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The effect of drying techniques on the milling quality of Nigerian rice varieties

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Abstract

The study was carried out at Omasi a predominantly rice producing area in Anambra State of Nigeria. The objective of the study was to determine a suitable and sustainable drying method for small and medium scale farmer that will ensure optimum quality milled rice that will compare with imported ones. The studied 3 rice varieties BG 90-2; IR 1416; and ITA 222 were parboiled using the same method before sundried under three different methods until 14% moisture content (mc) was obtained. The first batch samples were rapidly dried to 14% mc and subsequently milled without tampering. The second batch samples were gradually dried to 14 % mc without tampering before milling. The third batch samples were gradually dried to 20 % mc, and collected in heaps under shade for 4 hours before gradually drying to 14 % mc, and stored for 3 days for tampering. A significant difference in milling recovery (MR) and breakage were recorded between the three batch samples, with low milling recovery and high percentages breakage in the first and second batch samples, with the first batch samples taking the lead in all the varieties studied. The third batch samples gave high percentage milling recovery and least broken rice kernel. The study revealed that the best milling quality was obtained by gradually drying to 14% mc and subsequently storing under shade for a minimum of 3 days before milling. Both varieties and methods of drying have significance effect on milling quality.

Keywords: Paddy rice, parboiling, sun-drying, milling recovery, moisture content, tampering.

Introduction:

Rice has become one of the most important crops in the world, now being consumed by more than 50 percent of the world's population. Traditionally, it has been the staple food and main source of income for millions of people all over the world, and will continue to be the main stay of future generations (IRRI, 1994). In Nigeria, it is a major staple food whose demand is constantly on the increase, averaging an annual growth in consumption rate of 7.7% from 2.8mmt in 1996 (WARDA, 1996). Moreover, inconsistent government policies on rice development have been a major factor in not achieving a developed viable rice programme in the country.

Thus, the realization that local production could not meet demand coupled with the global food crisis, made the Federal Government to take the short-term measure by massively importing rice into the country. However, meeting the rising demand for rice through increase local production should have been the best option instead of massive importation into the country Diof (2010) attributed the crisis in Africa to low investment culture in agriculture and urged government to formulate programmes aimed at improving food security. He recommended assisting farmers through improving their production and productivity by providing them with modern inputs. He further noted that the food crisis in which sub-Saharan Africa had been the worst hit ordinarily shouldn't have been witnessed in Nigeria as the country had the potential of providing enough food for the continent and beyond.

Notably, local farmers are increasing their farm sizes and consequently the amount of rice produced showed an upwards trend (Nwakpu, 2003; NBS 2007). However, regardless of this increase in local rice production, demand for foreign parboiled rice was still on the increase inspite of the efforts to stem the tide. This is so even when no scientific evidence has shown that Nigerian rice is less nutritious than the foreign varieties imported into the country.

Investigation carried out during the course of this study to seek explanation for poor patronage of locally produced rice revealed that locally parboiled rice are of poor quality compared with the imported ones due to lack of scientific processing method. At this period of world-wide growing trend of trade liberalization, poor grain quality inevitably poses a serious constraint to the production and marketing of rice anywhere in the world. This is due to the fact that at such a situation where free and open market economy operates, consumers are usually provided with alternatives and prices are determined by the forces of demand and supply. Consequently, the demand for poor quality grain are often low and prices offered by consumers mostly poor leading to low net returns. Luh (1979) noted that it is sufficient to say that no rice variety would make it commercially unless it possessed high whole kernel (head) yield which is the quantity of intact whole kernels of well milled rice that can be obtained from a given quantity of rough rice, while total milled rice yield include whole kernel (head) and all sizes of broken kernels obtained from a specific amount of rough rice.

The overall appearance of the processed rice kernel is extremely important in judging the quality of rice. Many factors constitute general appearance in rice. Some including grain variety, size, shape, uniformity, vitreousness, translucency, chalkiness, color, damaged and imperfect kernels are important contributors to general appearance.

The aims of drying parboiled rice are to reduce the moisture content to an optimum level for milling and subsequently storage, and to obtain the maximum milling yield. Drying also affects the texture and color of the final product.

The objective of this study is to determine the effect of different drying techniques on milling quality of local varieties of rice grown in Nigeria and find a drying method that would produce maximum milled rice yield acceptable to consumers and can favourably compete with imported ones. .

2. THEORITICAL BACKGROUND:

2.1 <u>Grain Drying</u>

Agricultural products are hygroscopic materials. They absorb moisture from or release moisture to the atmosphere depending on the temperature and the relative humidity (RH) of the surrounding air. Relative humidity is the ratio between the amount of water the air is carrying and the amount it could carry at the same temperature when fully saturated. The lower the RH of air at a given temperature the faster the rate of drying that can be done at that temperature. Moisture Content ***(mc)*** is an important quantitative factor of rice. The measure of ***mc*** can be expressed as a wet or a dry basis number. Wet basis measure specifies the quantity of water in a solid as a percentage of the total wet weight. Thus the percentage of ***mc*** wet basis (% ***MC*** wb) is

$$\% MC_{wb} = \frac{\text{Total Wet weight} - \text{dry weight}}{\text{Total wet weight}} \times \frac{100}{1} \quad \text{.... 1}$$

and the percentage of moisture content dry basis (% MC $_{db}$) is

$$\% MC_{wb} = \frac{\text{Total wet weight} - \text{dry weight}}{\text{Dry weight}} \times \frac{100}{1} \quad \text{.... 2}$$

At a given temperature there is a condition of grain moisture content (MC) and RH of the air when the moisture retaining tendency of the grain and the moisture withdrawal tendency of the air come into balance. The air and the grain are then said to be in equilibrium during which condition the grain no longer loses moisture to the air nor does it pick moisture from it. This ***MC*** of the grain is called Equilibrium Moisture Content (EMC) and the corresponding RH is called Equilibrium Relative Humidity (ERH). The EMC of the grain and its temperature on the one hand, and RH of the air, on the other hand, play a major role in drying grain.

An empirical relation for grain isotherm known as Henderson's equation which is also called relationship of equilibrium is presented below:

[illegible]

Where RH = equilibrium relative humidity of air decimal

T = Absolute temperature of air, degrees Kelvin

Me = Equilibrium moisture content of grain, on dry basis decimal

c = Grain Constant (degree Kelvin)

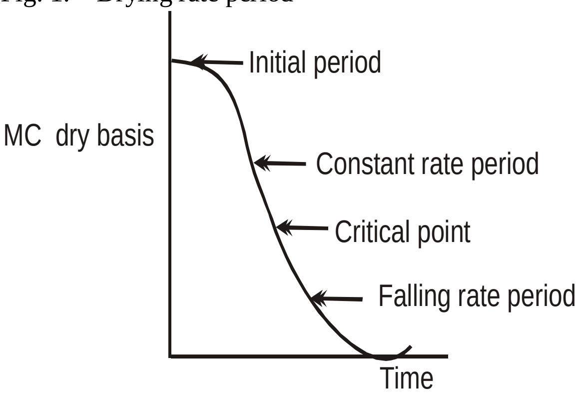
n = Grain Constant (Dimensionless)

Value of grain Constants c and n for paddy are 1.22 x 10^{-5} and 1.35 respectively.

Luh (1979) explained that the drying of a solid material involves the simultaneous processes of heat and mass transfer. During the drying of paddy rice, air is used to convey heat to the grain and take moisture away from it. Heat is required to evaporate moisture from the kernel. Mass transfer of water occurs within the kernel as well as on the grain surface.

Drying can be divided into 3 periods (Fig 1) initial, constant rate and falling rate. In the constant rate period the quantity of water removed per unit time per unit quantity of dry matter is constant. This pattern may occur in high moisture foods where the product surface will remain saturated with water. Luh (1979) noted that rice may exhibit a constant rate period if it is very wet at the onset of drying. Such conditions could prevail if rice is harvested after rain or heavy dew. In falling rate drying period the quantity of water removed per unit time per unit quantity of matter is not constant, reported Hall (1957)

Fig. 1. Drying rate period



The initial period, which is short and occurs at the start of drying, is a kind of warming time. The MC which marks the change from the constant rate to the falling rate period is generally referred to as the "Critical Point". Thus, drying of a rice kernel principally occurs in the falling rate period. Hall (1957) listed the following physical mechanisms as possibilities in controlling the transfer of moisture within agricultural products. Diffusion, (liquid or vapour), capillary action, shrinkage and vapour pressure gradient, gravity and vaporization of moisture.

In their studies, Yamazawa et.la. (1971) found capillarity to be the principal mechanism of moisture transfer between the hull and kernel during the initial stage of during. They also discovered that moisture was transferred by vapour diffusion through the gap between the hull and the kernel. It is generally accepted that moisture movement in a grain is a diffusion type process. Newton in his law of cooling in reference to thin layer drying behaviour of small grains stated that the rate of change of temperature of a body is proportional to the temperature difference between the body and surrounding medium. The analogy of drying to heat transfer is made by substituting a moisture content difference for a temperature difference. Thus, moisture instead of temperature would be the driving force.

The drying obtained from the Newton analogy would be:

[illegible]

Integration yields

[illegible]

Where

$$\frac{dm}{de} = \text{Drying Time}$$

M_o = Initial moisture content at time o (% dry basis)
M = Moisture Content at time t (% dry basis)
M_e = Equilibrium moisture content (% dry basis)
θ = Time (hr)
k = Drying rate constant (hr $^{-1}$)
K = Constant of integration

The drying equation (2) was used by Kachru et al. (1970) to analyze the thin layer of 4 varieties. They found a close relation between this equation and the drying rate of paddy. They also concluded that the drying rate constant (k) was a characteristic of paddy and not a function of the drying rate or grain moisture content. The effect of temperature in drying exposed grains may be seen as in fig. 2.

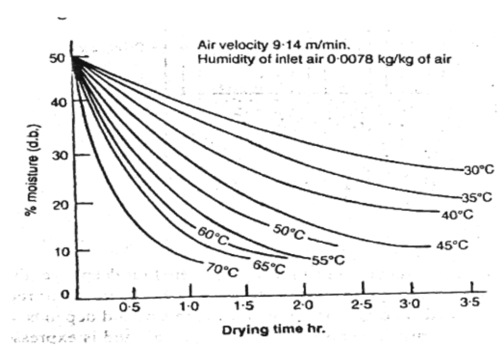


Fig. 2. The Effect of temperature in drying exposed grains. (Adapted from Ojha, 2009)

2.2 Rice Cracking

Rice cracking structurally weakens the kernel making it susceptible to breakage during milling and handling operations. The economic consequence of this are significant because the value of broken rice is much less than that of whole rice. It also reduces the viability of the seed rice and cracks which occur across the kernel, may reduce seedling vigor by decreasing endosperm availability.

The mechanism of rice racking has been studied by a number of researchers. Henderson (1954), in his studies with short grain rice concluded that cracking during fast drying was due to an increase in temperature rather then a decrease in moisture in portions near the surface of the kernel. He discovered that cracking could also be caused by a rapid increase in moisture which could occur in the filed if dew accumulated on the kernel. Kunze and Hall (1965) found that cracking occurred when brown rice, equilibrated at a particular humidity, was subjected to a high humidity environment. The degree of cracking was depending on the magnitude of change in relative humidity. They hypothesized that adsorptive fissures were caused when external cells expanded by adsorbing moisture and produced compressive stresses in surface layers. The internal parts of the kernel would resist these stresses and fail if the material tensile strength was exceeded. Rhind (1962) put forward that a change in the physical behaviour of rice starch occurs at 15% MC wb (Moisture Content at wet basis) and this change of state is a factor in the cracking phenomenon. MacDonald (1967) has suggested that a physical change within the rice kernel may also be a factor which contributes to rice cracking. He observed that cracks usually occur between the cell walls of the endosperm and rarely pass through them and hypothesized that it is not the cell walls which fail when overstressed but the gum holding the walls together. He further noted that the intercellular gums are somewhat plastic above 21% MC wb and become increasingly inelastic with lower moisture contents. Itoh et al. (1974) found that rice temperature at the exit of the drier was closely related to the number of checked kernels and recommended a 35^0C (95^0F) as a safe limit for rice temperature during drying. Henderson (1954) also advised that the following steps should be taken to minimize thermal strain to minimize cracking and achieve highest head yields: (a) harvest at a high moisture content, (b) dry at as low an air temperature as possible, and (c) use as many passes as convenient in multipass continuous flow drying The technique of drying parboiled paddy as a pre-milling process goes a long way to determining rice milling quality. This is because inadequate or excessive drying will result in enormous breakages at milling and thus reduce the percentage total rice recovery, and percentage head rice (Ojha, 2009). Paddy after parboiling contains about 35% moisture content (mc), therefore it is required that it should be dried to the milling moisture content of about 12-14% for milling (Nwakpu,2003; Ojha, 2009). It has been shown that drying rate of the parboiled paddy prior to milling has effect on the quality of the milled rice. If the paddy is dried slowly, the growth of microorganisms will be encouraged and spoil the parboiled paddy. On the other hand, if drying is done rapidly and continuously without allowance for tempering, cracks may result and there is the likelihood that breakage will occur during milling (Bhattacharaya, 1967). Martin, et al (1971) showed that rice paddy that was uniformly dried had lower incidence of milling breakages. The explanation was that when rice is rapidly dried, a steep moisture gradient develops between the surface and center of the kernel. This sets up a stress, and at a certain stage the kernel relieves the stress by cracking. These cracks are irreversible and setup lines of weakness along which fracture easily occurs under mechanical stresses of milling (Wodworth, 1990). For optimum result, (Ojha (2009) observed that the paddy should be dried in two phases. In the first phase, the moisture content of between 16-20% was realized, and they were then collected into heaps and covered for a period of 3-4 hours. Thereafter, the paddy was dried to a milling moisture content of 12-14%. Cooling is required before milling. In this condition, the grain becomes hard, wearing the desirable characteristic translucent, glazed shiny appearance (NCRI, 1994).

The objective of this paper is to determine the effect of these drying methods on the milling quality of local varieties of rice grown in Omasi rice field of Anambra state, Nigeria.

MATERIALS AND METHODS

The tests were performed under the prevailing farm conditions using the traditional sun drying method prevalent among the farmers. One hundred and fifty kilograms (150 kg) each of the three rice varieties produced in Omasi rice field viz: BG90-2, IR 1416, and ITA 222, was procured from the farmers at harvest. Each of the 150kg samples was divided into three batches of 50 kg each. Each batch was separately cleaned and parboiled under similar conditions, at a temperature of 70-75^{o}C. After attaining the temperature of 70-75^{o}C the source of heat was removed while the paddy was left in the water for a period of five hours (5hrs). This treatment was to gelatinize the polygonal starch granules of the endosperm, so as to reduce the breakage at the mill. It is this gelatinized starch that cements the grain segments caused by the fissures and cracks initiated in the grains at maturity. Time was taken to keep the temperature within 70 to 75^{o}C to avoid cooking the paddy (Nwankpa, 2003).The paddy was removed from the soaking tank and transferred to a parboiling drum containing water enough to cover the bottom of the tank up to the depth of about 4 cm. the top of the parboiling drum was covered with empty jute bags to trap the escaping steam and hence conserve and uniformly distribute the heat needed to perform parboiling process. This process was performed at a temperature of 100^{o}C for a period of 25 minutes. It is considered completed when a few grains at the upper layer were noticed to have split. At this point, the heat source was removed and the paddy quickly removed from the drum. Thereafter, cooling and drying of the parboiled paddy commenced.

MOISTURE MEASUREMENT

Moisture determination was made using standard oven method by placing the samples in a convective oven set at 103^{o}C for 72 hours. The sample was weighed until it has maintained a constant weight in two to three consecutive weighing. The final weight of the sample was subtracted from the initial weight of the sample and was expressed as a fraction of the initial weight in wet basis.

TEMPERATURE MEASUREMENT

The temperature was measured by mercury-in-glass thermometer calibrated in degrees Celsius (^{o}C).

The summary of the drying methods and milling conditions investigated in this study are presented in Tables 1 and 2 .

Table 1. The Summary of Pre-milling Drying Methods Investigated

Batch No.	Rice Variety	Method of Drying	Tempering period before milling. (days)
I	BG 90-2 IR 1416 ITA 222	Sun dried rapidly with regular turning to obtain even drying of the paddies until moisture content of 14% was attained.	No period of tempering was allowed as milling was done on the attainment of moisture content of 14%.
II	BG 90-2 IR 1416 ITA 222	Sun dried and turned regularly up to 20% M.C and subsequently gradually dried until moisture content of 14% was attained.	No period was given for tempering before milling.
III	BG 90-2 IR 1416 ITA 222	Sun dried gradually to moisture content of 20% and collected in heaps and covered under shade for 4 hours. Thereafter spread under a shade until moisture content of 14% was attained. Under this condition the samples became hard, translucent, glazed and, shiny in appearance.	All samples were collected and stored for 3 days to allow enough time for tempering before milling.

Table 2. Summary of the pre-milling factors and conditions

Batch No.	Rice variety	Quantity (kg)	Gelatinizing Temp.(^{o}C)	Soaking Period(hr)	Steaming Temp.(^{o}C)	Steaming Period (mins)
I	BG 90-2	40	70	5	100	25
	IR 1416	40	70	5	100	25
	ITA 222	40	70	5	100	25
II	BG 90-2	40	70	5	100	25
	IR 1416	40	70	5	100	25
	ITA 222	40	70	5	100	25
III	BG 90-2	40	70	5	100	25
	IR 1416	40	70	5	100	25
	ITA 222	40	70	5	100	25

Ajimuda Rice Huller with polisher (1-2 t/hr capacity) was used for milling the dried parboiled paddy. After milling, to determine the percentage milling recovery, percentage Head Rice and percentage Broken Rice, five samples were collected from each milled group. Average weights of the broken and unbroken grains were taken Batch by Batch as well as variety by variety and presented in Table 3.

Table 3. Properties of the Milled Rice under Prescribed Experimental Conditions

Bat. No.	Variety	Initial Weight of Paddy (kg)	Total Milling Recovery (kg)	Head Rice (Kg)	Broken Rice Kernel (kg)	Percentage Milling Recovery (%)	Percentage Head Rice (%)	Percentage Broken Rice Kernel (%)
I	BG 90-2 IR 1416 ITA 222	40 40 40	15.80 16.20 14.70	5.20 6.40 5.50	10.60 9.80 6.20	39.50 40.50 36.75	13.00 16.00 13.75	26.50 24.50 23.00
II	BG 90-2 IR 1416 ITA 222	40 40 40	19.70 20.10 18.80	15.40 16.20 14.30	4.30 3.90 4.50	49.25 50.25 47.00	38.50 40.50 35.75	10.75 9.75 11.25
III	BG 90-2 IR 1416 ITA 222	40 40 40	28.30 29.40 27.60	27.80 28.60 27.00	0.50 0.80 0.70	70.00 73.50 69.00	68.00 68.00 62.50	1.25 2.00 1.75

The following parameters were calculated using the experimental data and presented in Table 3: Total Milling Recovery (TMR), Percentage Milling Recovery (%MR), Percentage Head Rice (%HR) and Percentage Broken Rice (%BR).

The total milled rice recovered after milling a given quantity of rough rice is called the Total Milling Recovery (TMR). This is given in percentage as;

[illegible] …………

where

% TMR= percentage total milling recovery

MTRM= weight of total milled rice (kg)

IWP = initial weight of paddy

Head Rice (HR) is a term used to quantify the unbroken or whole rice kernels obtained after milling. It is calculated in percentage as follows;

[illegible] …………

where

% HR = percentage head rice

IWP = initial weight of paddy (kg)

WWMR= weight of whole kernel milled rice (kg)

The percentage broken rice (%BR) will then be equivalent to %BR = (%TMR-%HR) …(8)

where

% BR= percentage broken rise

% TMR= percentage total milled recovery

% HR= percentage head rice

RESULTS AND DISCUSSION

As can be seen from Table 3, ITA 222 variety had the least %MR; 69%, 47% and 36.75% for drying treatments III, II and I respectively. This was followed by BG 90-2; 70%, 49.75% and 39.5%, and IR 1416; 73.5%, 50.25% and 40.5% in the same order of treatment- III, II and I.

Equally, the %HR for ITA 222 variety were 62.5%, 35.75% and 13.75% for drying treatments III, II and I in that given order. IR 1416 yielded %HR of 68%, 40.5% and 16% for treatments III, II and I respectively. For BG 90-2, %HR were 68%, 38.5% and 13% for treatments III, II and I respectively. The %BR obtained for the varieties were as follows: ITA 222%; 1.75%, 11.25% and 23% for III, II and I drying treatments respectively, IR 1416; 2%, 9.75% and 24.5% for treatments III, II and I respectively, and BG 90-2; 1.25%, 10.75% and 26.5% for treatments III, II and I in that order. See Table 4 below:

Table 4: Percentage MR, HR and BR

Treatment No	Variety of Paddy	% MR	% HR	%BR
III	BG 90-2	70	68	1.25
	IR 1416	73	68	2
	ITA 222	69	62.5	1.75
II	BG 90-2	49.3	38.5	10.8
	IR 1416	50.3	40.5	9.8
	ITA 222	47	35.8	11.3
I	BG 90-2	39.5	13	26.5
	IR 1416	40.5	16	24.5
	ITA 222	36.8	13.8	23

For the variation of milling quality with drying method, treatment III gave the best milling recovery; 73.5% for IR 1416, 70% for BG 90-2 and 69% for ITA 222. Treatment II was next with %MR of 50.25% for IR 1416, 49.25% for BG 90-2 and 47% ITA 222. The least %MR was from treatment I; 40.5% for IR 1416, 39.5% for BG 90-2 and 36.75% for ITA 222. The %HR for treatment III was 68% for both IR1416 and BG 90-2 and 62.5% for ITA 222. Treatment I yielded %HR of 16% for IR 1416, 13.75% for ITA 222 and 13% for BG 90-2.

The %BR was least for treatment III, being 1.25% for BG 90-2, 1.75% for ITA 222 and 2 for IR 1416. This was followed by treatment II with 9.75 for IR 1416, 10.75% for BG 90-2 and 11.25% for ITA 222. The highest %BR was obtained in treatment I; 23% for ITA 222, 24.5% for IR 1416 and 26.5% for BG 90-2.

The results of this study showed that variety and method of drying have effect on the milling qualities of the studied samples as shown in Table 3.

The samples in Batch I which were rapidly dried to the milling moisture content of 14% had the lowest Total Milling Recovery and highest grain breakage.

Batch II where the samples were gradually dried yielded higher Total Milling Recovery than obtained in Batch I.

Batch III, where the samples were dried in two phases (stepwise process) gave highest milling quality with fewest breakages and high total Milling Recovery**

Conclusions

The result of the study showed that milling quality of rice paddy varied with both variety and drying method. Variety of paddy apparently made less impact on milling quality than drying methods did. Gradual drying with tempering was seen to yield best milling quality both in percentage Milling Recovery(%MR) and percentage Head Rice (%HR) and tremendously reduced percentage Broken Rice (%BR).

With these results, it is evident that for high quality milling, parboiled paddy should be dried gently and allowed to temper before milling. Moisture content of between 12 to 14% is recommended for milling. This should be achieved in two steps by first drying gradually to moisture content of 16 – 20% and then gradually to 12 – 14%. Tempering can be achieved by gathering the paddy in heaps under shade after the first phase of drying for 3 -4 hours, after which it is spread again under the sun for further drying to the desired moisture content of 12 – 14%. The so dried paddy should be cooled for 2-4 days before milling.

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