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Effect of Varying Parboiling Conditions on the Cooking and Eating/Sensory Characteristics of Jasmine 85 and Nerica 14 Rice Varieties

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ABSTRACT

Apart from the physical qualities such as hardness and “good head rice yield” usually associated with parboiling, the improvement or otherwise of cooking and eating/sensory characteristics of parboiled rice cannot be discounted. The extent to which these attributes are affected is paramount for consumers’ acceptability. The effect of varied parboiling conditions on the cooking and eating/sensory characteristics of Nerica 14 and Jasmine 85 rice varieties was assessed. The two varieties were parboiled at three levels as mild parboiling condition (6 h soaking; 40 min steaming), moderate parboiling condition (20 or 24 h soaking; 60 min steaming) and severe parboiling condition (36 h soaking; 90 min steaming). Milled rice from each parboiling condition was cooked and the attributes determined. After which the cooked rice was served to a trained panel of 9 who ate and sensory evaluated the rice. The functional differences in parboiled rice due to varied parboiling conditions were evident. Parboiling significantly affects ($p<0.05$) the cooking and eating/sensory characteristics of jasmine 85 and nerica 24. Medium parboiling condition (20 h soaking, 60 min steaming) gave the most acceptable cooking and eating/sensory characteristics as it gave good parametric values like water uptake rate of 2.5-2.8 mL g^{-1}, volum expansion rate of 6.5-6.6 cm^{-3} g^{-1} and taste score of 85.5-94.0%. At the same time it gave the least in negative parameter such as leached materials (4.0-4.3%) and stickiness level of 1.6-1.8%. Mediujm parboiling condition i.e., 20 h soaking, 60 min steaming is therefore rocommended for practitioners in the parboiling industry.

Key words: Parboiling condition, soaking hours, steaming time, jasmine 85, nerica 14

INTRODUCTION

Parboiling is a post harvest processing technique that affects the cooking and eating/sensory characteristics of rice. The extent to which this process is carried out determines the final quality of the rice and consequently consumer acceptability and marketability. The practice of parboiling done to certain cereals is aimed at causing physico-chemical change in the starch content in these cereals. The treatment is practiced in many parts of the world such as India, Bangladesh, Pakistan, Myanmar, Malaysia, Sri Lanka, Guinea, South Africa, Italy, Spain, Thailand, Switzerland, USA and France (Pillaiyar, 1981).

In Ghana for instance, parboiling is almost a custom done to paddy rice before milling especially at the rural setting. Ayamdoo *et al.* (2013a), found out that parboiling is an important practice to the rural folks in the area of food preparations, processing or preservation. And in the northern part of Ghana, especially in the Upper East region, not only rice that is parboiled but also millet, sorghum and Shea nuts. Rural women are been organized into groups supported by NGOs with funds to undertake paddy rice parboiling in commercial quantities as business entities. Rice is parboiled in Ghana mainly for the domestic market consumption. According to Ayamdoo *et al.* (2013b), the processes steps followed in parboiling paddy rice vary considerably among practitioners based on the locality and culture of the people concerned. Majority of these women are not aware of the simplicity and technicalities of parboiling (Diop *et al.*, 1997) and heat the paddy in a vessel, either after wetting with water or soaking for a few hour affecting the quality of the final product. In some cases, the paddy is boiled with excess water and then steamed (Behrens *et al.*, 2007). The difference in parboiling conditions should have different impact on the cooking/eating or sensory characteristics. The extent to which this affects the cooking and eating/sensory characteristics of Nerica 14 and Jasmine 85 is not yet known. As the most cultivated and preferred consumed varieties in Ghana, they were chosen for this study.

The two rice varieties were subjected to parboiling at different levels as mild parboiled rice (6 h soaking; 40 min steaming), medium parboiled rice (20-24 h soaking; 60 min steaming) and severe parboiled rice (36 h soaking; 90 min steaming). Afterwards the rice was cooked with no ingredients except salt and the cooking characteristics taken after which it's served to a panel of 9 who ate and sensory scored the features. Some of the cooked parameters looked for included cooking time, water uptake rate, volume expansion ratio and percentage soluble leached materials. Taste, stickiness and chewiness (softness) were also assessed. According to Chukwu and Oseh (2009) parboiling process and the resulting gelatinization of the starch have several beneficial effects including increased reduced stickiness of the cooked rice and the improved cooking behaviour of the parboiled rice. Cooked parboiled rice grains are significantly more intact and retain their natural shape as compared to non-parboiled rice and in some selected rice eating cultures of the world; this is viewed as a quality improvement over non-parboiled rice (FAO, 1998). Gayin *et al.* (2009), in their study evaluated the physical, pasting and sensory properties of six newly introduced rice varieties in Ghana, Jasmine 85 and Nerica 14 exclusive. They also did not take into consideration the influence of parboiling processes on the attributes studied. The consequences of parboiling on the behavior of rice on cooking and other end-user applications are important and therefore merit some thorough investigations. This work therefore aims to investigate the effect of parboiling processes on cooking and eating/sensory qualities of two main varieties grown in Ghana. The specific objectives are to (i) Find out the specific parboiling condition that maximizes the cooking and eating/sensory qualities of Jasmine 85 and Nerica 14 rice. (ii) Recommend appropriate parboiling condition that can add value to parboiled rice for high consumer acceptability and marketability.

MATERIALS AND METHODS

Samples preparations: The rice samples used for this study were foundation seed obtained from Rice Section of the Savanna Agricultural Research Institute of the Council for Scientific and Industrial Research (CSIR-SARI) at Nyankpala-Tamale, Ghana.

The parboiling process was done by first weighing 6 kg of cleaned paddy of Nerica 14 and Jasmine 85. A soaking container was filled with water to 1/3 of its length and placed on thermostatic water bath and heated to a temperature of 40°C. The cleaned paddy was steeped into the warm water and soaked for different time periods of 6, 20, 24 and 36 h. The water bath maintained the temperature of the content to ensure the paddy was soaked in warm water through the required period. After which the paddy was drained off the excess water and it is ready for steaming.

The moist paddy from each soaking period was divided into 2 kg each and poured onto three steaming containers and covered with lids. The lids of each steaming containers has a small opening at which a mercury-in-glass thermometer was inserted to take readings of gelatinization temperatures. A large cooking vessel that could house the three steaming containers was then filled with water to one-quarter (1/4) of it volume and boiled till 100°C. The three steaming containers with the moist paddy were placed onto the boiling water of the cooking vessel. Jute sacks were used to cover the content before the lid of the cooking vessel was put on. The content was steamed to a temperature of 80°C. After a period of 40 min, one container was removed and it content poured out to dry. Then at 60 min time the second container was removed and the last one taken out at 90 min time. The steamed paddy was dried under sun to prevent moldy conditions. The steaming temperature was read on the thermometer at the point of removing each paddy sample from the steaming vessel as the required time elapsed. The same procedure was followed for paddy soaked at 6, 20, 24 and 36 h for the two varieties. All samples were dried to equilibrium moisture content of 14+1%, before milling and the milled rice used to determine the cooking and eating/sensory characteristics.

Statistical analysis: The data was subjected to Analysis of Variance (ANOVA) to determine if they were statistically significant differences ($p<0.05$) in each attribute using the Z-significant score test.

Time taken to cook: The relative time taken to cook of each variety was determined as follows: 500 mL of fresh clean water was boiled in separate pots to 100°C. The various samples were weighed 400 g and put onto each boiling pot and cooked. After 5 min and subsequently at 2 min interval a few grains are removed and mashed between the thumb and finger to see if cooked. When properly cooked, would easily be mashed between thumb and finger. Time taken for each sample to get cooked was recorded. This was replicated twice and the average taken as the cooking time for each sample.

Water uptake ratio: Water uptake or absorption rate is the increase in volume (w/w) of the kernels after cooking. Five hundred milliliter of clean water was used to start the cooking of 400 g of each sample. The cooking pots were lined with mesh wire such that when the mesh wire is taken out; all cooked grains can be collected from it. Whenever the water in any pot drained off, a plastic bottle of clean water was quizzed to add 2 mL of water to the cooking rice. This was done till the rice got cooked and can no longer absorb more water. Excess water is drained off and the final weight was taken. The difference in weight is the ratio of water absorbed by the rice which was expressed according to Abulude (2004) as:

$$\text{Water uptake (\%)} = \frac{\text{Weight of cooked rice-Weight of raw rice}}{\text{Weight of raw rice}} \times 100$$

Volumetric expansion: Volume expansion is the increase in mass (v/v) of the cooked grains. An initial weight of 400 g of rice was measured into a graduated cylinder and the volume noted. After cooking the rice was transferred onto the same cylinder and the increase in volume recorded. This was repeated twice and the average value was determined by the following interppretation:

$$\text{Vol. expansion (\%)} = \frac{V_2 - V_1}{V_1} \times 100$$

where, V_1 = Initial volume and V_2 = Final volume

Leached materials: This is the amount of solutes dislodged from the kernels onto the boiling water during cooking process. The method of Sareepuang *et al*. (2008) was modified by taking 400 g of rice and cooked in 600 mL of water so that not all can be absorbed by the rice. The excess water was drained from the cooked rice and then used to assess the level of leached materials. The turbidity of the broth (drained water) was determined. Where the cooked rice leached more solutes onto the cooking water, it looks thick and creamy (more turbid). Less leached materials will give light and somewhat clear liquid (less turbid). This was scored on a scale as; 1-3 being little or minimal leaked materials, 4-5 as moderate leaching, 6-7 as highly leached materials. This was repeated twice and the average value determined and recorded as percentage leached materials.

Sensory evaluation: Sensory profiling or descriptive analysis methods consist of formal procedures for assessing, in a reproducible manner, specific attributes of a sample and rating intensity on a suitable scale. These methods can be used for evaluating aroma, flavor, appearance and texture, separately or in combination (ISO, 1994). As such, descriptive sensory profiling is the most sophisticated sensory tool available to the sensory professional (Stone and Sidel, 1993). Results from descriptive analysis provide a complete sensory description of an array of products and can provide a basis for distinguishing those sensory attributes that are important for acceptance by consumers (Stone and Sidel, 1993). Parameters that were sensorial evaluated are taste, chewiness (softness), stickiness and adhesiveness/cohesiveness.

Taste evaluation: The cooked samples had no ingredient added, except salt. A panel of 9 members were made to taste the cooked sample and score the taste characteristics of each treatment on a scale of 10-100%. The scale was; no taste 40-49%, somehow tasty-50-69%, tasty: 70-89% and very tasty: 90-100%. All samples were test permutated. That is those samples that scored tasty and very tasty were compared again to get the tastiest sample. Then all samples that pass the test within treatment level (intra treatments) were compared to other treatments (inter treatment) to get the best one out. At the end, all parameters tested were related to the parboiling condition in order to identify the best soaking/steaming combination.

Chewiness/softness: Chewiness (softness) is the relative ease at which the cooked grains are mashed between the lower and upper jaws when chewed. Sitakalin and Meullenet (2000), method was modified to get chewiness/softness of the rice samples. Cooked rice was served to the panel of 9. They each chewed and ranked the various samples from soft to hard in terms of chewiness and these were scored on a scale of 1-4. The scores were 1.0-2.0 as very hard to chew; 2.1-2.9 as moderate hard; 3.0-3.5 as soft and 3.6-4.0 as very soft to chew.

Stickiness: Cooked rice stickiness is the ability of the rice starch to stick to and hold the upper and a lower jaw as it is mashed during chewing (property of elasticity). Stickiness was determined by the 9 trained panel members that chewed the cooked rice and gave their impression about how the elastic property of the mashed starch holds their upper and lower jaws together. No stickiness attraction scored between 1-1.4, little/minimal stickiness scored 1.5-2.4, moderate attraction scored from 2.5-3.9 and very strong attraction was scored 4-5 and. This was repeated twice and the mean stickiness values determined.

Adhesiveness and cohesiveness: The adhesiveness and cohesiveness of the rice were determined by looking at the lumpiness' of the individual grains when cooked. Rice that produced thick-mucus after cooking have its individual grains adhering to each other in lumps and stack to object they come into contact. A test to assess the extent to which cooked kernels cling together forming lumps as well as clog to surfaces of ladle was performed by fetching the cooked rice and poured onto a plate and the plate toasted twice. The extent to which the cooked grains fell out and separate into individual grains on the plate was noted. A score of 10-20% meaning little or no cohesiveness/adhesiveness was given to grains that will separate into lumps constituting 2-3 grains. Such rice will fell out without sticking to the ladle. Those that have moderate adhesiveness and cohesiveness were rice that had 5-10 grains forming lumps and these were scored 21-30%. Next was rice that had sufficient adhesiveness and cohesiveness with lumps constituting up to 11-20 grains stack together and these was scored 31-40%. A score of 40% are the highly adhesive/cohesive rice such that more than 20 kernels could stuck together in a lump.

RESULTS

Cooking time: The soaking time, soaking/variety and variety/steaming interactions did not have any significant effect ($p>0.05$) on cooking time. However, steaming time, steaming/soaking interactions and varietal differences showed significant effects ($p<0.05$) on cooking time (Table 1). The cooking periods for the different levels of parboiled rice ranges from 14.0 to 20.5 min (Table 2). Amongst the Nerica 14 samples, all 40 min steamed rice have the shortest cooking time of 17 min except control samples of 16 min cooking time. When soaked for 20 and 24 h and steamed for 60 min, it took longer time (20.5 and 20 min), respectively to cook. For 90 min steamed rice of 20 or 24 h soaking, cooking time reduced to 19 and 19.5 min, respectively for Jasmine 85 and Nerica 14. All samples of Nerica 14 variety took more time to cook than Jasmine 85. For example, 36 h soaked; with 90 min steamed of Jasmine 85 took 14.5 min to cook while that of Nerica 14 samples took 16 min. Thus cooking time significantly decrease from 20.5 to 14.5 min as parboiling time increases from 6 h; 40 min to 36 h; 90 min (Table 2).

Table 1: Analysis of variance (ANOVA) on attributes/properties of parboiled rice as affected by different parboiling conditions

			Prob.>F						
Property	Overall mean	Error mean Square	Variety	Soaking time	Steaming time	Variety/ soaking	Variety/ steaming	Soaking/ Steaming	Variety/ Soaking/steaming
Cooking time (%)	16.28	4.180	0.345	0.055	0.012*	0.902	0.826	0.001*	0.020*
Water uptake (%)	2.28	0.004	0.001*	0.001*	0.001*	0.001*	0.792	0.020*	0.025
Vol. Expan. (%)	5.53	0.350	0.178	0.037*	0.001*	0.482	0.896	0.001*	0.001*
Taste (%)	80.76	5.160	0.001*	0.001*	0.001*	0.001*	0.001*	0.001*	0.002*
Chew/Soft (%)	23.29	30.000	0.021*	0.030*	0.010*	0.002*	0.001*	0.001*	0.010*
Stickiness (%)	2.26	2.080	0.024*	0.446	0.755	0.915	0.962	0.901	0.030*
Adhes/Coh. (%)	29.38	53.600	0.300	0.001*	0.001*	0.001*	0.407	0.001*	0.024*
Leached Mat (%)	5.10	0.170	0.809	0.001*	0.001*	0.088	0.976	0.021*	0.001*

*Statistically significant

Table 2: Cooking characteristics as affected by variety, parboiling conditions and variety/parboiling interactions

Variety	Soaking period (h)	Steaming period (min)	Cooking time (min)	Water uptake ratio (mL g^{-1})	Volumetric expansion (cm^3 g^{-1})	Leached materials (%)
Jasmine 85	6	40	15.5±0.7^a	1.8±0.3^c	5.2±0.3^b	5.4±0.1^b
		60	18.0±1.4^a	2.3±0.1^a	6.0±0.1^a	5.1±0.2^b
		90	18.0±2.3^b	2.4±0.3^a	6.1±0.1^a	5.4±0.6^b
	20	40	15.7±2.5^b	2.1±0.3^b	5.5±0.4^b	4.2±0.4^d
		60	20.4±1.9^b	2.5±0.4^a	6.5±0.1^a	4.3±1.0^d
		90	19.0±2.2^b	2.4±0.6^b	6.5±0.4^a	4.7±0.8^b
	24	40	16.5±1.9^b	2.1±0.1^b	5.6±0.5^c	5.2±0.4^b
		60	20.0±0.8^b	2.5±0.1^a	6.5±0.6^a	4.4±1.0^d
		90	19.5±1.0^b	2.5±0.1^a	6.3±1.1^a	5.1±0.9^b
	36	40	15.1±0.2^b	1.9±0.3^c	5.6±0.4^b	5.1±0.3^b
		60	15.0±0.2^b	2.5±0.3^a	6.0±1.1^b	5.4±0.2^b
		90	14.5±1.2^c	2.4±0.1^b	5.8±0.4^a	5.7±0.8^a
	18-20 (hi)	Si	18.0±1.3^b	2.3±0.1^b	5.5±0.2^b	5.2±0.1^b
	Control (h0)	0	15.5±1.9^a	1.5±0.2^c	4.5±0.1^c	6.2±0.1^a
Nerica 14	6	40	18.0±0.8^a	1.9±0.1^c	5.4±0.8^b	5.4±0.2^b
		60	18.6±2.2^a	2.5±0.0^a	5.8±0.9^a	5.0±0.1^b
		90	17.0±0.9^b	2.7±0.2^a	6.3±0.4^a	4.8±0.5^c
	20	40	18.9±0.2^b	2.3±0.6^b	5.2±0.7^b	4.6±0.6^c
		60	20.5±0.4^b	2.8±0.3^a	6.5±0.4^a	4.0±1.3^d
		90	19.4±0.8^c	2.5±0.2^a	6.6±0.5^a	5.0±0.4^b
	24	40	17.2±0.1^b	2.0±0.4^b	5.5±0.3^b	4.6±0.1^c
		60	20.0±2.2^b	2.7±0.3^a	6.5±0.5^b	5.4±0.4^b
		90	19.5±0.8^b	2.6±0.2^a	6.2±0.4^a	5.5±0.3^a
	36	40	17.0±0.3^b	1.9±0.3^c	5.6±0.2^b	5.1±0.6^b
		60	16.5±0.1^c	2.5±0.4^a	6.2±1.0^a	5.6±1.0^a
		90	16.2±0.1^c	2.2±0.1^b	6.0±0.5^a	5.9±0.9^a
	18-20 (hi)	Si	19.7±1.6^b	2.2±0.3^b	6.3±0.2^a	5.1±0.1^b
	Control (h0)	0	16.0±1.0^a	1.7±0.2^c	5.0±0.1^b	6.0±0.8^a

Mean±Standard deviations of 2 replicates. Within a column having the same superscript letters are not significantly different at 5% based on z-score test, 0: Control, h0: No hour, 18-20 (hi Si): Conventional parboiling by women used as check, hrs: hours, min: Minutes

Water uptake rate: The results on ANOVA table indicated there are significant differences in water uptake for both first and second order interactions levels of the treatments. Water uptake ratios of well parboiled rice were higher than the mild parboiled ones and non-parboiled rice as well. For instance, when Nerica 14 and Jasmine 85 rice were soaked for 20 or 24 h and steamed for 60 or 90 min and cooked, the highest water uptake rate was 2.5 and 2.8% respectively. But that of 6 h soaking with 40 min steaming, the water uptake was 1.8% in Jasmine 85 and 1.9% in Nerica 14. The control samples gave water uptake rates of 1.5-1.7%, respectively for Jasmine 85 and Nerica 14 (Table 2).

Volume expansion ratio: Volume expansion followed the same patterns as water uptake ratio from this study. For example, 20 and 24 h soaking with 60 or 90 min steaming, showed a significant high water uptake and this corresponded to a high volume expansion rate from 6.0 and 6.5 cm^3 g^{-1}, respectively. The mild steamed samples (40 min steaming) gave a less volume expansion rate of 5.4 $cm^3\ g^{-1}$ whereas the control samples had the least volume expansion rate of 4.4 $cm^3\ g^{-1}$ (Table 2). However, beyond a certain point, the level of expansion decreases with increasing parboiling levels.

Thus the severe parboiling (36 h soaking with 90 min steaming) gave less expansion volume of 5.8-6.0 $cm^3\ g^{-1}$) than values obtained from medium parboiled rice (20 and 24 h soaking; 60 min steaming) (Table 2). Therefore steaming time, variety/soaking/steaming interactions have a significant impact on the volume expansion of parboiled rice when cooked. Varietal differences and soaking time however do not influences significantly volume expansion of cooked parboiled rice.

Percentage leached material: Analysis for leached materials from the samples showed that soaking/steaming periods and their interplay have a significant influence ($p<0.05$) on amount of leached materials during cooking process of parboiled rice. For example, 36 h soaking with 90 min steaming gave rice that have significant high leached materials of 5.9% as compared to 20 and 24 h soaking; 60 min steamed samples of 4.2 and 4.7% leakage respectively. Leached materials from 6 h soaking; 40 min steaming was 5%. Control samples were worst (6.2%) of leached materials (Table 2).

Chewiness (softness): Chewiness/softness (how easy the cooked grains are to bite through) was found to be affected significantly by the different treatments. Softness score ranges from 2.3 to 4.0% (Table 3). The results however showed that well gelatinized rice is hard to chew than the less gelatinized once. Medium parboiled rice (20 and 24 h soaking with 60 min steaming) resulted in rice that was difficult to chew (2.3%) compared to mild parboiled rice (6 h soaked; 40 min steamed) with softness score of 3.6%. Interestingly those hard to chew rice was the well gelatinized rice without core spots of non-gelatinize starch. The control rice was softer (4.0 and 3.8%) for both Jasmine 85 and Nerica 14, respectively. A clear picture of this is shown on Fig. 3 below as chewiness for the control and the mild steamed rice (40 min) gave taller bars than the proper steaming of 60 and 90 min with well gelatinized rice. The conventional parboiled samples also gave almost same level of softness as those steamed 60 min at the laboratory.

Stickiness: The results indicated that 60-90 min steaming that gelatinize the starch very well gave less stickiness (1.7%) when cooked compared to that of 40 min steamed rice which gave 2.7% stickiness. Non- parboiled rice (control) has a significantly higher stickiness value of 2.9%. The second order interaction (variety/soaking/steaming interactions) for stickiness showed significant difference ($p<0.05$) amongst treatments according to Table 1. The level of stickiness decreases as steaming time increases resulting in well gelatinized starch but where paddy is saturated with moisture and steaming is too long stickiness increases again (Table 3).

Adhesiveness and cohesiveness: Adhesiveness and cohesiveness of the parboiled rice showed significant difference ($p<0.05$) at both first and second order interactions except variety-steaming interaction (Table 1). The adhesive and cohesive attraction of less parboiled (6 h soaking; 40 min steam) was up to 40%. Soaking for 20 or 24 h, followed by 60 and 90 min steaming gave 25% adhesiveness and cohesiveness while that of control samples was 53%, a significant higher value than all the rest (Table 3).

Taste: Taste score was statistically different ($p<0.05$) between variety, soaking, steaming as well as the interactions among these factors as shown in Table 1. The taste of Jasmine 85 from the

Table 3: Sensory evaluation of the rice samples as affected by variety parboiling conditions and variety/parboiling interactions

Variety	Soaking period (h)	Steaming period (min)	Taste (%)	Chewiness (softness) (%)	Stickiness (%)	Cohesiveness/Adhesiveness (%)
Jasmin 85	6	40	53.5±1.8^{a}	3.6±0.6^{b}	2.7±0.3^{a}	35.0±2.9^{b}
		60	76.8±0.9^{c}	3.0±0.9^{c}	2.5±0.4^{a}	23.4±2.3^{d}
		90	75.5±1.7^{c}	2.5±0.8^{a}	2.2±0.6^{a}	24.4±0.8^{d}
	20	40	63.0±3.5^{d}	2.4±0.5^{b}	2.4±0.4^{b}	24.1±1.6^{d}
		60	85.5±2.1^{b}	2.5±1.1^{a}	1.8±0.2^{b}	22.2±3.1^{d}
		90	80.9±0.9^{b}	2.6±1.2^{a}	2.0±0.1^{b}	26.0±1.6^{d}
	24	40	71.5±0.7^{c}	2.5±0.8^{a}	2.1±0.4^{c}	26.5±3.7^{d}
		60	84.5±1.1^{b}	2.3±1.2^{b}	1.7±0.6^{c}	22.0±0.1^{d}
		90	81.6±2.1^{c}	2.5±1.2^{c}	2.1±0.4^{b}	33.0±3.0^{c}
	36	40	66.3±1.8^{d}	2.4±0.8^{c}	1.9±0.5^{c}	30.0±1.7^{c}
		60	77.0±1.6^{c}	2.6±1.3^{a}	2.4±0.8^{c}	34.5±1.3^{c}
		90	74.0±2.8^{c}	3.5±1.6^{b}	2.8±0.6^{b}	40.0±1.8^{c}
	18-20 (hi)	Si	82.0±0.7^{b}	2.4±1.1^{a}	2.2±0.8^{b}	25.9±2.8^{d}
	Control	0	50.8±0.7^{c}	4.0±1.3^{b}	2.9±0.3^{a}	53.0±3.1^{a}
Nerica 14	6	40	68.5±1.4^{b}	3.5±0.1^{c}	2.5±0.6^{a}	33.5±1.9^{b}
		60	78.0±2.1^{b}	2.6±0.9^{a}	2.4±0.8^{a}	23.0±1.7^{d}
		90	78.5±4.2^{b}	2.3±1.2^{c}	2.3±0.8^{a}	25.5±0.6^{d}
	20	40	88.0±1.4^{b}	2.4±0.5^{a}	2.5±0.4^{b}	26.4±0.8^{d}
		60	94.0±1.4^{a}	2.4±1.1^{b}	1.9±1.0^{b}	21.5±1.1^{d}
		90	94.0±2.8^{a}	2.5±1.3^{b}	1.8±1.2^{b}	22.3±2.4^{d}
	24	40	90.0±3.5^{a}	2.4±0.8^{b}	2.1±1.3^{c}	28.5±2.2^{d}
		60	92.5±1.4^{a}	2.5±1.5^{a}	2.0±1.2^{b}	23.9±1.8^{d}
		90	92.0±2.1^{a}	2.5±1.6^{a}	2.4±0.9^{b}	29.8±1.7^{c}
	36	40	91.5±0.7^{a}	2.4±0.9^{c}	2.2±1.0^{b}	23.2±1.1^{d}
		60	91.5±1.4^{a}	2.5±1.3^{b}	2.7±1.4^{b}	27.0±1.4^{d}
		90	90.0±0.7^{a}	3.4±1.5^{c}	2.9±1.1^{a}	41.5±2.1^{c}
	18-20 (hi)	Si	90.5±1.8^{a}	2.3±1.0^{c}	2.3±0.8^{b}	23.5±2.1^{d}
	Control	0	51.8±1.3^{c}	3.8±0.8^{a}	2.9±0.6^{a}	47.5±3.5^{d}

Means±Standard deviations of 2 replicates, values within columns having the same superscript letters are not significantly different at 5% based on Z-score test, 0: Control, h0: No hour, 18-20 (hi Si): Conventional parboiling by women used as check, hrs: hours, min: Minutes

different parboiling levels range from 53.5 to 85.5% while that of Nerica 14 was 68.5 to 94% (Table 3). Soaking for 20 and 24 h combined with 60 or 90 min steaming gave a significant high taste score of 81.6 to 85.5% as against 6 or 36 h soaking that yielded rice with taste 74 or 83%, respectively in Jasmine 85 variety. In the case of Nerica 14 samples, the taste scores when parboiled at 20 and 24 h soaking; 60 and 90 min steaming, was 94 and 92.5%, respectively. This was significantly higher than 36 h soaking; 90 min steaming of 90% taste. Six hours soaking produced rice with less taste than 36 h soaking and 36 h soaking also gave rice with less taste than 20 and 24 h soaking at the various levels of steaming (Table 3). Control samples were the least taste (50.8%) for Jasmine 85 and 51.8% for Nerica 14 (Table 3).

DISCUSSION

Cooking time: The differences in cooking time came as a result of the degree of gelatinization attained by the rice. The results from this experiment showed that cooking time increased as gelatinization increases. Thus, well-parboiled rice took more time to cook than the less parboiled rice. In this study, the well-parboiled rice came from 20 and 24 h soaks combined with 60 min steaming and this rice took the longest time (21 min) to cook. This confirms Parnsakhorn and Noomhorm (2008) findings that parboiling process resulted in higher cooking time. However, severe parboiling that is, rice soaked for longer period of 36 h followed by 90 min steaming took less time of 19 min to cook. It therefore means that rice varieties used for this study have shorter cooking time as compared to other varieties with 10-25 min cooking time as reported by Adeyemi *et al.* (1986) and Rao and Juliano (1970). The reasons why well-parboiled rice (20 and 24 h soaking; 60 min steaming) took much time to cook can be attributed to the hardness attained after thorough parboiling. Such rice is hard and this slow down water penetration to prolong the cooking time. The slow rate of water penetration in well-gelatinized rice is due to transformation of starch into translucent that becomes glacial and compact when cooled. Also, during maximum steaming temperatures, pores can be clogged by movement of molecules and oil contained in the embryo in and out the kernel. This means more time would be needed for water to penetrate the tightly packed molecules. Chukwu and Oseh (2009) observed that due to the strong cohesion between the endosperm cells which are tightly packed, this makes the starch grains to hydrate at a slower rate, which leads to a decrease in water penetration into the grains, hence a longer cooking time. The severe parboiled rice on the other hand took less time to cook because they were cooked already at the steaming stage as lots of the kernels got ruptured to expose the endosperm starch. Such rice will therefore have fast hydration rate hence less cooking time.

The mild parboiled samples (6 h soaked; 40 min steamed) took less time of 15.4 min to cook second to control samples with 14 min cooking time (Table 2). The fast cooking nature of the control samples and less parboil rice can be attributed to the high broken percentage of these rice during milling. The excessive breakage provides maximum surface area to facilitate easy cooking. Even though, parboiled rice requires longer time to cook, the cooked qualities of this rice outweigh that of straight milled rice. For example, they absorb more water, expands and increase in quantity than non-parboil rice. It must be emphasized that cooking time depends on several factors, aside parboiling, which included; rice variety, intensity of heat supply, moisture content and kernel hardness among other things.

Samples from Nerica 14 took more time to cook than Jasmine 85 even though cooking time between these two varieties was statistically insignificant. Nerica 14 took longer time to get cooked possibly because of the high protein content in Nerica 14. This is in accordance with Juliano and Perez (1986) who found out that the higher the protein content of rice, the higher the gelatinization temperature hence, cooking time. The hydrophobic nature of proteins, act as a barrier to inward diffusion of water into the grain prolonging the cooking period.

Water absorption rate: The water absorption rate of the parboiled rice was higher than that of the non-parboiled rice; likewise water absorption of Nerica 14 was more than that of Jasmine 85 variety. Medium parboiling, that is 20-24 h soaking; 60 min steaming gave rice that has high water uptake ratio. As a result of proper gelatinization the endosperm starch melted together and compacted in mass. And at cooking, the cells hydrate at maximum taking in more water than before resulting in the high water absorption rate. Also, the gelatinized starch molecules when exposed to water, an adhesion-cohesion force develops between the starch and water molecules resulting in a strong gradient to pull and retain water molecules more than would do in gritty starch grains of non-parboiled rice. Severe parboiling up to 36 h soaking combined with 90 min steaming gave rice with less water uptake when compared to medium parboiled rice. This might be due to excessive intake of water during soaking period that subsequently rupture the kernels during long steaming periods of 90 min. And ruptured kernels cannot retain much water like the wholesome ones. Straight milled rice (control samples) was the least in water absorption followed by mild parboiled rice (6 h soaking; 40 min steamed). The floury nature of starch grains in those rice might have been the cause of this little water absorption rate in them.

This agrees with Mustapha (1979) who stated that parboiled rice has higher water absorption, which may be as a result of the steaming pressure during parboiling which in turn affects starch gelatinization.

Volume expansion rate: There were significant differences in volume expansion rate of the rice from various treatments. Figure 1a and b showed the volume expansion rate of the two varieties at each parboiling conditions. In both figures, 20 and 24 h soaking combined with 60 min steaming gave the tallest bars followed by 90 min steaming. A high volume expansion rate was recorded for rice soaked for 20 or 24 h and steamed for 60 to 90 min. And this was expansion rate of 6.5 and 6.6 cm^3 g^{-1} for Jasmine 85 and Nerica 14 varieties, respectively. This was far higher than those paddy soaked for 36 h followed with 60 or 90 min steaming, with an expansion rate of 5.8 or 6.2 cm^3 g^{-1}, respectively. This difference in volumetric expansion may be due to the difference in gelatinization levels. The medium parboiled rice (20-24 h soaking; 60-90 min steamed) expanded more than the severe parboiled rice because they were well gelatinized, absorb more water at cooking and therefore expanded more (Fig. 1a and b). Unlike the mild or severe parboiled rice, cells of the medium parboiled rice are flaccid and imbibed water to expand readily to full length when placed in high water potential environment. The control rice was least in volume expansion probably due to the loose endosperm starch unable to absorb much water. Since they were not pre-treated by way of parboiling, the kernel membranes' are not conditioned to withstand the heat being supplied at cooking time. They thus easily get destroyed and release it content in to the water instead of absorbing up the water.

Leached materials: The alternation of soaking/steaming time can have serious effects on amount of soluble materials leaching out the kernel during cooking process. The amount of leached materials if so high makes the rice difficult to cook. In this experiment, the leached materials range from 4.0 to 6.2%. The worst leached materials came from the control samples, followed by severe parboiled rice (36 h soaks; 90 min steaming) according to Table 2. The control samples had the worst leakage because of the highly broken nature of it. This means more surface area exposed at cooking for the endosperm starches to easily dislodge out.

Taste: When it came to taste, the medium parboiled samples that is 20 and 24 h soaking; 60 min steaming produced the tastiest rice in both varieties followed by severe parboiling condition of 36 h soaks; 90 min steaming (Fig. 2). The rather low taste of severe parboiling might be due to the loss of nutrients at long soaking and steaming periods. Since medium parboiled rice did not suffer this nutrient losses stand the chance of tasting good than the latter. Parboiling confers some peculiar aroma on the rice especially if properly gelatinized. The mild or lesser-parboiled rice (6 h soaks; 40 min steamed) did not show any appreciable taste. However, this was better than the control or straight milled rice in both varieties. The poor taste of control and partially parboiled rice

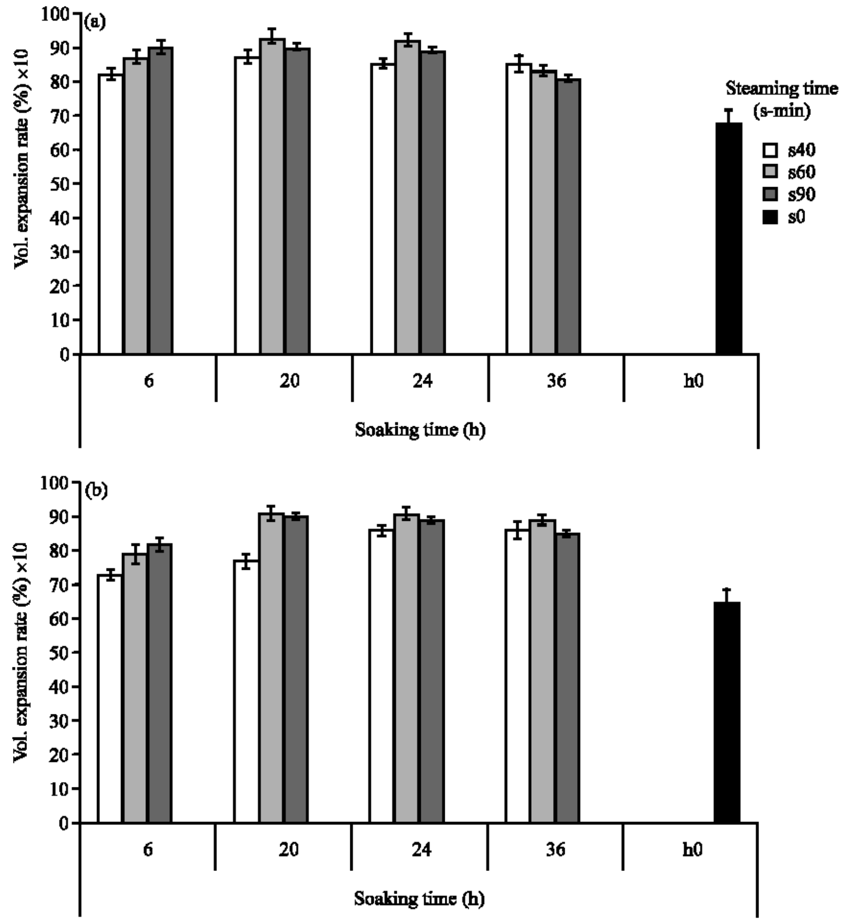

Fig. 1(a-b): Volume expansion rate of cooked rice from the various parboiling conditions, (a) Jasmine 85 variety and (b) Nerica 14 variety

might be attributed to poor or no gelatinization of the endosperm starch. Thus some biochemical changes that could transform or inactivate certain pigments or enzymes enabling taste in parboiled rice to be evoked did not occur. It therefore pre-supposes that parboiling adds some degree of taste to rice.

Chewiness (softness): There was great difference in the chewiness (softness) of Jasmine 85 and Nerica 14 such that Jasmine 85 samples had the highest (3.6%) chewiness (softness) than Nerica 14 with 3.5% chewiness (Table 3). The results of a clear picture of this is shown on Fig. 3 below as chewiness for the control and the mild steamed rice (40 min) gave taller bars than the proper steaming of 60 and 90 min with well gelatinized rice. This study also showed that chewiness or softness decreases as gelatinization increases to a peak. For instance mild parboiling of 6 h soaks; 40 min steamed resulted in high softness level of 3.6% than medium parboiled with softness 2.5%. The hardness of medium parboiled rice was of the fact that it's well gelatinized and therefore has very hard kernels. The lesser or mild parboiled rice (6 h soaks; 40 min steam) were softer to chew because their starch was not well compacted. Instead the starch is chalky and gritty that easily got soaked and softens up when cooked. Severe parboiling on the other hand recorded higher softness level than medium parboiled rice (Fig. 3) because they have hollow kernels since most of the

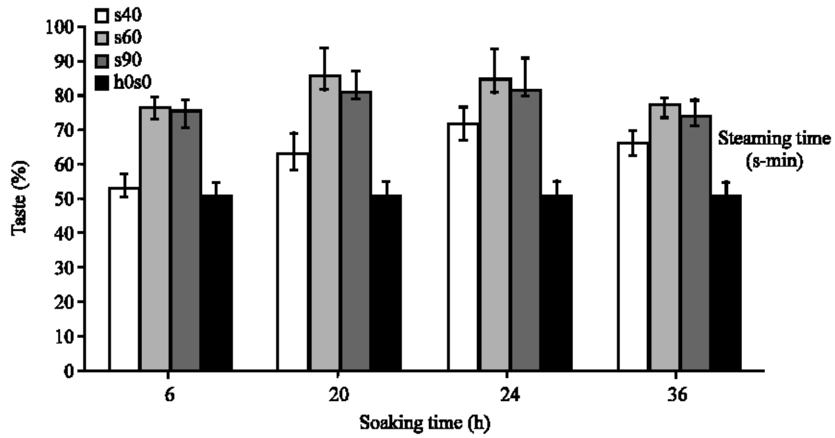

Fig. 2: Taste as affected by variety/soaking/steaming interactions

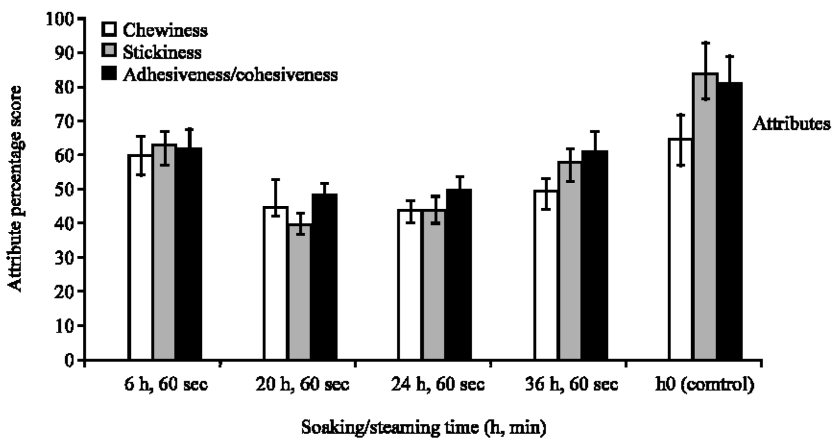

Fig. 3: Effect of different soaking/steaming time on sensory attributes of Jasmine 85

endosperm starches are removed due to leakage. The intact kernels of well gelatinized rice fully protecting their endosperm starch would surely have hard kernels thereof. In the same vein, the control rice (straight milled rice) had the highest chewiness (softness) level than all the samples tested (Fig. 3). This was because of excessive removal of the endosperm starch onto the cooking water making it a thick paste rather than the usual individual grains to chew.

Stickiness: This study showed that stickiness was high in control or raw samples up to 2.9% followed by mild parboiled rice (6 h soaks; 40 min steam) that has stickiness value of 2.7% (Table 3). Where the parboiling was properly done e.g., 20 and 24 h soaking; 60 min steaming, the rice gelatinizes well and showed much elastic property when mashed by chewing. Over parboiling or severe parboiling where the paddy was soaked for 36 h and then steamed for 90 min, resulted in high stickiness value than 20 and 24 h soaking (Fig. 3). This was so because most of the kernels ruptured and exude lots of soluble materials when cooked. This resulted in thick viscous liquid that binds the individual grains together. Stickiness in raw samples (straight milled rice) was the highest followed by mild parboiled rice as shown above in Fig. 3. And this can be attributed to the little or no transformation of carbohydrate starch prior to cooking. At once heating of raw starch in hot water such as endosperm starch in rice kernels tends to improve the elastic property of the starch.

Adhesiveness/cohesiveness: Adhesiveness/cohesiveness is the inherent ability of the individual grains to attach to each other in lumps and sticks to any container it comes into contact with. It differs from stickiness in that stickiness is the elastic ability of starch caused by mashing the cooked grains, whereas cohesiveness and adhesiveness is as a result of inherent forces caused by viscous substances. The results revealed that, control samples were leading with adhesiveness and cohesiveness (Fig. 3). This might be due to the fact these produced more thick viscous liquid after cooking. Severe parboiling such as 36 h of soaking and 90 min of steaming also gave high adhesiveness and cohesiveness (40 and 42.8%) for the two varieties, probably because of same viscous substances when cooked. Mild parboiling (6 h soaking; 40 min steaming) also produced rice with high adhesiveness and cohesiveness levels than medium parboiled rice, but lower when compared to sever parboiled rice (Fig. 3). The low adhesion and cohesion force on medium parboiled rice are largely due to the loosely individual nature of it kernel grains since there are no or less viscosity in them. Excessive leakage of endosperm starch in hot water gives the thick viscous substance, the main reason of high adhesiveness/cohesiveness in raw samples, mild and severe parboiled rice.

CONCLUSION

The varieties studied exhibited good cooking and eating/sensory characteristics when parboiled especially cooking time, volume expansion rate, taste, stickiness and adhesiveness/cohesiveness. ANOVA results indicated there are significant differences ($p<0.05$) in all attributes and therefore concluded that varied parboiling conditions statistically affect cooking and eating /sensory characteristics of rice. Varietal differences however do not affect these qualities to any appreciable level.

Medium parboiling condition of 20 h soaking; 60 min steaming gave the highest mean values in all properties observed, followed by 24 h soaking; 60 min steaming. It's recommended for processors to soak in warm water 35-40°C for 20 h and proceed to steam the moist paddy for 60 min for better value addition in terms of cooking, eating/sensorial characteristics and also at a lower processing cost.

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