60	65.5	8	9
200	56.5	60.3	9.9	11.4	58.2	62	11.6	12.5	59.3	63	9	10.5
Over-night	34.4	39	9.9	11.4	34,.2	37.8	11.6	12.5	31.2	32.8	9.1	10.2

NCRI PM is National Cereals Research Institute parboiling method
LIPM is Local Improved parboiling method

Table 3. Effect of different parboiling methods on physical characteristics of long, medium and short grain Moisture content at 12-13%

	Rice Varieties								
	FARO 44(Long grain)			FARO 28 (Medium grain)			FARO 44 (Short grain)		
Parboiling method	Milled rice%	Head rice%	Broken rice%	Milled rice%	Head rice%	Broken rice%	Milled rice%	Head rice%	Broken rice%
NCRI method	68.5	95.0	5.0	70.0	96.0	4.0	69.1	95.5	4.0
Local improved method	68.5	97.0	2.0	70.0	97.5	2.5	69.5	97.0	3.0