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Effect of Varying Parboiling Conditions on Physical Qualities of Jasmine 85 and Nerica 14 Rice Varieties

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ABSTRACT

As part of research towards enhancing the value chain of parboiled rice in Ghana, a study was conducted to ascertain the ideal parboiling condition that optimizes the physical qualities of rice. The study was carried out at the Spanish Laboratory of University for Development Studies, Tamale, Ghana. Two rice varieties (Nerica 14 and Jasmine 85) were parboiled in the Laboratory at four different conditions (soaking and steaming time combinations) to ascertain the effects of each parboiling condition on the physical qualities of the parboiled rice. A combination of four (4) soaking times (6, 20, 24, 36 h) and three (3) steaming levels (40, 60, 90 min) was used. Samples were also taken from conventional parboiling groups and used as check alongside the control samples. The parboiled rice were milled and physical properties such as milling yield, Head Rice Yield (HRY), colour, hardness, broken percentage, translucency and gelatinization temperature were evaluated. The results showed that parboiling at 20 to 24 h soaking with 60 min of steaming produced rice with best physical qualities except for colour i.e Milling yield was 80%, HRY was 60% and whiteness was 49%. The commercial samples gave values that were close to medium parboiling. Also ANOVA results showed that soaking and steaming time have direct impact on the final quality of parboiled rice. It was recommended for processors to soak paddy rice for 20 h in warm water between 30 to 40°C followed by steaming for 60 min at 80°C to maximize the physical qualities of parboiled Jasmine 85 and Nerica 14.

Key words: Parboiling, soaking, steaming, physical qualities, paddy rice

INTRODUCTION

The art of parboiling paddy rice is a post harvest processing technique that is widely practiced across the globe. This is a hydrothermal treatment process done on rice and other cereals using water and heat to bring about changes in the treated grains. It causes physico-chemical modifications in the grain, leading to favorable changes such as easier de-husking, higher head rice yield, increased resistance to insects, firm cooked rice texture, less solids losses etc. (Gariboldi, 1972; Bhattacharya, 1985; Pillaiyar, 1988). Bhattacharya (1969) established that cracks, chalkiness and incomplete grain filling are totally rectified and many of the previous defects are cured when paddy is properly parboiled. However, a common problem with the parboiling process, especially in high temperature and pressure operations, is darkening of the rice and its consequent effect on consumer acceptability according to Luh and Mickus (1991). In general, the parboiling processes are of three stages: (1) Soaking the cleaned paddy to a saturated moisture level, (2) Gelatinization of rice starch by adding heat to the moist kernels through steaming and (3) Drying the product to moisture content suitable for milling or storage.

In Ghana, parboiling of paddy rice is practiced mostly in the Volta and the three Northern regions. The production and consumption of the rice varieties, Jasmine 85 and Nerica 14 are on the high note in Ghana. Nerica 14 variety is noted for its red bran colour making it suitable for rice and cowpea meal popularly known as 'wakye' while Jasmine 85 variety has aromatic characteristics and other features that makes it attractive to consumers. Meanwhile the processes steps followed in parboiling paddy rice vary considerably among practitioners based on the locality and culture of the people concerned. Such variations in practices result in quality differences of the final product. This study was carried out to (1) Generate baseline information towards the standardization of paddy rice parboiling process in Ghana, (2) Develop and identify a parboiling level (soaking/steaming time combination) that gives optimal product quality in terms of physical characteristics and (3) Recommend a parboiling system that is cost efficient, effective and sustainable for the rural processors.

MATERIALS AND METHODS

Materials fabricated and parboiling set up: Containers were designed and fabricated to simulate the parboiling processes in the laboratory. They are a 205 m^3 cylindrical container with a lid made of aluminum sheets that could contain 6 kg of paddy during soaking. Three containers (steaming vessels) were also made each with a volume of 26.6 m^3 that can take at least 2 kg of paddy. Each vessel has a tripod stand and was perforated with holes all over the surface area. This was to allow the vessel stand upright during steaming process for effective vapour percolation. A large cooking pot measuring 2,651 m^3 used to house the three steaming vessels.

Laboratory parboiling methods: Six kilograms each of the rice varieties were weighed and soaked for 6, 20, 24 or 36 h on a thermostatic water-bath set at 40°C. After each soaking time the rice were taken out of the bath and excess water was drained off leaving the paddy ready for steaming. Two kilograms lots of the soaked paddies were weighed into the steaming vessel and covered with lids. The large cooking vessel was filled with water to one-quarter (1/4) of it volume and heated to boiling temperature (100°C). The steaming vessels containing the soaked paddy were then placed in the cooking vessel of boiling water such that the tripod stands of the steaming vessels made the rice to be above the boiling water. This ensured that steaming vapour percolated around the rice. At interval of 40, 60 and 90 min, a steaming vessel was removed from the cooking vessel and it content poured out to sun dry. This laboratory parboiling process was repeated twice on each rice variety. The two varieties were also processed by a commercial parboiling rice company (Lolandi Rice Processing Centre, Tamale) in their conventional parboiling processes that was used as a check. Control (non-parboiled) samples were also taken from each of the two varieties. All samples were dried, packaged in polyethylene sheets and appropriately labeled for milling.

Milling Process: The milling was done using a micro mill (Satake THU-35, Satake Corp., Hiroshima, Japan. Before milling, the samples were conditioned to equilibrium moisture content at approximately 15% on a moisture meter. One and half kilograms of each sample was milled separately, collected and labeled accordingly.

Analysis

Saturated moisture content: The saturation moisture level of each soaking period was determined by the method of the Association of Official Analytical Chemists' (AOAC, 1984) using the formulae:

$$\text{Moisture content (\%)} = \frac{\text{Weight of west sample} - \text{weight of dry sample}}{\text{Weight of wet sample}} \times 100$$

Husking/milling quality: The milling quality (husking efficiency or recovery percentage) was calculated according to the International Rice Research Institute method (IRRI, 2002) as:

$$\text{Milling quality (\%)} = \frac{\text{Grams of milled grains}}{\text{Paddy sample weight}} \times 100$$

Broken percentage: Broken grains are estimates of those kernels that are less than ¾ of their normal length after milling (dehusking). This was calculated by simply subtracting head yield rice from recovered:

$$\text{Milled rice as; broken (\%)} = \frac{\text{Weight of broken grains}}{\text{Weight of paddy sample}} \times 100$$

Head rice yield: Head rice yield is the weight percentage of head rice (excluding broken grains less ¾ of their length) obtained from a sample of paddy. The head rice yield was calculated using IRRI method (IRRI, 2002):

$$\text{HRY (\%)} = \frac{\text{Weight of whole grains}}{\text{Weight of sample sample}} \times 100$$

Colour: This was determined and scored on a scale of 10-100 according to (BNS, 2003) method as follows; 10-24% was considered ash-white; 25-44% was milk white; 45-64% was paper white; 65-80% was chalky white, 81-90% was clear white and 90-100% was polished white. Colour determination was repeated twice and the average value taken.

Level of gelatinization (Translucency): Translucency was determined by adopting and modifying the method (Cagampang *et al*., 1973) as follows; Firstly, women who are into commercial retail business of parboiled rice were made to visually examine and rank the samples according to the degree of gelatinization and give a score from 40-100%. Well gelatinized rice of highly translucency, giving glazier outlook was ranked 9-100%. Those samples with very few grains with opaque spot or dot on them were scored 70-80%. Samples with quiet few grains having single opaque spots on them were scored 60-69%. Those that have lot of kernels with common opaque spots or core belly were given a score of 45-59%. While those samples having several grains with no translucent spots on them at all were scored of 0-44% meaning poor gelatinization.

Maximum steaming temperature: Gelatinization temperature was taken by inserting a mercury-in-glass thermometer through a slit on the lid of the steaming containers into the center of the steamed parboiled rice. The temperature reading was taken at 40, 60 and 90 min of steaming.

This measurement was taken twice to get the maximum steaming temperatures for the different parboiling levels.

Grain hardness: This parameter was determined by the method of Fofana *et al.* (2011) but modified as follows. Hundred wholesome grains (kernels) were counted into a bottle crown cork and then placed under a screw press. One complete turn (360°) of the screw press was made to press on the 100 kernel applying a pressure of approximately 170 pa on the 100 kernels. The content was then poured out and counted the number of grains crushed and the extent to which it pulverize the kernels into fine particles, gave an indication of hardness level of the grains. This was repeated three times to obtain an average hardness score. Hardness was calculated as:

$$\text{Hardness (\%)} = \frac{\text{No. of grains exposed} - \text{No. of crushed}}{\text{Total No. of grains exposed}} \times 100$$

Statistical data analysis: The data obtained were analyzed using Analysis of Variance (ANOVA) of the software package SAS 9.2 at a 95% confidence level to determine significant variations among the various physical characteristics.

RESULTS

Saturated moisture content: The saturated moisture content ranges from 58-90% at the four different soaking levels. The longer the soaking time, the more moisture in the grain. However, the rate of increase in moisture content was sharp at the initial soaking periods (between 0-20 h) after which the rate decrease drastically and almost static from 24 h and beyond (Fig. 1).

Milling quality (husking efficiency/milling recovery), broken%, colour and translucency: The milling quality of rice samples from all the treatment range from 54.5 to 96.5% (Table 1). The results showed that, all 40 min steaming (s40) resulted in low husking efficiency (high No. of unmilled grains) relative to 60 or 90 min steamed rice with the control samples having

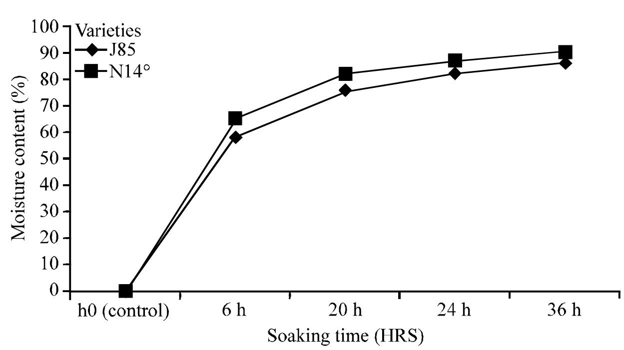

Fig. 1: Moisture content of J85 and N14 varieties at different soaking times

Table 1: Husking efficiency (milling quality), broken%, colour and level of gelatinization (translucency) as affected by variety, parboiling conditions

Variety	Soaking period (h)	Steaming period (min)	Hulling efficiency (%)	% Broken	Colour (%)	Level of gelatinization (Translucency) (%)
Jasmin 85	6	40	73.2±2.7^{c}	30.0±1.4^{a}	69.2±1.8^{c}	68.0±2.8^{d}
		60	76.0±3.3^{b}	28.5±2.1^{a}	71.1±1.3^{b}	68.0±2.8^{d}
		90	77.5±0.7^{b}	24.0±1.4^{b}	69.2±1.4^{c}	68.5±2.1^{d}
	20	40	76.0±1.4	28.2^{c}±4.2	58.1^{a}±2.8	73.0±2.8^{d}
		60	96.0±2.3^{a}	12.0±1.4^{c}	51.7±6.1^{d}	91.5±2.1^{a}
		90	95.5±1.2^{a}	13.5±1.4^{c}	56.7±1.9^{d}	91.5±0.7^{a}
	24	40	77.0±2.8	24.0±2.1^{c}	52.1±1.4^{d}	76.8±0.5^{d}
		60	95.5±1.4^{a}	12.5±1.4^{d}	51.4±1.1^{d}	94.3±1.3^{a}
		90	95.5±2.1^{a}	13.0±1.4^{d}	52.0±1.4^{d}	95.5±2.1^{a}
	36	40	75.5±2.1	21.5±2.1^{d}	48.9±2.1^{d}	90.6±0.8^{a}
		60	95.0±1.4^{a}	15.5±1.4^{d}	44.1±1.3^{f}	94.5±2.1^{a}
		90	94.5±2.1^{a}	15.0±2.1^{f}	45.1±0.0^{f}	93.5±1.4^{a}
	18-20(hi)	Si0	93.0±1.4^{a}	14.0±1.4^{d}	55.4±1.5^{d}	95.4±1.4^{a}
	Control	0	54.5±0.7^{f}	47.0±2.8^{a}	85.5±2.0^{a}	0.0±0.0^{h}
Nerica 14	6	40	70.5±0.7^{c}	27.5±2.1^{a}	75.9±1.9^{b}	69.0±1.4^{d}
		60	77.0±0.7^{c}	22.5±2.1^{b}	71.9±2.1^{b}	68.5±2.1^{d}
		90	81.0±1.4^{b}	24.0±2.8^{b}	72.0±1.4^{b}	74.5±0.7^{c}
	20	40	79.0±1.4^{d}	22.0±1.4^{b}	52.1±1.1^{d}	76.5±2.1^{c}
		60	96.7±1.4^{a}	09.5±2.1^{f}	49.4±2.1^{f}	86.0±1.4^{b}
		90	96.0±1.4^{a}	10.0±1.4^{d}	51.6±2.2^{d}	86.0±1.4^{b}
	24	40	75.5±2.1^{c}	21.0±2.8^{d}	43.6±1.6^{f}	82.5±3.5^{b}
		60	93.0±2.8^{a}	9.5±2.1^{d}	41.7±1.1^{f}	96.0±1.4^{a}
		90	96.0±1.4^{a}	10.5±0.7^{f}	43.2±1.7^{f}	96.5±2.1^{a}
	36	40	72.5±2.1^{c}	18.8±1.1^{c}	41.5±1.7^{f}	88.0±2.8^{b}
		60	94.5±2.1^{a}	12.0±2.1^{d}	42.2±2.5^{f}	94.5±2.1^{a}
		90	94.0±4.2^{a}	12.5±2.1^{d}	41.7±2.1^{f}	96.0±1.4^{a}
	18-20(hi)	Si0	92.5±2.1^{a}	10.5±1.0^{d}	51.4±1.0^{d}	95.5±2.1^{a}
	Control	0	62.0±2.8	45.5±1.5^{a}	89.3±1.1^{a}	0.0±0.0^{h}

Mean±SD from 2 replicates within a column having the same letter(s) are not significantly different at 5% level based on z-test significant differences test, 0: Control; 18-20(hi), Si0: Conventional parboiling by women used as check

the least in husking efficiency (54.5 and 62%) for Jasmine 85 and Nerica 14, respectively (Table 1). Milling quality (husking efficiency) showed significant difference ($p<0.05$) for the different soaking and steaming time combinations (Table 3).

Broken grains significantly decrease from 47% of control samples to 9.5% of parboiled rice (Table 1). Broken percentage showed significant difference ($p<0.05$) between varieties, variety/soaking, soaking/steaming, as well as varietal/soaking/steaming interactions as shown in Table 3. The values obtained for colour of the parboiled rice were statistically different at 5% significance level (Table 3). Results on colour revealed that longer parboiling gives poor colour especially Jasmine 85 (Table 1).

Level of gelatinization or translucency was significantly affected by the soaking/steaming combination treatments as shown on the ANOVA Table. When Jasmine 85 variety was soaked for 20 h and steamed for 60 or 90 min, it resulted in 91.5% gelatinization, while that of Nerica 14 gave 95% (Table 1).

Table 2: Gelatinization temperature, hardness and head rice yield for Jasmine 85 and Nerica 14 varieties as affected by the various parboiling conditions

Variety	Soaking period (h)	Steaming period (min.)	Maximum steaming temp (°C)	Hardness (%)	Head rice yield (%)
Jasmin 85	6	40	75.0±1.0^{7a}	50.6±2.0^{a}	70.5±2.2^{b}
		60	82.1±2.3^{a}	55.5±2.1^{a}	73.0±2.8^{b}
		90	80.4±2.2^{a}	57.0±1.4^{a}	75.5±4.9^{b}
	20	40	79.8±0.4^{a}	54.5±3.5^{a}	75.0±4.2^{b}
		60	83.0±2.2^{a}	62.5±3.5^{a}	88.5±3.5^{a}
		90	81.9±1.7^{a}	61.5±1.1^{b}	87.0±2.8^{b}
	24	40	81.0±1.7^{a}	60.0±2.0^{a}	80.0±2.1^{b}
		60	83.8±2.1^{a}	62.0±0.9^{b}	87.0±1.4^{b}
		90	79.2±0.9^{a}	61.4±0.7^{b}	86.5±2.1^{b}
	36	40	81.6±2.2^{a}	60.3±1.1^{b}	82.5±4.9^{b}
		60	81.1±1.6^{a}	60.5±1.5^{c}	83.0±2.1^{a}
		90	82.9±3.0^{a}	60.0±2.8^{c}	87.5±3.5^{b}
	18-20(hi)	Si0	82.9±2.6^{a}	59.6±2.0^{a}	85.5±0.7^{b}
	Control(h0)	0	0.0^{h}	45.0±2±1.4^{a}	50.0±1.4^{c}
Nerica 14	6	40	79.0±1.4^{a}	55.5±0.9^{a}	73.0±2.8^{b}
		60	77.5±3.5^{a}	60.6±0.6^{a}	75.5±1.4^{b}
		90	83.5±2.1^{a}	65.4±2.3^{a}	80.0±2.1^{b}
	20	40	78.8±2.5^{a}	60.2±2.5^{a}	75.0±4.2^{b}
		60	81.9±0.1^{a}	66.5±2.3^{a}	89.5±2.8^{b}
		90	82.3±2.5^{a}	65.0±1.8^{a}	87.0±1.4^{a}
	24	40	80.8±1.8^{a}	61.5±0.7^{a}	80.0±2.8^{b}
		60	83.3±2.5^{a}	63.0±1.4^{a}	88.0±2.1^{a}
		90	81.4±1.6^{a}	63.4±0.9^{a}	86.5±0.7^{a}
	36	40	80.0±2.1^{a}	61.5±1.9^{b}	81.5±3.5^{b}
		60	81.4±1.9^{a}	61.0±2.8^{b}	85.0±2.8^{a}
		90	83.8±1.8^{a}	60.5±2.1^{b}	84.5±2.1^{a}
	18-20(hi)	Si0	80.8±1.8^{a}	61.9±1.6^{a}	86.0±2.8^{b}
	Control(h0)	0	0.00^{h}	50.4±0.9^{b}	51.0±1.4^{c}

Mean±SD from 2 replicates within a column having the same letter(s) as superscript are not significantly different at 5% level based on z-significant differences test, 0: Control; 18-20(hi) Si0: Conventional parboiling by women used as check

Maximum steaming temperature, hardness, head rice yield: The mean values for gelatinization temperature, hardness and head rice yield of the different soaking and steaming time combinations are presented on Table 2 below. It can be seen that head rice yield of Jasmine 85 variety when straight milled (control) gave 50.5% which was significantly lower than 88.5% from parboiling condition "20 h soaking; 60 min steaming". And head rice yield for Nerica 14 ranges from 51 to 89.5% amongst all the treatments (Table 2). The trend at which head rice yield occurred in the parboiling conditions is shown in Figure 3 where it went low at 6 h soaking, then rose between 20 to 24 h soaking period but decline again at 36 h soaking time.

Maximum steaming temperature for all the treatment ranges between 75-83°C (Table 2) and did not vary so much (no significant difference) among the factors.

The various treatments and their interactions significantly affect the grain hardness as shown in Table 3. The percentage score on hardness ranges from 42.0-62.5% for Jasmine 85 and 52.4-66.5% for Nerica 14. The hardest grains came from parboiling condition of 20 to 24 h soaking, 60 min steaming (Table 2).

DISCUSSION

Physical qualities/attributes of parboiled rice: The physical characteristics of the two varieties were affected in several ways by the different soaking/steaming combinations as explained below.

Husking efficiency or milling yield: From this study there was high significant difference ($p<0.05$) in quality of milled rice or milling yield amongst the varied varieties/soaking/steaming time combinations (Table 3). The highest quality milled rice came from parboiling condition of 20 h and 24 h of soaking; 60 min steaming that gave significant high values of approximately 96-97% milling yield (Table 1). This might be as a result of the salvaging effect of good gelatinization attained at this level of parboiling. This is because the processes of parboiling improves the milling recovery of paddy rice as it salvages poor quality or spoiled paddy rice to meets the demand of consumers. The high quality of milled rice at this level of parboiling could also be traced to the husk been loosely attached to the kernel. This was because during the soaking stage, the kernels expand and fill the husk. Then at steaming stage the kernel gelatinized and retrograde becoming compact such that when dried it pulled away from husk. Milling thus becomes easier since the kernel is loose inside the husk. Figure 2 showed how husking efficiency increased and later decreased at the different soaking/steaming time combinations.

In this study, soaking for 36 h followed by 90 min steaming produced less recovered milled rice than 20 to 24 h soaking; 60 min steaming (Fig. 2). This could probably be due to over parboiling at 90 min steaming time which make the paddy get cooked. Paddy that were soaked for 6 h and

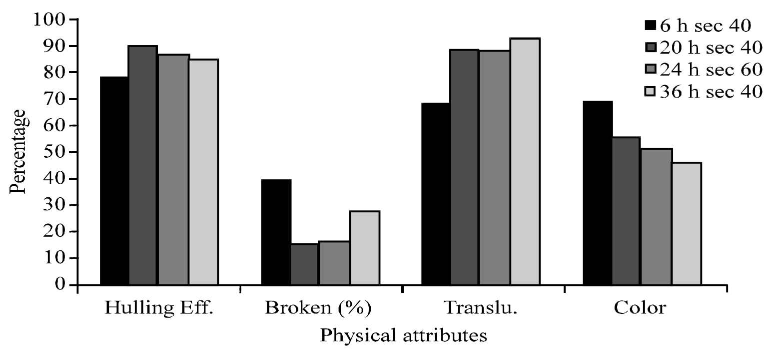

Fig. 2: Effect of soaking/steaming periods on husking efficiency, broken%, translucency and colour of J85 variety

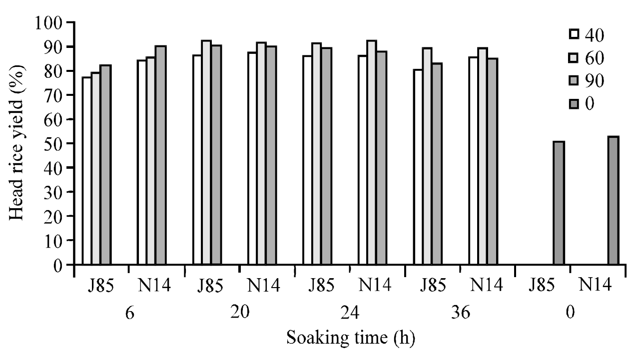

Fig. 3: Head rice yield of J85 and N14 as affected by different soaking/steaming time combinations

Table 3: Analysis of variance (ANOVA) of parboiled rice properties as affected by variety, parboiling conditions and variety/parboiling interactions

			Prob.> F						
Property	Overall mean	Error mean square	Variety	Soaking time	Steaming time	Variety/ Soaking	Var/ Steaming	Soaking/ Steaming	Variety /Soaking/ Steaming
Milling qlty (%)	84.00	33.17	0.731	<0.001*	<0.001*	0.297	0.998	0.009*	0.001*
Head rice Y. (%)	86.38	0.02*	0.002*	<0.001*	<0.001*	<0.001*	0.020*	<0.001*	<0.001*
Broken (%)	17.24	0.75	<0.001*	<0.001*	<0.001*	<0.001*	0.020*	<0.001*	0.020*
Colour (%)	56.34	0.23*	0.075	<0.001*	<0.001*	0.088	0.998	<0.001*	0.020*
Hardness (%)	58.79	3.91	<0.001*	0.065	<0.001*	0.048*	0.032*	0.002*	0.003*
Gelat. (Tran.) (%)	79.52	0.05	0.082	<0.001*	<0.001*	0.054	0.020*	<0.001*	<0.001*
Gelat Temp(°C)	75.31	0.02*	0.969	<0.001*	0.020*	0.842	0.342	0.030*	0.120

*Statistically significant

steamed for 40 min gave the lowest milling yield of 70% (Table 1), probably because of tight or intimate contact between the husk and the kernel that impeded against easy dehusking. The 6 h of soaking was not long enough for absorption of water to expand and push the hull away. The husk remained intimately attached to the kernel thus making de-husking difficult. This was evident from the control samples that had several of the paddy grains passing through the milling machine without been dehusked. In several instances, the machine forcefully de-husks the paddy thereby removing away the hull together with the germ (embryo) where nutrients are concentrated. This lowers the nutrient availability in such rice e.g straight milled rice. In some situations the kernels are broken or grounded into powder as the machine force to mill unloose husk in non-parboil paddy. The problem of unloose husk of non-parboiled rice is even worse for rural women who use mortar and pestle to pound their paddy rice for de-husking purposes.

Broken percentage: Broken grains are of great worry to processors especially the commercial processors because it lowers the market value of their product. Broken percentage was significantly affected ($p<0.05$) by all the treatments (Table 3). In this study, parboiling condition at 20 to 24 h soaking and 60 min steaming gave the least broken grains of 12% in Jasmine 85 and 9.5% in Nerica 14 according to Table 1. This means parboiling at this level optimize gelatinization thereby salvaging poor quality to a large extend. Because there are several factors such as cracks or fissures during harvesting and broken kernels that are been held together by the husk would be salvage after parboiling. When such rice are soaked and steamed at maximum temperatures, the chalky endosperms is melted to a gelatinous state and then re-unite to seal all cracks, fissures and broken edges. Also the low breakages at this 20 to 24 h soak; 60 min steaming could be that, the art of parboiling increases the tensile strength of kernels via starch gelatinization. This enables the kernels to resist shear force of machine parts applied to it during milling operations hence reducing the number of breakages. It is therefore not out of order to conclude that broken percentage of parboiled rice during milling process is a function of gelatinization level among others. Longer soaking time up to 36 h and steaming for 90 min gave moderate number of broken grains at approximately 15 and 11% for Jasmine 85 and Nerica 14 respectively (Table 1). The increase in broken percentage may be due to the presence of cooked grains that were crack-opened during the steaming process. On the other hand a lot of the over-parboiled grains can lose out much of the endosperm starch by means of dissolution and leaching leaving hollow grains. Such improperly filled grains would easily break when milled. The highest broken grains (30-35%) came from 6 h soaking; 40 min steaming as shown in Table 1. This high numbers of broken percentage is as a result of intimate contact between the husk and kernel since the soaking time meant to supply water to loosen the contact was too short (6 h). And since the steaming temperature was high at 80°C the little moisture quickly evaporate without gelling the starch grains. Thus breakages easily occur.

Colour: Discoloration of rice due to parboiling is another important quality parameter that negatively affects market value and consumer acceptability in most countries. The lightness value and colour of parboiled rice decreased significantly ($p<0.05$) as long as soaking/steaming time increases (Table 3). All samples steamed for 40 min showed a better colour value than 60 and 90 min steaming as depicted in Figure 2. This is possibly so because the short soaking time was not enough to activate enzymes that will influence the staining activities to discolour kernel as compared to longer soaking periods. Also, Bhattacharya (2004) and Lamberts *et al*. (2006) observed that parboiled rice turns light yellow to amber due to Maillard type of enzymatic browning. In this study, control samples gave the best white colour (85%) and light red (89%) for Jasmine 85 and Nerica 14 respectively (Table 1). This agreed with Parnsakhorn and Noomhorm, 2008) who stated that parboiled paddy gave lower whiteness as compared to straight-milled rice.

Level of gelatinization (Translucency): Apart from varietal differences, the remaining treatments (soaking/steaming times) significantly influences ($p<0.05$) the level of translucency attained (Table 3). The optimum gelatinization (translucency) was achieved at a parboiling condition of 20 h soaking, 60 min steaming at 80°C. This level of parboiling gave 96% level of gelatinization, a significant high value compared to "6 h soaking; 60 min steaming." with 68% gelatinization (Table 1). According to Marshall *et al*. (1993), the degree of starch gelatinization is responsible for many of the attributes of parboiled rice. Figure 2 shows the translucency level of all the soaking/steaming time combinations. The 20 to 24 h soaking enabled the paddy to absorb enough moisture needed to heat and transform the granular starch. Also, the heat supply of 80°C for 60 min was long enough to cause gelatinization and re-association of starch. This gave the glassier appearance upon cooling. Presumably, the few or absence of broken grains in properly parboiled rice are as a result of sealed cracks or fissures to form continuous mass of carbohydrates. Biswas and Juliano (1988) and Pillaiyar (1988) observed that when gelatinized, the granules no longer exhibit birefringence under polarized light and the orderly polyhedral structure of the compound granules changes into a coherent mass. Soaking beyond 20 and 24 h would increase the moisture content in the grain so much so that any little increase in steaming time beyond 60 min could cook the rice instead of steaming it.

Maximum steaming temperature: Maximum steaming temperature for all the treatment was not statistically significant ($p>00.05$) as shown in Table 3 above, though the duration of heat supply was varied at 40, 60 and 90 min. The temperature ranges between 75°C-83°C (Table 2). An annealing behaviour of the temperature was observed as it raised to peak, then it declines a little and stabilized at that temperature irrespective of the duration. This confirmed the finding that increased of onset gelatinization temperature in parboiled rice may be attributed to annealing effect because of soaking (Knutson, 1990; Nakazawa and Wang, 2003).

Head rice yield: The amount of gelatinized starch is an indicator of the severity of parboiling process and research in the past correlated this parameter with head rice yield. From Table 3, all the treatments showed highly significant effect (p = 0.001) on head rice yield. The 20 and 24 h soaking with 60 min steaming gave a significant high head rice yield of 88% than the rest (Table 2). Probably there was well gelatinization at that soaking/steaming time. The control samples gave the least head rice yield with 50%+1.4. Severe parboiling condition of 36 h soaking with 90 min steaming also produce more head rice yield than 6 h soaking; 40 min steaming but less than 20 and 24 h soaking; 60 min steamed. The reason why longer parboiling condition (36 h soaked; 90 min steamed) yielded less head rice than medium parboiling condition could be that, the husk of severe parboiling got ruptured and the kernels became cooked and leached out it content. If dried, such hollow kernels become shorter and some will easily break. This all can affect head rice yield. The head rice yield of these two varieties was low at 6 h soaking but rose between 20-24 h soaking time and decline again at 36 h soaking time. Therefore head rice yield from 60 min steamed rice (s60) stands tall followed by 90 min steamed rice (s90) and the least was 40 min steaming (s40) as shown in Figure 3 below. Head rice yield could be used to judge the nutritive value of parboiled-rice to an extent. This is because long whole kernels being the head rice yield, is as a result of the germ (embryo) not taken off with the husks during milling. These long kernels invariably have intact germ hence more nutrients in these kernels. Shorter kernels have lost the germ (embryo) with the husk during milling process and therefore have lost these vital nutrients (relatively less nutritive).

Grain hardness: The outcome of this study pointed out that rice parboiled at "20 or 24 h soaking; 60 min steaming" were harder with score values of 60.6% hardness in Jasmine 85 variety and 69.6% in Nerica 14 respectively (Table 2). This was so because the endosperm starch of parboiled rice kernel became compacted upon cooling. It might be the result of the molecular re-arrangement in the endosperm during the steaming stage. This is in agreement with the findings that increase in cooked rice hardness subsequent to parboiling has been mainly attributed to the re-association of gelatinized starch (Ali and Bhattacharya, 1980; Biswas and Juliano, 1988; Ong and Blanshard, 1995). Over parboiling or severe parboiling condition "say 36 h of soaking with 90 min of steaming" produced grains that are harder than short-parboiling condition i.e., 6 h soaking; 40 min steaming. Short-parboiling condition gave poor hardness because the grains have not gelatinizes to become compact. Grain hardness is a very important trait, especially when it comes to storage. Harder grains are more resistant to insect attack and less susceptible to the development of moulds. It reduces breakage during milling process which has a direct influence in the market value of the rice.

CONCLUSION

The outcome of this study showed that parboiling condition at 20 to 24 h soaking followed with 60 min steaming gave the best physical attributes. However, there was no significant difference in terms of physical qualities between rice produced from 20 h and 24 h soaking; all steamed for 60 or 90 min. The lowest (poor) physical qualities came from 40 min steaming irrespective of the soaking time. Severe or longer parboiling condition (36 h soaking; 60 or 90 min steaming) gave the same products quality level but were inferior to 20 and 24 h soaking with same steaming times. It is worth noting that 36 h soaking with 40 min of steaming gave good quality rice than

6 h soaking; 60 or 90 min steaming. It can therefore be concluded that the best parboiling condition is the medium parboiling condition i.e. 20 to 24 h soaking combined with 60 to 90 min steaming. Any parboiling time within this range would give optimum physical qualities of Jasmine 85 and Nerica 14.

RECOMMENDATIONS

For cost efficient production, a combination of 20 h soaking with 60 min steaming is recommended since this has the same product qualities as 24 h soaking; 90 min steaming. Thus the time and resources wasted in the extra 4 h of soaking from the 20-24th hour would be saved. Also, the extra resources and time wasted in steaming from the 60-90th min would be saved. However, processors who unavoidably soak for more than 20 h by attending to other equally important activities should not let the soaking time exceed 24 h long. Again, steaming time if unavoidably go beyond 60 min should never be allowed to go beyond 90 min since any soaking/steaming times beyond these periods will not only waste resources and increase cost of production but also affects the physical qualities of the rice negatively.

REFERENCES

AOAC, 1984. Official Method of Analysis. Association of Official Analytical Chemists, Washington, DC.

Ali, S.Z. and K.R. Bhattacharya, 1980. Pasting behavior of parboiled rice. J. Texture Stud., 11: 239-245.

BNS, 2003. Barbados national standard specification for rice. BNS 154: 2003, ICS 67.060, Barbados National Standards Institution, Barbados, pp: 1-24. http://www.teknikengel.gov.tr/docs/BRB6_EN.pdf

Bhattacharya, K.R., 1969. Breakage of rice during milling and effect of parboiling. Cereal Chem., 46: 478-485.

Bhattacharya, K.R., 1985. Parboiling of Rice. In: Rice: Chemistry and Technology, Juliano, B.O. (Ed.). American Association of Cereal Chemists, Saint Paul, Minnesota, pp: 289-348.

Bhattacharya, K.R., 2004. Parboiling of Rice. In: Rice Chemistry and Technology, Champagne, E.T. (Ed.). AACC Int., Saint Paul, Minnesota, ISBN-13: 978-1-891127-34-2, pp: 329-404.

Biswas, S.K. and B.O. Juliano, 1988. Laboratory parboiling procedures and properties of parboiled rice from varieties differing in starch properties. Cereal Chem., 65: 417-423.

Cagampang, G.B., C.M. Perez and B.O. Juliano, 1973. Agel consistency test for eating quality of rice. J. Sci. Food Agric., 24: 1589-1594.

Fofana, M., J. Wanvoeke, J. Manful, K. Futakuchi, P. Van Mele, E. Zossou and T.M.R. Bleoussi, 2011. Effect of improved parboiling methods on the physical and cooked grain characteristics of rice varieties in Benin. Int. Food Res. J., 18: 715-721.

Gariboldi, F., 1972. Parboiled Rice. In: Rice: Chemistry and Technology, Houston, D.F. (Ed.). AACC Int., Saint Paul, Minnesota, pp: 358-380.

IRRI, 2002. Measuring quality, physical properties of paddy. TropRice, International Rice Research Institute, Los Banos, Laguna, The Philippines, pp: 168-169, 201-203.

Knutson, C.A., 1990. Annealing of maize starches at elevated temperatures. Cereal Chem., 67: 376-384.

Lamberts, L., K. Brijs, R. Mohamed, N. Verhelst and J.A. Delcour, 2006. Impact of browning reactions and bran pigments on color of parboiled rice. J. Agric. Food Chem., 54: 9924-9929.

Luh, B.S. and R.R. Mickus, 1991. Parboiled Rice. In: Rice, Volume 2: Utilization, Luh, B.S. (Ed.). Van Nostrand Reinhold, New York, ISBN-13: 9780442004859, pp: 51-88.

Marshall, W.E., J.I. Wadsworth, L.R. Verma and L. Velupillai, 1993. Determining the degree of gelatinization in parboiled rice: Comparison of a subjective and an objective method. Cereal Chem., 70: 226-230.

Nakazawa, Y. and Y.J. Wang, 2003. Acid hydrolysis of native and annealed starches and branch-structure of their *Naegeli amylodextrins*. Carbohydr. Res., 338: 2871-2882.

Ong, M.H. and J.M.V. Blanshard, 1995. Texture determinants of cooked, parboiled rice. II: Physicochemical properties and leaching behaviour of rice. J. Cereal Sci., 21: 261-269.

Parnsakhorn, S. and A. Noomhorm, 2008. Changes in physicochemical properties of parboiled brown rice during heat treatment. Agric. Eng. Int.: CIGR E-J., Vol. 10.

Pillaiyar, P., 1988. Rice Post Production Manual. Wiley Eastern, New Delhi, India, pp: 167-229.