DEVELOPMENT OF AN IMPROVED MINI RICE PADDY PARBOILER

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Abstract

A 5kg per batch capacity mini rice paddy parboiler was developed to improve the efficiency of the parboiling operation and also to increase both the milling quality and yield of parboiled paddy. The parboiler consists of the soaking/steaming chamber, steam generation chamber and the furnace. The performance of the parboiler was evaluated using 3 rice varieties (FARO 44, FARO 52 and FARO 60). Assessment of efficiency of the equipment was based on Steaming Time (ST), Head Rice Yield (HRY) and percentage Broken Rice (BR). The results obtained were compared to those obtained using the traditional parboiling pots. The developed improved parboiler produced HRY of 73.7%, 71.9% and 73.1% HRY at 35 minutes steaming time for FARO 44, FARO 52 and FARO 60 rice varieties respectively. HRY produced with the conventional method were 62.3%, 67.1% and 65.8% for FARO 44, FARO 52, and FARO 60 respectively at 35minutes steaming time. Percentage broken grains was observed to be between 0.3% and 2.1% for the developed parboiler while it was over 10% with the traditional method. The equipment produced good quality rice at steaming time between 30 and 35 minutes. Paddy soaking and steaming were efficiently done in the same chamber, thus removing variation in the batch quality of the product. It can be concluded that the developed parboiling equipment is more efficient for small scale paddy parboiling at the rural level in Nigeria.

Keywords: Parboiling, Soaking, Steaming, Rice paddy, Head rice, Broken rice, Performance evaluation

Introduction

Rice parboiling is the hydrothermal treatment of rice paddy prior to milling, leading 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 (Roy *et al,* 2013). It offers higher milling recovery, more translucent kernels, longer storage life, easy dehulling and increased swelling when cooked (Roy *et al.* 2013, Federal Ministry of Agriculture and Rural Development (FMARD), 2006). The yield of parboiled paddy is about 15% higher than non-parboiled paddy and the nutritional values (vitamin A and protein) and the appearance are much better (Houssou and Amonsou 2004). However, because parboiled rice is harder in texture, it takes longer time to cook than white rice (Danbaba *et al*., 2014).

Parboiling of rice paddy is an essential activity of rice processing in Nigeria and it is still mostly carried out using traditional methods. The use of the traditional method of rice parboiling comes with a number of challenges which negatively affect the efficiency of the operation and largely affect the milling quality and yield of the parboiled paddy (Ogunbiyi, 2011). Such challenges include: inefficient steam circulation and use, overcooking of paddy, difficult and laborious discharge of parboiled paddy, long and tedious parboiling process, high fuel consumption (Adewuyi, 2004).

Different communities have over the years developed and practiced various parboiling methods. However, the result is still that the produced milled rice are still very inconsistence in all its physical and cooking qualities. This has largely influenced Nigerians' preference to consuming imported foreign rice that has the preferred qualities (Bamidele *et al.* 2010). Improper steeping resulting from soaking at lower temperature causes microbial contamination while soaking at higher temperature causes sloughing-off of the surface before hydration of the core of the kernel is achieved (Sareepuang *et al*. 2008). Also uncontrolled soaking results in leaching loss, development of off-flavour due to fermentation, kernel bursting and colour change (Danbaba *et al*., 2014).

Traditional parboiling equipment that arecommonly used in Nigeria includealuminum pots and metallic drums and containers. In most rice processing communities, soaking and steaming are done with thesame containers while in other communities these are done in different pots and drums of varying capacities (Plates I a-c).

a. Parboiling pots **b. Large capacity drum** **c. Small capacity drums**

Plate I: Traditional parboiling equipment

Source: Federal Ministry of Agriculture and Rural Development (2016)

The traditional parboiler consists essentially of a metallic container (drum or pot). Soaking of the paddy is done in the container at a desired temperature and duration. At the end of the soaking time, the paddy is drained and then simply placed in the same container or smaller one for the steaming operation. A relatively small amount of water is added to the paddy - to steam all the rice - and the container is heated until the water in the bottom begins to boil. The resulting steam does partial cooking of the paddy. In some cases, the container is covered with jute bags while the steaming progresses. Steaming is completed when the husks begin to split. A major defect of this process is the tendency to for the paddy to be overcooked in the steaming water or gets burnt when the water dries during steaming. This results in discoloration of some kernels, leading to overall low quality and losses. The traditional parboiling equipment and method require a lot of attention and monitoring from the rice processor and also exposes the processor to hazards and injuries due to excessive exposure to the heat source and steam. This method is also not energy efficient because the steaming is often done without a cover on the drum/pot (Plate Ib) or covered with a piece of cloth or bag (Plate Ia) leading to the loss of considerable amount of steam which escapes from the top of the parboiling drum/pot. During steaming, the paddy at the bottom of the drum/pot is overcooked because it is in contact with steaming water. The parboiled paddy is discharged by scooping from the parboiling pot/container and this could be very laborious and hazardous due to the hot paddy and steam.

The objective of this study is therefore to develop a compact, safe and easy to operate paddy parboiler that will address the challenges associated with the use of traditional parboiling equipment.

Materials and Methods

Material

Rough rice samples of three improved varieties FARO 44, FARO 52 and FARO 60 obtained from the National Cereals Research Institute (NCRI), Badeggi, Niger State, Nigeria were used for this study. The samples were cleaned manually and foreign matter such as stones straw/chaff and dirt were removed.

Methodology

Design and construction of the parboiling equipment

A mini paddy parboiling equipment was designed and fabricated (Figure 1). The equipment has a maximum parboiling capacity of 5kg of paddy per batch.

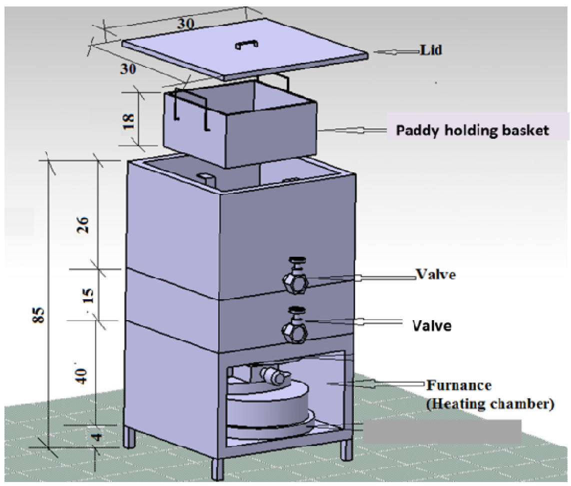

Figure 1: Design of the mini parboiler

The following are the design parameters and considerations

i. Soaking and steaming capacity: 5kg
ii. Material of construction: Mild steel
iii. Total dimension: 0.3m x 0.3m x 0.85m
iv. Source of heat: 3-5kg capacity gas cylinder with burner, charcoal pot or an electric hotplate.
v. Provision of a false bottom for the steaming chamber to prevent paddy from getting in contact with the boiling water during steaming.
vi. The total parboiling capacity, measured in weight of paddy, per batch, W_{batch} was calculated as follows:

$$Weight\ of\ paddy\ per\ batch\ W_{batch} = Volume_{basket}\ X\ Bulk\ density_{paddy}$$

……………. *Equation (1)*

w*here* V_{basket} = Volume of paddy holding basket

Volume of paddy holding basket = 0.23mx 0.23m x 0.16m = 0.0084m^3

Given that the bulk density of rice paddy is 498kg/m^3 - 597kg/m^3 (Adebowale *et al.* 2011).

W_{batch} = 0.0084m^3 x 597kg/m^3 = 5.01kg

vii. Provision of a lid at the top of the steaming chamber to conserve the steam and enhance adequate circulation of the generated steam.

The equipment was constructed at the Engineering workshop of the National Cereals Research Institute (NCRI), Badeggi, Niger State, Nigeria.

Evaluation of the parboiling equipment

The efficiency of the parboiling equipment was evaluated using paddy of 3 different varieties of rice namely, FARO 44, FARO 52 and FARO 60.

Paddy soaking: Two hundred grams (200g) paddy of each variety, held in wire mesh basket, was soaked at 75°C for 12 hours in the soaking/steaming chamber of the parboiling equipment.

Paddy Steaming: The soaked paddy samples were steamed in the steaming chamber for 20, 25, 30 and 35 minutes. Each sample was held in a wire mesh basket and placed in the paddy holding basket of the parboiling equipment. The water level in the steam generating chamber was such that it is below the perforated bottom of the steaming chamber. Time of onset of kernel splitting was noted for all the samples. The temperature of the steam was monitored throughout the steaming period with a digital thermometer.

Drying, husking and milling: The steamed paddy was dried uniformly at room temperature until 14% moisture content was attained. Husking and milling of the dry parboiled paddy were done in the laboratory using Test Husker THU35B, (SATAKE Corporation, Japan) and Test Mill TM05C, (SATAKE Corporation, Japan).

Parboiling with traditional method

Rough rice samples (15kg) of the 3 improved rice varieties were provided to a local rice processor and member of the *Akpajeshi Rice Processing Cooperative Society* in *Passo* Village, along *Dobi* Road, *Gwagwalada*, North Central Nigeria. The parboiling process and method employed by the local processor were monitored. Clean rough rice was soaked in hot water (63-66°C) and for 12 hours in open aluminum pots. Soaked paddy was steamed in a pot for 35 minutes. Folded portion of jute bag was placed at the bottom of the steaming pot containing some quantity of water before the rice was poured into the pot. Parboiling was deemed complete when splitting of the rice kernels has been established. The parboiled samples were uniformly sundried. The dry paddy samples were husked and milled with Test Husker THU35B, (SATAKE Corporation, Japan) and Test Mill TM05C, (SATAKE Corporation, Japan).

Head Rice Yield and Broken Rice Ratio

Whole and broken grains were separated automatically from all the samples using a cylinder-type test rice grader TRG 05B (SATAKE Corporation, Japan). Whole grains and broken grains that are three quarters of the whole kernel or longer were classed as whole kernel while the remainders were considered as broken grains (Fofana *et al*. 2011). Whole grains were collected and weighed. Head rice yield was calculated as the ratio of the weight of whole grain to the weight of the dry parboiled samples as follows:

$$Head\ rice\ yield(\%) = \frac{Weight\ of\ whole\ grain\ rice}{Weight\ of\ dry\ parboiled\ paddy} x\ 100$$ ………………*Equation (2)*

Similarly, the broken rice was collected from the rice grader and the ratio of broken grains was also determined as follows:

$$Broken\ rice\ ratio(\%) = \frac{Weight\ of\ broken\ rice}{Weight\ of\ dry\ parboiled\ paddy} x\ 100 \quad \text{………………… Equation (3)}$$

The efficiency of the developed equipment was assessed based on the effect of steaming time on the Head Rice Yield (HRY) and percentage Broken Rice (BR) and compared with the traditional method of rice parboiling. The percentage of whole grain is the most important parameter in the rice processing industry (Bleoussi *et al.* 2010).

Results and Discussion

Description of the developed parboiling equipment

The fabricated parboiling equipment is shown in Plate II. It consists essentially of a soaking/steaming chamber measuring 30cm x 30cm x 26cm and a heat generation chamber or furnace measuring 30cm x 30cm x 40cm. The equipment is designed to use a variety of heat sources (either a movable 5kg capacity gas cylinder with burner, a raised bed charcoal pot, a kerosene stove or an electric hot plate). The soaking/steaming chamber has a false bottom made of perforated mild steel plate and contains a movable perforated paddy basket which holds the paddy for soaking and steaming.The chamber is fitted with 2 drain valves. One valve drains the water to a level just below the false bottom to facilitate effective steaming of the paddy in the steaming chamber while the second valve drains the water completely from the equipment. A lid is provided at the top of the steaming chamber to conserve the steam and enhance adequate circulation of the steam generated.

a. The mini parboiler with the gas burner option **b. Paddy holding baskets**

Plate II: The fabricated improved parboiling equipment

The design is an improvement over the traditional parboiling pots. This design prevents the paddy from getting in contact with the boiling water and prevents overcooking of the paddy. It also prevents absorption of too much water by the paddy which usually leads to increase in the paddy drying time. The varieties of the sources of heat the equipment can use are sources that produce constant heat intensity and thus result to uniform and regular steaming. Uniform steaming results to uniform gelatinization, uniform drying and efficient milling thus reduced cracking and breakage of the rice kernels.

An advantageous feature of this equipment is that soaking and steaming are both performed in the same chamber providing for convenience and uniformity in product quality in the same parboiling batch. The steam temperature during the evaluation of the equipment was 103±2°C and this was constant during the process of steaming.

The removable paddy holding basket in the steaming chamber (Figure 1) provides for easy and safe discharge of the parboiled paddy. The paddy basket is suspended in the steaming chamber with a clearance of 5cm around the basket. This provided for even and uniform circulation of steam in and around the paddy in the basket. The effect of this is that the paddy is uniformly exposed to good quantity of steam throughout the parboiling period. A corresponding effect of this is that less fuel is utilized to achieve the desired parboiled state of the paddy making the equipment very economical to operate. Periodic inspection of the paddy during parboiling is made easy by the provision of a relatively airtight lid which can easily be opened and closed. A thermometer probe outlet is also provided to seamlessly monitor the temperature of the steam during the parboiling operation.

Performance evaluation of the parboiling equipment

The results of the performance evaluation of the parboiling equipment are as presented in Table 1. The results show that the HRY of the paddy parboiled by the designed parboiling equipment is between 67.5% and 73.7%. The HRY increased with increase in the steaming time for all the rice varieties with the maximum yield obtained at 35 minutes of paddy steaming.

Paddy soaking and steaming were efficiently done in the same chamber, thus removing variation and enhancing uniformity in the batch quality of the product. FARO 44, FARO 52 and FARO 60 rice varieties produced 70.3%, 67.5% and 71.1% HRY respectively at 30 minutes steaming time and 73.7%, 71.9% and 73.1% HRY respectively at 35 minutes steaming time. HRY with the traditional cooking pot was 62.3%, 67.1% and 65.8% for FARO 44, FARO 52, and FARO 60 respectively at 35minutes steaming time. The low HRY from the traditional method may be attributed to the non-uniform distribution of the moisture content of the parboiled paddy (Houssou and Amonsou, 2004) leading also to non-uniform drying. The over dried grains have the tendency to crack and subsequently break during milling. Onset of kernel splitting was observed at 18 minutes of steaming for the three rice varieties using the designed parboiling equipment.

Evaluation of the ratio of broken rice also shows a maximum value of 2.9% for FARO 44, 1.8% for FARO 52 and 3.3% for FARO 60 at 20 minutes steaming time. However, the broken rice reduced significantly at 30 and 35 minutes steaming times for the 3 rice varieties. This is probably due to the expected increase in hardness of the grain as the steaming time increases as reported by Fofana *et al.* 2011. Hardness of the grain has also been reported to positively affect the resistance of the grain to breakage during milling (Mir and Bosso, 2013).

However, other steaming conditions such as inadequate quantity of steam, ineffective steam circulation and direct contact of paddy with boiling water also contribute to grain breakage during milling (FMARD, 2016). Percentage broken was very high with the traditional parboiling pot at 10.0%, 8.4% and 8.8% respectively for FARO 44, FARO 52, and FARO 60 respectively.

Table 1: Head rice yield and percentage broken rice using the developed paddy parboiling equipment and traditional pot/method

Variety	Soaking time (Hours)	Steaming time (Minutes)	Improved parboiling equipment		Traditional parboiling pot *	
			HRY (%)	Broken rice (%)	HRY (%)	Broken rice %)
FARO 44	12	20	70.3	2.9	-	-
	12	25	71.6	1.1	-	-
	12	30	72.0	2.1	-	-
	12	35	73.7	0.3	62.3	10.0
FARO 52	12	20	67.5	1.8	-	-
	12	25	69.0	0.8	-	-
	12	30	71.5	0.8	-	-
	12	35	71.9	0.7	67.1	8.4
FARO 60	12	20	71.1	3.3	-	-
	12	25	72.4	1.2	-	-
	12	30	72.8	0.9	-	-
	12	35	73.1	0.2	65.8	8.8

*Steaming was done for only 35 minutes with the traditional parboiling pot/method

Conclusion

The developed mini parboiling equipment is effective and efficient for paddy parboiling in Nigeria. The parboiler produced milled rice grains of very good qualities in terms of the head rice yield and percentage broken grains. These qualities are better than those produced with the traditional parboiling pot. The improved parboiling equipment is also very easy, safe and economical to use. It is therefore a better alternative to increase productivity and income of rice processors in Nigeria. However, further work is required in upscaling the capacity of the mini parboiler to be able to process large quantity of paddy per batch.

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