ISSN: 2141 – 3290
www.wojast.com

IMPROVED METHOD OF PAR-BOILING PADDY FOR BETTER QUALITY RICE

ITUEN, E. U. U. AND UKPAKHA, A. C.
Department of Agricultural and Food Engineering,
University of Uyo, Uyo, Nigeria
E-mail: Dreuuituen@yahoo.com

ABSTRACT: In rice processing, par-boiling (hydrothermal process) of paddy determines to a large extent, the quality of milled rice. In this work, an improved method of par-boiling of paddy (harvested rice) which consists of pre-soaking of paddy in hot water for 3 hours only and then passing it through steam for 20 minutes, was employed. This was compared with traditional method practiced in Akwa Ibom State, Nigeria. The traditional method involves pre-soaking in cold water overnight before boiling in hot water for several hours to crack, thus taking between 16 and 24 hours to complete one batch. The result showed that drying of par-boiled paddy was faster with the improved method than with the traditional method. During milling, the improved method gave high grain yield (whole grains) of 91.2%, while the traditional method had grain yield of 48.8%. The improved method also produced rice with brighter colour than the traditional method. Proximate analysis showed that the nutrient contents were higher in rice of improved method than the one of traditional method. This indicates better solubilization (nutrient distribution in soaked grains) during hot water soaking. With the improved method, more than 7 batches of paddy could be par-boiled using the same time of 1 batch for the traditional method. The steam rice par-boiler was fabricated locally.

INTRODUCTION

Rice farming, which was introduced in Akwa Ibom State, Nigeria in the late 1960s, has become a major occupation especially in the northern part of the state, the low lands of Enyong creek. More farmers are now engaged in rice cultivation. They plant up to 2 crops yearly thereby greatly increase their yearly output. What they need is to produce rice of high quality that will compete favourable with others in the market. They should adopt improved methods of rice processing, notably in par-boiling and drying. Drying is partly determined by par-boiling. Proper par-boiling will lead to good drying. When paddy is over par-boiled, it becomes difficult to dry it. Therefore par-boiling becomes very delicate in rice processing.

Par-boiling is a hydrothermal process that leads to the gelatinization of the starch and disintegration of protein bodies in the endosperm, which expand and fill the internal air spaces in the grains, (Adewusi, 1982, Ayotade, 1982). During gelatinization, the starch granules are squeezed together, the structure and cracks present in the endosperm are closed, making the grains translucent, hard and tough (Ali and Pandya, 1974). This process enhances better quality of milled rice with reduced broken quantity. The hardness and compactness of the endosperm improve the storability of the processed rice, making it resistant to perforation by insects and less liable to absorb moisture. During gelatinization starch voids and granules are changed to gelatinous or jelly form which then fills and cements the fissures in the grain (Ali and Pandya, 1974). In par-boiling, soaking of paddy is required so as to bring about solubilization, during when the nutrients, taste and flavour from the outer layers are infused into the grains interior. Ali and Ojha (1975) stated that the soaked paddy should attain a moisture content of about 30-35% for proper solubilization and this takes about 36-48 hours of cold water soaking. In the traditional method as practiced in Akwa Ibom State, soaking is done overnight, about 15 hours in cold water. Sometimes, paddy is not soaked at all, but washed and par-boiled at once. That

means the paddy may not have attained a moisture content of about 30% required for full solubilization. However, prolonged soaking in cold water, e.g. for 24 hours and above, results in the fermentation of the paddy, and this brings about microbial activities, undesirable odour and the development of micotoxins (Bhattacharya and Rao 1966 and Dauda et al, 1999).

Hot water soaking has been found to be very effective in the par-boiling paddy because it reduces the soaking time from about 36 hours to about 3 hours (Onwuka, 2003). Thus larger production of processed rice can be achieved within a short time. In hot water soaking, water and heat are added to the rice simultaneously. The rate of solubilization increases rapidly because of the increased temperature. The water requirement in the hot water soaking is smaller than in the cold water soaking because frequent changes of soak water are not necessary.

Par-boiling is completed by removing the paddy from the hot water and steam allowed to pass through it for about 20 minutes. The steam gelatinizes the paddy and adds no water to it. Thus hot water soaking and steaming can take about 3 hours instead of about 20hours. Onwuka (2003) observed that in hot water soaking and streaming, about 6 batches of paddy can be par-boiled in 24 hours, while one or 2 batches can be done n the same time in the traditional method. The time value of money can be appreciated using this improved method of par-boiling. Since the paddy has been soaked in hot water and consequently steamed, yellow colour can be easily obtained in the rice to suit the needs of customers. Secondly, the paddy is easier to shell and suffers less breakage during milling than in the traditional method (Bhattacharya, 1969, Rhind, 1962).

The improved method of par-boiling envisaged here would consist of hot water soaking and steaming. The two operations are to be performed in one equipment, the steam par-boiler. Its design is an improvement on the works of Ngoddy (Onwuka, 2003). Paddy par-boilded shall be dried and milled, and the product characteristics determined and compared with those of the traditional method.

MATERIALS AND METHOD

The fabrication of the steam par-boiler was based on existing design by Ngoddy with modifications on the insulation of the walls, using glass wool and fire clay. Again, the water inlet pipe was provided with a graduated transparent slide to monitor the level of water inside the stream par-boiler. The lid was made heavy and steady to restrain lifting by steam pressure which is at atmospheric conditions (the outlet pipe exposing the steam to ambient condition). Hence there was no danger of explosion.

Clean paddy 50kg, contained in tiny nylon netting was introduced into the basket which was soaked in hot water at 80^{o}C for solubilization. The basket was hanging midway of the par-boiler. The temperature of the soak water dropped to about 72^{o}C. After 3hours of soaking, the drain tap was opened for the soak water to drain to the level below the basket containing the soaked paddy. The par-boiler was again heated and this time to produce steam to par-boil the paddy. After 14 minutes of steaming, the paddy had cracked from bottom to top and the steaming was stopped. The paddy was then sun dried thinly on woven mats. The dried paddy was allowed to cool in sacks for some time for temperature and stress distribution before milling.

In the traditional method the clean paddy was soaked in cold water overnight. It was then transferred to fresh cold water contained in a par-boiling equipment, half of a 200-litre capacity drum and boiled until it started to split. The paddy was turned again in the drum for the top to go to the bottom and vice versa. The par-boiling was stopped when the paddy showed sufficient splitting. It was dried on woven mat, cooled and milled.

RICE QUALITY DETERMINATION

Samples from the two methods, improved and traditional, were used in the determination of their quality. The quality determination included among others:

(i) Swelling rate/water absorption:

100g of each sample was placed in the measuring cylinder. Water was added to make 150ml volume in the two samples simultaneously. The rice began to absorb water and swell. As the grains swelled, the level of water in the measuring cylinder rose. The reading was taken every 10 minutes until it became constant at its water absorption capacity.

(ii) Grain yield:

From 5g of each of the two samples of rice, brokens were separated from the wholes. The percent yield or whole grains was calculated, based on weight of the sample.

(iii) Nutritional quality:

Proximate analysis was carried out on the two samples to determine the quality of the rice nutritionally. Thus carbohydrate content, protein, ash, fat, vitamins and mineral contents were determined. It was expected that the method of par-boiling especially at solubilization should affect their nutritional content. Also, the colour of the rice was observed.

RESULTS AND DISCUSSION

It was observed that steam par-boiling takes quite a short time, about 3 hours, 20 minutes, as compared with traditional method which takes more than 12 hours. Onwuka (2003) said that about 6 batches of paddy can be par-boiled in the steam par-boiler in 24 hours when the traditional par-boiling can take about 2 batches in the same period. However, larger quantities up to 10 batches could be par-boiled in less than 12 hours; if paddy is soaked in hot water using many coolers sequentially every 30 minutes and steaming is also done sequentially every 30 minutes. This system can help farmers in timely processing of paddy and in making effective use of available good weather in drying. Again, since soaking in hot water as in the improved method takes a short time, fermentation of the paddy may not take place. Hence bad odour may not occur in the milled rice. The product quality of the 2 methods of par-boiling; the steam and the traditional methods, was based on the following criteria:

(i) Water Absorption/Swelling capacity of soaked milled rice

The rate of swelling of rice when soaked in water was used as an indication of how the paddy was gelatinized during par-boiling. Higher swelling capacity would indicate better gelatilization, which also reflects on better method of par-boiling.

Table 1: Water absorption and swelling capacity of rice par-boiled in 2 methods.

Soaking time (mins)	Swelling capacity, ml/100g	
	Traditional method	Improved method
0.2	150	150
10	150	170
20	165	185
30	175	190
40	185	200
50	190	210
60	195	215
70	200	225
80	205	228
90	210	230
100	210	230

Table 1 shows the swelling capacity of milled rice from the 2 methods of par-boiling, compared with soaking time. The steam par-boiled rice absorbed more water and swelled per unit time more than the traditionally par-boiled rice. Hence there was better gelatinization with steam par-boiled method.

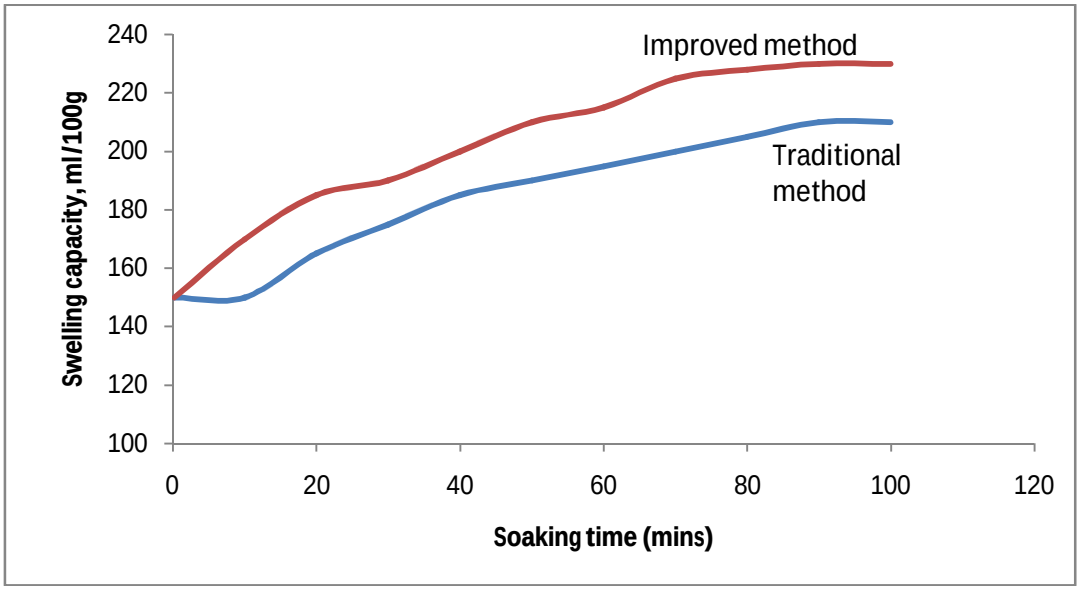

Figure 1: Swelling capacity of rice par-boiled in 2 methods

Kunze and Choudhung (1972) observed that rice kernels, when exposed to a higher relative humidity atmosphere or moisture absorption environment, do not fissure immediately, but require a lapse of time called the "retardation time". The retardation time is said to depend on exposure relative humidity, variety and form of grain crop. They also found that brown rice required more time than polished rice for an initial fissuring response because polished rice absorbed moisture faster than brown rice.

Kunze, and Choudhung (1972), Ituen, et al (1986) and Ituen (1995), have represented the water absorption process in grains with a first order systems equation given by

$$y = Kx_o\ (1\text{-}e^{-t/\tau}) \qquad 1$$

Where:

y = output value
Kx_o = dynamic sensitivity
τ = system's time constant
t = process time

Equation (1) shows that for better dynamic response, τ should be as small as possible.

For water absorption in grains, the plot of moisture against soaking time gives a response curve similar to that derived from equation (1) but beginning from an intercept on the moisture content axis because of the initial moisture content of the dry grain. An equation of moisture absorption in grains is hence given by the expression.

$$C_t = C_0 + C_r (1\text{-}e^{-t/\tau}) \quad 2$$

where

C_t = total moisture content of grain at soaking time t.
C_0 = initial moisture content before soaking
C_r = moisture content due to water absorbed at time t.
τ = system time constant, measures how fast the system responds to disturbance. This is time when 63.2% of the process occurs (Shearer, et al, 1967).

Equation (2) is applicable to the swelling capacity of rice produced by the two methods of par-boiling as shown in Figure 1,

where

C_t = total swelling volume at soaking time, t
C_0 = initial swelling volume at start of swelling.
C_r = swelling volume due to water absorbed.
τ = system time constant,
t = process time or swelling time

From equation (2):

At $t = 0$, $C_t = C_0$

At $t = \infty$, $C_t = C_0 + C_r = C_{sat}$ 3

Where C_{sat} = swelling at its moisture absorption capacity, ie at saturation.

At $t = \tau$, equation (2) becomes,

$$C_r = C_0 + C_r (1\text{-}1/e)$$
$$= C_0 + C_r (0.632) \quad 4$$

At $t = 2\tau$, $C_{2\tau} = C_0 + C_r (0.865)$ 5
At $t = 3\tau$, $C_{3\tau} = C_0 + C_r (0.95)$ 6
At $t = 4\tau$, $C_{4\tau} = C_0 + C_r (0.982)$ 7
At $t = 5\tau$, $C_{5\tau} = C_0 + C_r (0.993)$ 8
At $t = 6\tau$, $C_{6\tau} = C_0 + C_r (0.998)$ 9
At $t = 7\tau$, $C_{7\tau} = C_0 + C_r (0.999)$ 10

4τ is often used as the time at which the variation is essentially over, since less than 2% of the changes remains to occur. Therefore 4τ is a standard time for change to occur (Shearer, et al, 1967):

From the above information,
$C_{4\tau} = C_{sat}$ = Swelling capacity at saturation.

From equation (7), $C_{4\tau} = C_0 + C_r (0.982)$

$$\frac{C_{4\tau} - C_0}{0.982} = C_r$$

From Fig. 1: $C_{4\tau}$ for traditional method = 210ml/100g
C_0 for traditional method = 150ml/100g
$C_{4\tau}$ for improved method = 230 ml/100g
C_0 for improved method = 150ml/100g
C_r for traditional method = $\frac{210 - 150}{0.982}$ = 61.1ml/100g

C_r for improved method = $\frac{230-150}{0.982}$ = 81.47ml/100g

System equation for traditional method: $C_t = 150 + 61.1\ (1- e^{-t/\tau})$ 11
System equation for improved method: $C_t = 150 + 81.47\ (1- e^{-t/\tau})$ 12

Table 2: Swelling capacity of Rice generated from systems equations (11) and (12).

Response time	**Swelling Capacity ml/100g**	
	Traditional method	**Improved method**
τ	188.62	201.49
2 τ	202.85	220.47
3 τ	208.05	227.40
4 τ	201.00	230.00
5 τ	210.67	230.90
6 τ	210.98	231.31
7 τ	211.04	231.39

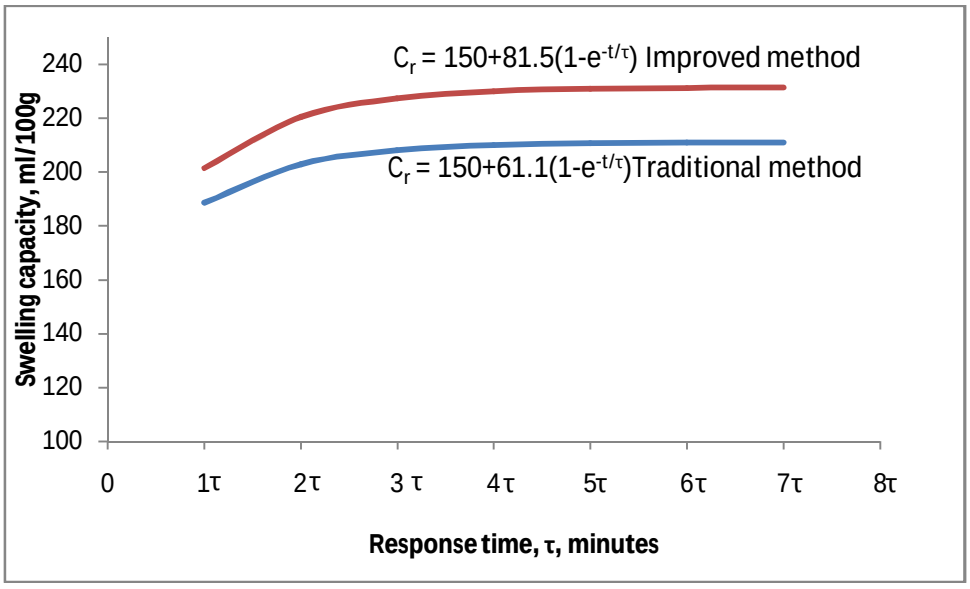

Figure 2: Swelling capacity of milled rice par-boiled in 2 methods as generated from system equations

From Tables 1, the actual values of the system time constant, τ, minutes, corresponding with the swelling capacity of C_τ(ml/100g) in Table 2, was obtained by interpolation as shown in Table 3.

Table 3: Response time for water absorption and swelling of Rice.

Response time	**Corresponding time in mins**	
	Traditional method	**Improved method**
T	47.24	41.49
2τ	75.70	65.47
3τ	86.10	78
4τ	95	95

Table 3 shows that the response time, τ, in minutes, is smaller for the improved par-boiled rice than that of the traditional method. That means rice obtained from improved method of par-boiling absorbed water and swelled faster than that of the traditional method. This is confirmed by the values in Table 2 in which the level of swelling C_τ was higher for the rice of improved method than that of the traditional method in the time, Ł, minutes. It is a further confirmation that gelatilization of paddy during par-boiling was better in the improved method than in the traditional method.

Figure 2 was obtained by plotting the response time, τ minutes in Table 3 against swelling capacity C_τ in Table 2. This curve plotted with the generated values of the system equation of both traditional and improved methods are similar to those in Figure 1.

(ii) Grain yield

From the average values of 10 samples of each method, it is observed that the whole grain yield of improve method was 91.20% while that of the traditional method was 48.80%. The brokens were very high with the traditional method. This analysis shows that the better the par-boiling the better the grain yield (whole grain yield). The dried paddy of improved method could shell better during milling. Thus the steam par-boiled method gave very high grain yield (Table 4).

Table 4: Breakage composition of milled Rice of the two methods of par-boiling paddy.

Sample no (Repetitions	**Traditional method**			**Improved method**		
	Weight of sample (g)	**Brokens (g)**	**Whole graing (g)**	**Weight of sample (g)**	**Brokens (g)**	**Whole grains**
1	5	2.96	2.04	5	0.32	4.68
2	5	2.41	2.59	5	0.54	4.46
3	5	2.01	2.99	5	0.36	4.64
4	5	1.90	3.10	5	0.26	4.74
5	5	2.68	2.32	5	0.38	4.62
6	5	1.88	3.12	5	0.41	4.59
7	5	3.01	1.99	5	0.52	4.48
8	5	2.86	2.14	5	0.54	4.46
9	5	2.91	2.09	5	0.48	4.52
10	5	2.98	2.02	5	0.58	4.42
Average	**5**	**2.56**	**2.44**	**5**	**0.44**	**4.56**

(iii) Nutritional Composition of the Rice grains:

The proximate analysis of milled rice of the two methods of paddy par-boiling, (Table 5), shows that the steam par-boiled rice generally had higher nutrient contents that the water par-boiled rice. The lower moisture contents with the improved method shows that drying of paddy was faster and better than that the traditional method. That is also why it could swell faster due to water absorption. The higher carbohydrate content also indicated that improved method of

par-boiling made the grains to be more compact and hard, an attribute desired for storability of rice. Other nutrients were higher for grains of improved method of par-boiling. The hot water soaking that was followed by steaming might have enhanced higher solubilization, when the nutrients from the outer layer were well distributed to settle in the rice endosperm. Thus rice from the improved method of par-boiling (steaming) is richer nutritionally.

Table 5: Nutritional composition of milled rice of improved and traditional methods of paddy par-boiling.

Food composition	Traditional method	Improved method
Moisture content (%)	12	10.30
Carbohydrate		
Total (%)	77.4	81.30
Fibre (%)	0.70	0.20
Crude protein (%)	6.70	7.40
Ash (%)	0.50	0.70
Fat (%)	0.40	0.30
Vitamin, mg/100g		
Thiamin	0.34	0.44
Niacin	4.70	3.50
Minerals, mg/100g		
Calcium	32.00	60.00
Phosporus	221.00	200.00
Iron	5.00	9.00

CONCLUSION

Steam par-boiled rice (improved method), was found to be better than the water par-boiled (traditional method) rice. In steam par-boiling of paddy, there is hot water soaking for 3 hours only, followed by 20 minutes steaming instead of 12-24 hours soaking in cold water or no soaking at all before par-boiling in boiling water as in the traditional method. Thus many batches of steam par-boiling (up to 6) can be done in one day. A farmer can process large quantities of rice within a short time.

Steam par-boiling enhances better gelatinization as shown by the level of swelling when soaked in water as compared with the boiling water par-boiling. Better par-boiling and hence better gelatinization leads to high grain yield, impartation of golden yellow colour to the rice which is preferred by consumers. Good par-boiling increases strength of rice grains and hence make them resistant to insect attacks while in storage. Steam par-boiling led to fast drying of the paddy and hence good quality of milled rice, while boiling water par-boiling led to slow and difficult drying and this resulted in poor quality products such as moulded and broken grains. Proximate analysis of the rice showed that nutritional contents of steam-par-boiled rice (improved method) were generally higher than those of boiling water par-boiled rice.

Value addition is what the farmer needs to raise the quality of his products so as to make profit. It is therefore necessary that additional cost should be incurred to purchased the steam-par-boiler (Figs. 3 - 5) for better quality products.

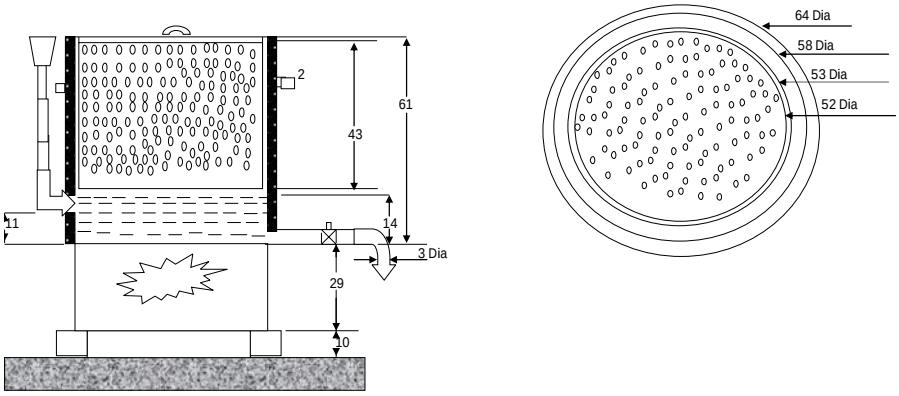

Figure 3 Cross sectional Layout of Rice Steam Parboiler (All dimensions in cm)

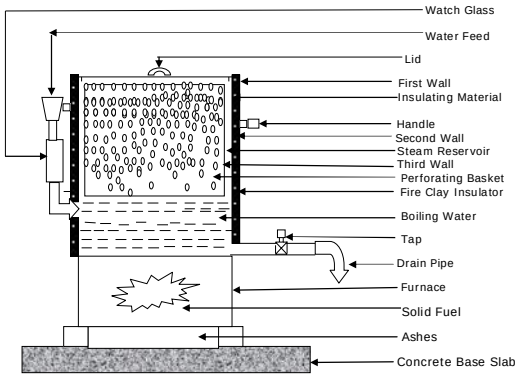

FIG. 4: Structure of Steam Rice Par-boiler

Fig. 5: Locally Fabricated Steam Rice Par-Boiler

REFERENCES

Adewusi, A. O. (1982). Par-boiling of rice and strategies for hardware development in West Africa. Paper at workshop on Rice par-boiler hardware development project. U.N.N.I.

Ali, Z. S. and Ojha, T. P. (1975). Soaking characteristics of paddy. Journal of Agric. Engineering. Res. (20) 4, 353.

Ali, Z. S. and Pandya ,T. P. (1974). Basic concept of Par-boiling paddy. Journal of Agric Engineering. Res. 19 (2), 11

Ayotade, K. A. (1982) Rice par-boiling and milling studies in National cereals research institute. Paper at workshop of the African Regional centre for Tech. Dakar, U.N.N 20-21. September, 1982.

Bhattacharya, K. R. (1969). Breakage of Rice during milling and effect of par-boiling Cereal chemistry. 64 (5) 478-485.

Bhattacharya, K. R. and Subba Rao, P.V. (1966) Effect of processing conditions on quality of par-boiled Rice, Journal of Agric Food Chem. (14), 476-479.

Dauda, S. M., Misan, S. M., Dzicama, A. U. and Agidi, G. (1999). Performance evaluation of local Rice par-boiling techniques in Borno State. Proceedings of the Nigerian institution of Agricultural Engineers (21):125-130.

Ituen E. U. U., Mittal, J. P. and Adeoti, J.S. (1986). Water absorption in Cereal Grains and its Effect on their Rupture stress. Journal of Food process Engineering (8), 147-158.

Ituen, E. U. U. (1995). Dynamic Response of water absorption in soaked Cereal grains. Procedings of the Nigeria society of Agricultural Engineers, held in Akure, Nigeria, 25th - 28th April, 1995 NSAE (17) 179-287.

Kunze O.R. and Choudhury, M.S.U. (1972). Moisture absorption related to tensile strength of rice. Cereal Chemistry (49) 684.

Onwuka, N. D. K. (2003). Essential Elements of Food and Related processing Engineering. UCO-Academic Publishers Nigeria Limited. Nsukka, Enugu.

Rhind, D. (1962). Breaking of rice in milling. Tropical Agriculture (39) 19.

Shearer, J. L., Murphy, A. T. and Richardson, H. B.(1967). Introduction to system Dynamics. Addison-Wesley publishing company, Reading, assachusetts.