



Effects of varied parboiling conditions on proximate and mineral composition of Jasmine-85 and Nerica-14 rice varieties in Ghana

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ABSTRACT

Parboiling of paddy rice is an integral part of post-harvest rice processing. This practice of parboiling varies among individuals or groups. This study investigated the effect of different parboiling conditions on the nutrient content of two rice varieties, Jasmine-85 and Nerica-14. The paddy was soaked in a warm water of 40°C at four different periods of 6, 20, 24 and 36 h, and then steamed at 40, 60 and 90 min at a temperature of 100°C. Guidelines of Association of Official Analytical Chemists were used to obtain the proximate and mineral compositions of the parboiled rice. Concentration of minerals like iron, zinc, calcium and manganese was determined using Atomic Absorption Spectroscopy while Flame Emission Spectroscopy technique was used to determine the concentration of potassium and sodium. Results obtained from the varied levels of parboiling showed that averagely protein content decreased from 6.8 to 5.1% ($P < 0.05$), carbohydrate content decreased from 70.3 to 55.9% ($P < 0.05$) and crude fibre content reduced from 2.9 to 2.1% ($P < 0.05$) after parboiling. Also the concentration of the iron, zinc, calcium, manganese, potassium, and sodium decreased as a result of parboiling. For instance iron concentration decreased from 1.8 ppm in non-parboil rice to 1.0 ppm in parboiled rice ($P < 0.05$) and Zinc also reduced by 0.33 ppm due to parboiling ($P < 0.05$). A parboiling condition of 20 h soaking; 60 min steaming gave better results on all the parameters. In conclusion, parboiling of paddy rice affects the proximate and mineral contents of rice. It is recommended that practitioners should parboil for 21 h (20 h soaking followed by 1 h steaming) for optimum nutrients and minerals content.

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INTRODUCTION

Rice is important to Ghana's economy and agriculture, accounting for nearly 15% of the national Gross Domestic Product (Kranjac-Berisavljevic, 2000). Rice meals have become an important part of the daily Ghanaian menu, both in terms of its caloric value and share of the household budget. Among the cereals in Ghana, per capita consumption of rice is second to maize (Quaye et

al., 2000). Rice consumption in Ghana increased from 7.4 kg per capita/annum between 1982 and 1985 (WARDA, 1986) to 13.3 kg per cap/annum (Government of Ghana, 1996) resulting in a total annual consumption of 239 400 tonnes of milled rice (that is, estimated on 18 million population). The annual consumption (1991-1996) thus showed an increase of 119 000 tonnes over that of 1990 (Oteng, 1997). Ghanaians, especially urban and suburban dwellers eat rice not only as a source of calories but also as a convenient food. It is therefore not surprising that rice is one of five staple crops

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recommended by Ghana's Food and Agricultural Development Sector Policy (FASDEP II) for productivity improvements in order to accelerate Ghana's pace towards attaining the millennium development goal one (MDG1) that is, to eradicate extreme poverty and hunger (Amikuzuno et al., 2013).

As an economic crop of critical importance to household food security, nutrition, income and improved livelihood, it is fast becoming the world's most important staple for poverty alleviation. Several kinds of rice meals are prepared and consumed by lots of people around the globe. In African countries such as Guinea, Guinea-Bissau, Gambia, Liberia, Senegal and Cote d'Ivoire, rice supplies between 22-40 % of dietary energy and 23-39 % of dietary protein (Kennedy et al., 2002).

Again rice can contribute nutritionally-a significant amount of 0.1% thiamin, 0.11% riboflavin, 2.8% niacin and 2.9% zinc to the diet. This translates approximately to 2, 12, 9, 17 and 21% of respectively of the daily recommended nutrient intake (RNI) of these nutrients per 300 g of cooked rice consumed (Kennedy et al., 2002). Consumption of brown rice increases the recommended nutrient intake for iron, thiamin and niacin by more than 10 % as compared to polished rice (Kennedy et al., 2002).

There are many factors that influence the nutrient content of rice. These include postharvest and value addition practices such as parboiling. Parboiling of rice paddy entails the soaking and steaming of the paddy till it gelatinizes and then dries for milling processes. Mostly the harvested paddy is processed by way of parboiling for easy husking without breaking the kernel. Parboiling causes physical and chemical modifications in the grain, leading to such favorable changes like easier shelling, higher head rice yield, fewer broken grains, increased resistance to insects, firm-cooked rice texture, less solids loss during cooking, better retention of nutrients (for example, proteins, vitamins and minerals), and higher oil content in the bran (Gariboldi, 1972; Bhattacharya, 1985; Pillaiyar, 1988). The act therefore was seen as a postharvest-practice employed for rice quality improvement in the area of milling recovery of paddy rice; salvages poor quality or spoiled paddy thereby reducing breakages to meet the demand of consumers. The value addition that is associated with parboiling cannot be underestimated. The intensity of parboiling process is therefore key to producing good quality rice as it can lead to high nutrient retention or losses in the grain.

The world effort to reduce food insecurity and malnutrition has to be enhanced both at the production space through improved breeding, and in the consumption space via improved processing and postharvest practices that maximizes nutrients in the grain. In developing countries such as Ghana, parboiling is an important method for processing and adding value to paddy rice.

The production and consumption of Jasmine 85 and

Nerica 14 rice varieties in Ghana is on the high note due to the red bran colour of Nerica 14 making it suitable for rice and cowpea meal popularly called 'waakye' while the variety Jasmine 85 has aromatic scent when cooked that makes it attractive to consumers. There is therefore the need to devise and adopt measures of post-harvest handling processes such as parboiling to maintain high level of nutrients elements in the rice grain that will benefit consumers.

In Ghana the procedure of parboiling paddy is not standardized and may vary considerably with location and culture of the people involved (Ayamdoo et al., 2013a). Over or under parboiling such as too long or short a soaking and steaming period may cause nutrient losses in the kernel. Ayamdoo et al. (2013b) in their study using these two varieties (Jasmine 85 and Nerica 14) stated that parboiling condition of 18-20 h soak; 60 min steaming yield optimum physical attributes such as milling quality, head rice yield, less breakage, colour, well gelatinization and high water absorption when cooked. This research therefore aimed at identifying an appropriate parboiling condition that will maintain high levels of nutrient elements in the rice kernels for consumption. The study will therefore help to develop the commodity value chain of the rice industry. It will reveal the value of parboiling and its nutritional consequences on rice as a staple food.

MATERIALS AND METHODS

The key equipments used in the study are; micro mill (Satake THU-35, Satake Corp., Hiroshima, Japan); Electronic scale (TE 4101 Sarbrius); Electronic Oven (Gallenkamp oven 3,000-Wagtech Britain); Muffle furnace-Gallenkamp 1100; Digestion Block (Kjeldatherm (England); Galvanometer (cam metric limited (England); Ballistic Bomb Calorimeter (Gallenkamp (England), cat number 19/ID6790); Atomic Absorption Spectrometer (United States USA, serial number 1058); spectrometer 20+D (Milton Roy (United States USA, serial number 37E7205036); Flame Photometer; weighing balance of $\pm 0.001g$ sensitivity, serial number HS2764, Metler (Switzerland), Moisture tester, thermometer, stop clock and Gas stove.

The tests and analyses of proximate composition of nutrients were carried out using the Association of Official and Analytical Chemist (AOAC, 1980) guidelines for determining nutritional parameters. Standard solution of Fe, Zn, Ca, Mn, K and Na were obtained from Hugel Limited-Ghana, agents for Sigma Aldrich Company of Germany while sample stock solution was prepared using AOAC 2000 procedure. Atomic Absorption Spectroscopy (AAS) and Flame Emission Spectroscopy (FES) method was used to determine minerals concentration in both sample and standard solutions as described by Aadil et

al. (2011). For Fe, Zn, Ca and Mn, absorbance of standard solutions as well as sample solutions was taken by atomic absorption spectrophotometer using their respective cathode lamp. Concentration of sample was determined by the graph between concentration along X-axis and absorbance along Y-axis. The flame photometer was turned on and set for sodium and potassium determination. All the standards and sample was subjected to the flame photometer and emission from photo cell was measured from digital read out system according to the concentration and absorbance along x- and y-axis, respectively.

Samples preparation

The rice samples used for this study were foundation seed of Jasmine-85 and Nerica-14 varieties supplied by the Rice Section of the Savanna Agricultural Research Institute of the Council for Scientific and Industrial Research (CSIR-SARI), Ghana. The following containers were fabricated and used to simulate the parboiling processes as practiced at the conventional setting.

- A 200 m³ cylindrical aluminum container with a lid.
- Three steaming aluminum vessels (30 m³) with the surface area perforated all over. Each steaming vessels had tripod stand.
- A large cooking pot of 2,600 m³ that could house the three steaming vessels.

Parboiling was done by weighing 6 kg of each variety and soaks it in preheated water at 40°C for 6, 20, 24 and 36 h). The moist paddy from each soaking period was drained of excess water and divided onto the steaming containers of 2 kg each. Then a glass thermometer was inserted to record temperature readings during steaming process. The steaming containers were placed on a large cooking vessel of preheated water at 100°C, covered and steamed for a specified time period of 40, 60 and 90 min. At each steaming time, one container was removed and its content poured out and dries under sunshine. The same soaking and steaming procedure was applied to paddy of the two varieties in two replicates. Non-parboiled samples were also taken from each of the two varieties as control. All samples were dried to equilibrium moisture content of 14±1%, before milling and the brown rice obtained packed and labeled appropriately for analysis.

Statistical analysis

The data was subjected to analysis of variance (ANOVA) to see if there were statistical differences in nutrients content using GENSTAT VSN international. Statistically significant differences between samples means were

identified at 5 % using Z-tests.

RESULTS

The nutrients composition of the rice was determined according to the various parboiling conditions for the two varieties. The results indicated that parboiling significantly affects ($P<0.05$) the nutrients content of paddy rice (Table 1).

Maximum saturated moisture for the two varieties after soaking ranges from 58 - 90% at the various soaking periods. For example, soaking for 6 h gave lower moisture content of 58% whereas soaking for 20, 24 and 36 h resulted in moisture content levels of 80, 80.8 and 88% respectively in Jasmine-85 variety and that of Nerica-14 variety saturated moisture ranges from 65-90% at the different soaking periods (Table 2).

Crude protein was found to be significantly different ($p<0.05$) in all parboiling conditions of the two varieties (Table 1). Crude protein content ranges from 5.1 - 6.8% (Table 2). The crude protein content was higher for control (6.6% in Jasmine 85 and 6.8% in Nerica-14 respectively), followed by the mild parboiled rice (6 h soak; 40 min steamed) and the least in crude protein content was the severe parboiled rice (36 h soak; 90 min steamed).

Varietal differences together with varied soaking/steaming time showed significant effect of carbohydrate content of paddy rice (Table 1). Minimum Carbohydrate content was 57.1 and 55.9% while maximum values were 70.3 and 69.5% for Jasmine-85 and Nerica-14, respectively (Table 2). In both varieties, the maximum values came from the non-parboiled (control) samples while the lower values came from the severe or over parboiled rice.

Crude fibre values range from 2.2-2.9% and showed no significant difference ($P>0.05$) amongst the treated samples except between varieties (Table 1). On total lipids content, varietal differences, soaking/steaming time as well as variety/soaking/steaming interactions showed significant effects (Table 1). In Nerica-14 variety, the total lipids ranged from 2.2 to 3.4% and that of Jasmine-85 ranges between 2.5-3.4%. Thus Jasmine-85 variety showed high lipid content than Nerica-14 variety (Table 2).

The mean values of ash content were in the range of 1.6-2.3% in Nerica-14 and 1.5-2.2% in Jasmine-85 as shown in Table 2. There were significant effects ($P<0.05$) of variety, soaking / steaming interaction and variety / soaking/steaming interactions on ash content (Table 1).

Analysis on minerals concentration showed that parboiling significantly ($P<0.05$) affect minerals content (Table 1). The minerals content at the varied parboiling conditions were significantly different from each other (Table 3). Manganese for instance from 2.3 ppm

Table 1. Multivariate analysis of effects of parboiling on the nutritional and minerals concentration of parboiled rice.

Property	Overall mean	Error mean square	P value (5%)						
			Variety	Soaking Time	Steaming Time	Variety/ Soaking	Variety/ Steaming	Soaking/ steaming	Variety/soaking/ steaming
Crude protein (%)	5.7	0.04	0.001*	0.001*	0.939	0.001*	0.843	0.001*	0.001*
CHO (%)	62	136	0.001*	0.001*	0.484	0.004*	0.717	0.026*	0.009*
Lipids (%)	2.8	0.78	0.723	0.063	0.333	0.237	0.195	0.019*	0.020*
Crude fibre (%)	2.5	8.23	0.005	0.089	0.836	0.841	0.997	0.911	0.411
Ash content (%)	2.0	1.68	0.001*	0.138	0.113	0.069	0.887	0.040*	0.001*
Iron (ppm)	1.5	0.02	0.003*	0.068	0.071	0.085	0.058*	0.127	0.002*
Zinc (ppm)	0.8	0.06	0.020*	0.235	0.127	0.096	0.005*	0.095	0.020*
Calcium (ppm)	3.0	0.70	0.003*	0.127	0.205	0.155	0.004*	0.890	0.001*
Manganese (ppm)	3.8	0.45	0.025*	0.248	0.189	0.162	0.030*	0.677	0.005*
Potassium (ppm)	1.8	0.97	0.050	0.152	0.240	0.217	0.001*	0.255	0.003*
Sodium (ppm)	2.0	0.35	0.001*	0.117	0.400	0.315	0.005*	0.221	0.001*

*Significantly different (P<0.05).

Table 2. Proximate nutrients content of Jasmine-85 and Nerica 14 after the different parboiling conditions.

Variety	Soaking period (h)	Steaming period (min)	Crude protein (%)	Total carbohydrate (%)	Crude fibre (%)	Total lipids (%)	Ash content (%)	Moisture content (%)
Jasmine-85	6	40	6.5±0.3 ^a	68.5±2.5 ^b	2.7±0.2 ^a	3.2±0.1 ^a	1.9±0.1 ^b	58.0±2.0 ^c
		60	6.0±0.2 ^b	65.1±3.4 ^b	2.6±0.7 ^a	2.8±0.1 ^b	1.7±0.4 ^b	
		90	5.6±0.3 ^c	64.2±3.0 ^c	2.4±0.4 ^c	2.7±0.1 ^b	1.6±0.6 ^b	
	20	40	5.9±0.4 ^c	62.2±3.7 ^c	2.6±0.8 ^a	2.8±0.5 ^b	1.8±0.4 ^c	80.0 ±1.0 ^b
		60	6.5±0.1 ^a	69.5±3.5 ^a	2.6±0.8 ^a	3.1±0.2 ^a	2.0±0.2 ^a	
		90	6.1±0.2 ^b	68.5±2.1 ^b	2.5±1.5 ^b	3.0±0.4 ^a	1.9±0.3 ^b	
	24	40	5.8±0.4 ^c	57.1±3.4 ^d	2.5±0.6 ^b	2.9±0.4 ^b	1.9±0.3 ^b	80.8±0.7 ^b
		60	6.3±0.2 ^b	68.5±2.6 ^b	2.5±0.6 ^a	3.0±0.1 ^a	1.9±0.3 ^b	
		90	5.6±0.1 ^d	66.6±2.6 ^b	2.4±0.1 ^c	2.9±0.6 ^b	1.8±0.4 ^b	
	36	40	5.5±0.3 ^d	67.4±2.4 ^b	2.5±0.5 ^b	2.7±0.6 ^b	1.7±0.1 ^b	88.5 ±2.1 ^a
		60	5.2±0.5 ^d	61.6±1.5 ^c	2.3±0.2 ^c	2.7±0.1 ^b	1.9±0.1 ^b	
	0	0	90	5.1±0.2 ^e	62.1±3.3 ^c	2.4±0.1 ^c	2.5±0.0 ^c	1.5±0.3 ^b
0			6.6±0.1 ^a	70.3±0.4 ^a	2.8±0.8 ^a	3.4±0.5 ^d	2.2±0.4 ^a	28.5±0.7 ^d

Table 2. Cont.

Nerica-14	6	40	6.4±0.1 ^b	68.0±3.6 ^b	2.7±0.2 ^a	3.3±0.1 ^a	2.0±0.4 ^a	65.0±1.4 ^c
		60	6.0±0.8 ^b	63.8±1.9 ^c	2.7±0.8 ^a	3.2±0.0 ^a	1.9±0.2 ^b	
		90	5.7±0.1 ^d	61.5±1.7 ^c	2.3±0.2 ^c	2.9±0.5 ^b	1.8±0.4 ^b	
	20	40	5.9±0.2 ^c	62.5±1.7 ^c	2.5±0.4 ^b	2.3±0.2 ^d	1.9±0.6 ^b	82.0 ±1.4 ^b
		60	6.6±0.4 ^a	68.5±2.4 ^b	2.7±0.9 ^a	3.0±0.6 ^a	2.1±0.2 ^a	
		90	6.2±0.5 ^b	66.2±2.8 ^c	2.6±0.6 ^a	2.9±0.4 ^b	2.0±0.1 ^a	
	24	40	5.6±0.3 ^d	56.6±2.8 ^d	2.3±0.6 ^c	3.0±0.3 ^a	1.8±0.6 ^b	82.5±2.8 ^b
		60	6.5±0.1 ^a	55.9±1.5 ^d	2.5±0.3 ^b	2.9±0.1 ^b	1.9±0.3 ^b	
		90	6.2±0.4 ^b	56.8±2.8 ^d	2.5±0.7 ^b	2.6±0.1 ^b	1.8±0.2 ^b	
	36	40	5.4±0.6 ^e	57.6±2.5 ^d	2.4±1.1 ^c	2.2±1.0 ^d	1.7±0.1 ^b	90.0±3.5 ^a
		60	5.4±0.3 ^e	59.2±1.9 ^d	2.4±0.3 ^c	2.3±0.2 ^d	1.6±0.2 ^b	
	0	0	5.2±0.4 ^e	56.7±1.6 ^d	2.2±0.5 ^c	2.2±0.8 ^d	1.6±0.1 ^c	30.0 ±2.7 ^d
		0	6.8±0.4 ^a	69.5±0.7 ^a	2.9±0.8 ^a	3.4±0.4 ^a	2.3±0.4 ^a	

Means ± standard deviations of 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 (non-parboil rice); h, hours; min, minutes.

decreased in non-parboil rice to 1.6 ppm in parboiled rice and Sodium concentration also reduced from 2.4 - 1.7 ppm after parboiling (Table 3). Among the two varieties, Nerica-14 recorded high minerals concentrations than Jasmine-85.

DISCUSSION

Moisture content

The soaking process possibly enables paddy rice to imbibe water and become moist. The process of moisture absorption was facilitated by heating water to a warm temperature of 40°C that energizes molecules for faster movement across barriers into the rice kernel. Thus the longer the soaking period, the greater the moisture content of the soaked paddy. However, the rate of increase in moisture level was sharp at the initial

soaking periods (between 0 - 20 h) after which the rate of increase in moisture content fell sharply. In this study, Nerica-14 absorbed more water at all levels of soaking than Jasmine-85 (Figure 1). As a result of differential gradient in water concentration between the internal content of the seed and the aqueous environment, a likely potential exist to facilitate water movement across barriers especially energized molecules. During the steaming process, the moisture content reduces from the saturation point to a normal level as the excess moisture evaporates as vapour. The moist starch would then be converted into gelatinous substances. This agreed with and Mustafa (1979) that moisture content of rice decrease under gradual increase in temperature of parboiling and subsequent drying. The long soaking period resulting in high moisture content could also be advantageous since toxin or other unwanted substances deposited by micro-

organisms during long storage get dissolved or diluted. This is in line with Ayamdoo et al. (2013a) findings that 'the long hours of soaking in warm water do not only facilitate water absorption but also further reduces toxic substances like aflatoxins that are found old stock. Soaking to good moisture content will ensure well gelatinization when steamed and consequently good parboiled rice. If the moisture content is not raised to an appreciable level during soaking period, then the steaming alone cannot improve the quality of the parboiled rice. This possibly explains why paddy soaked for long with optimal moisture level gave good parboiled rice than short soaking period. On the other hand, long hours of soaking can also lead to poor quality of the parboiled rice if not properly steamed. In this study, 24 and 36 h long soak followed by 90 minutes steaming resulted in cooked kernels instead of gelatinization. It also caused the husk

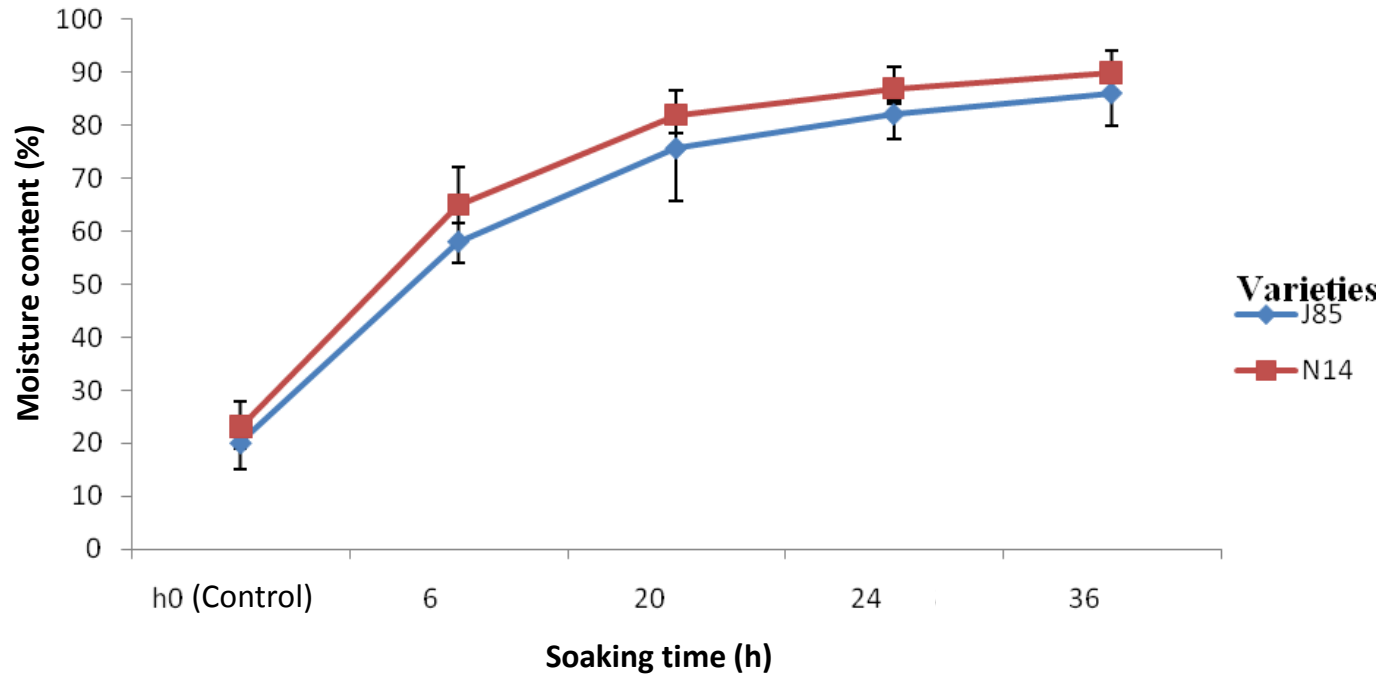


Figure 1. Saturated moisture levels of J85 and N14 varieties at different soaking periods.

Table 3. Minerals content of Jasmine-85 and Nerica 14 at the different parboiling conditions.

Variety	Soaking period (h)	Steaming period (min)	Iron (ppm)	Zinc (ppm)	Calcium (ppm)	Manganese (ppm)	Potassium (ppm)	Sodium (ppm)
Jasmine85	6	40	1.6±0.1 ^b	0.83±2.5 ^b	2.8±0.6 ^a	2.1±0.1 ^a	3.2±0.2 ^a	2.1±0.2 ^a
		60	1.5±0.2 ^b	0.56±1.9 ^e	2.7±0.2 ^a	1.9±0.0 ^b	3.0±0.3 ^a	1.9±0.3 ^b
		90	1.5±0.1 ^b	0.55±1.7 ^e	2.6±0.2 ^b	1.9±0.5 ^b	2.9±0.2 ^b	1.8±0.2 ^b
	20	40	1.4±0.2 ^c	0.75±1.7 ^c	2.6±0.4 ^b	1.9±0.2 ^b	2.8±0.4 ^b	1.9±0.4 ^b
		60	1.5±1.0 ^b	0.81±2.4 ^b	2.7±0.9 ^a	2.0±0.6 ^a	3.1±0.2 ^a	2.0±0.2 ^a
		90	1.5±0.5 ^b	0.80±2.8 ^b	2.6±0.6 ^b	2.0±0.4 ^a	3.1±0.3 ^a	1.9±0.3 ^b
	24	40	1.2±0.3 ^d	0.65±2.8 ^d	2.5±0.6 ^b	1.8±0.3 ^b	2.9±0.3 ^b	1.8±0.3 ^b
		60	1.5±0.1 ^b	0.80±1.5 ^b	2.5±0.3 ^b	1.9±0.1 ^b	3.0±0.1 ^a	2.0±0.1 ^a
		90	1.4±0.4 ^c	0.78±2.8 ^c	2.4±0.7 ^c	1.9±0.0 ^b	2.9±0.2 ^b	1.8±0.2 ^b

Table 3. Cont.

Nerica-14	36	40	1.4±0.6 ^c	0.63±2.5 ^d	2.5±1.1 ^b	1.7±1.0 ^c	2.8±0.1 ^b	1.7±0.1 ^c
		60	1.4±0.3 ^c	0.58±1.9 ^e	2.5±0.3 ^b	1.7±0.2 ^c	2.9±0.2 ^b	1.8±0.2 ^b
		90	1.0±0.4 ^d	0.74±1.6 ^c	2.4±0.5 ^c	1.6±0.8 ^c	2.8±0.1 ^b	1.8±0.1 ^c
	0	0	1.8±0.2 ^a	0.86±0.7 ^b	3.0±0.8 ^a	2.2±0.4 ^a	3.3±0.2 ^a	2.3±0.2 ^a
		40	1.7±0.1 ^a	0.92±3.6 ^a	2.7±0.2 ^a	2.1±0.1 ^a	3.2±0.4 ^a	2.2±0.2 ^a
		60	1.6±0.8 ^b	0.90±1.9 ^a	2.5±0.8 ^b	2.0±0.0 ^a	3.0±0.2 ^a	1.9±0.3 ^b
	6	60	1.5±0.1 ^b	0.89±1.7 ^b	2.3±0.2 ^c	2.0±0.5 ^a	2.9±0.4 ^b	1.8±0.2 ^b
		90	1.4±0.2 ^c	0.88±1.7 ^b	2.5±0.4 ^b	1.9±0.2 ^b	2.9±0.6 ^b	1.9±0.4 ^b
		40	1.5±0.4 ^b	0.91±2.4 ^a	2.7±0.9 ^b	2.1±0.6 ^a	3.2±0.2 ^a	2.1±0.2 ^a
	20	60	1.5±0.5 ^b	0.90±2.8 ^a	2.6±0.6 ^b	2.1±0.4 ^a	3.0±0.1 ^a	2.0±0.3 ^a
		90	1.4±0.3 ^c	0.64±2.8 ^d	2.4±0.6 ^c	2.0±0.3 ^a	2.8±0.6 ^b	1.9±0.3 ^b
		40	1.5±0.1 ^b	0.91±1.5 ^a	2.5±0.3 ^b	1.9±0.1 ^b	3.1±0.3 ^b	2.0±0.1 ^a
	24	60	1.4±0.4 ^c	0.89±2.8 ^b	2.5±0.7 ^b	1.9±0.0 ^b	3.0±0.2 ^b	1.9±0.2 ^b
		90	1.4±0.6 ^c	0.65±2.5 ^d	2.4±1.1 ^c	1.9±1.0 ^b	2.8±0.1 ^b	1.8±0.1 ^b
		40	1.4±0.3 ^c	0.55±1.9 ^e	2.4±0.3 ^c	1.8±0.2 ^b	2.9±0.2 ^b	1.9±0.2 ^b
	36	60	1.3±0.4 ^c	0.77±1.6 ^c	2.5±0.5 ^b	1.7±0.8 ^c	2.8±0.1 ^b	1.8±0.1 ^b
90		1.8±0.4 ^a	0.95±0.7 ^a	2.9±0.8 ^a	2.3±0.4 ^a	3.4±0.4 ^a	2.4±0.2 ^a	
0								

Means ± standard deviations, n = 2. 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 (non-parboiled rice).

to crack open as the kernel swells and expand in volume at the steaming stage. Exposed kernels from ruptured husk get into contact with steam vapour tainting the kernels thereby lowering the quality in terms of colour in the final product.

Protein

There was a decrease in crude protein content in the parboiled rice than the non-parboiled ones. This is in agreement to the findings that 'the longer the parboiling process, the lower the protein content and this might be due to the leaching out of non-protein nitrogen' (Adeyemi

and Mustafa, 1979; Omobuwajo, 1982). Also, Ibukun (2008) observed in his study that the magnitude of losses of nutrient is higher because of prolonged parboiling with protein content being the most affected. In this study longer soaking such as 24 and 36 h followed by long period of steaming (90 min) produced rice with the least crude protein content while control and less-parboiled rice gave more protein levels. Thus 40 min steamed rice (s40) gave high protein content than 60 min steaming (s60) and this in turn gave higher protein content than 90 min steaming (s90) as shown in Figure 2. Since the control samples were not soaked nor steamed, leaching does not occur hence the higher protein level in

such straight milled rice. This result from the study also suggests that Nerica-14 variety had high protein content than Jasmine-85 variety (Figure 2) and this can be attributed to varietal differences.

Carbohydrate

Carbohydrates provide the bulk of the calories in parboiled rice. According to this study total carbohydrate content follows the same pattern as crude protein. Total carbohydrates content was significantly lower in well-gelatinized rice (60.2%) than straight milled rice (70.3%). This is contrary to the findings of Ogbonnaya and Friday (2009)

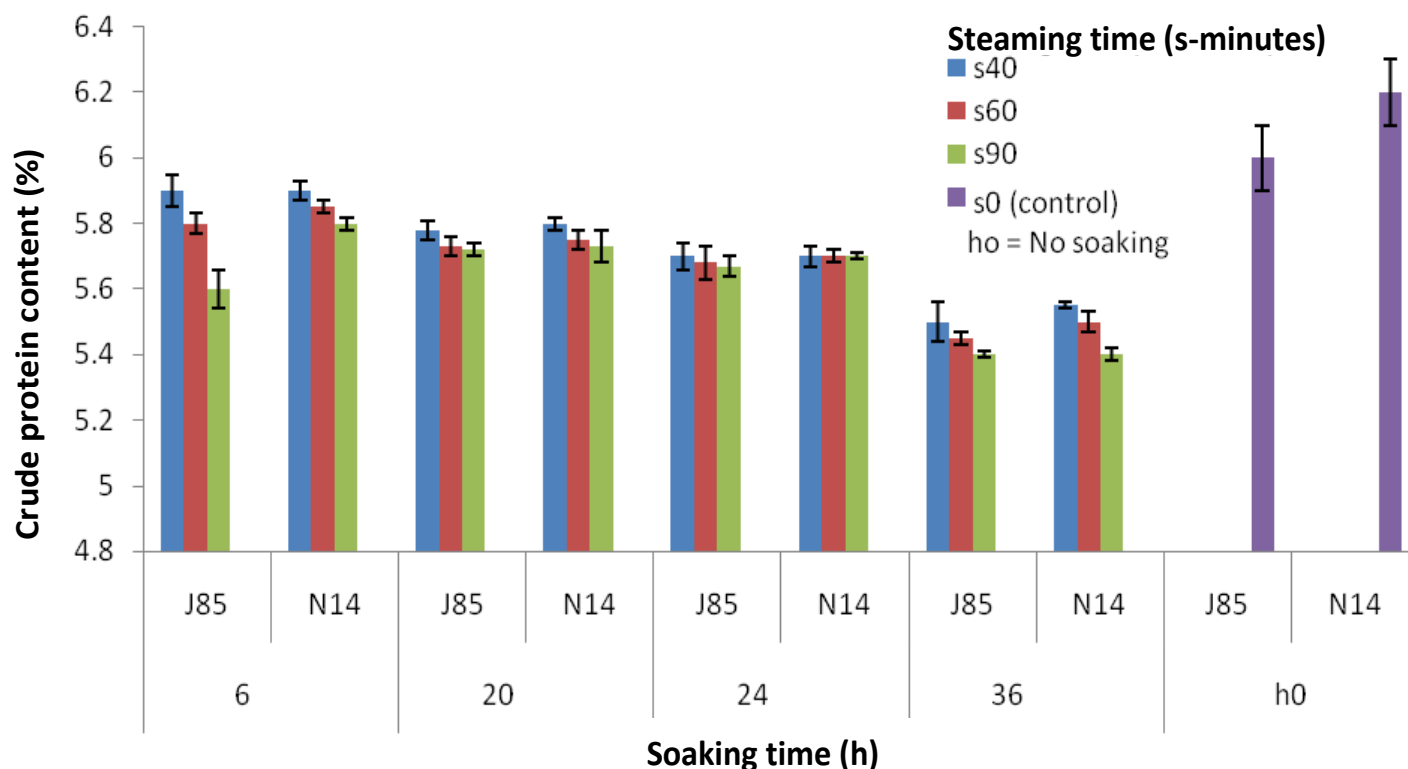


Figure 2. Crude protein levels at various parboiling conditions.

that saw that carbohydrates content of parboiled rice are higher than non-parboiled rice. This decrease in carbohydrates content may be explained as starch gelatinization where the moist starch turns into gelatinous substance before it retrogrades and become compacted. Therefore good gelatinized rice have their starch in the kernels compacted that pulled away from the husk as it cools and dry making hulling easier. According to Rao and Juliano (1970), starch re-association increase in some carbohydrate components like reducing sugars, and change in molecular size and partial dextrinization of the starch that occurs during parboiling may be responsible for the less carbohydrate content in parboiled rice than straight milled rice. Dissolution or exudation of endosperm starch as it gelatinizes during steaming process are possibly some of the reasons associated with low carbohydrates contents in parboiled rice especially the severe parboiled rice (36 h soak; 90 min steam).

As Islam et al. (2004) and Bello et al. (2006) explained in their study that it might be during soaking process at higher temperatures that if the variety has low amylose content, there might be severe deformation of the grain as it loses the exuded endosperm content while absorbing excessive moisture that could lead to reduced milling yield.

Fibre content

Crude fibre is a measure of the quantity of indigestible cellulose, lignins and other components of this type present in food (Aurang et al., 1987). Results on crude fibre were not significantly different among the various soaking/steaming time combinations possibly due to the heat capacity generated being too low to cause any degradation of the fibre present. The two varieties however exhibited significant differences in the crude fibre content in their control (non-parboiled) samples and this may be attributed to genetic differences between the two varieties. The low fibre content in parboiled rice possibly accounted for its high energy digestibility.

Lipids

The parboiled rice has less lipids content than the control (non-parboiled) or partially parboiled rice. It is my opinion from this study that oil contained in the embryo could get dissolved and diffuses out of the grain during the steaming process to give it low fat content. And this probably accounted for the low lipid content in the parboiled rice. This however is contrary to Patindol et al. (2008) who found surface total lipid (isopropyl alcohol

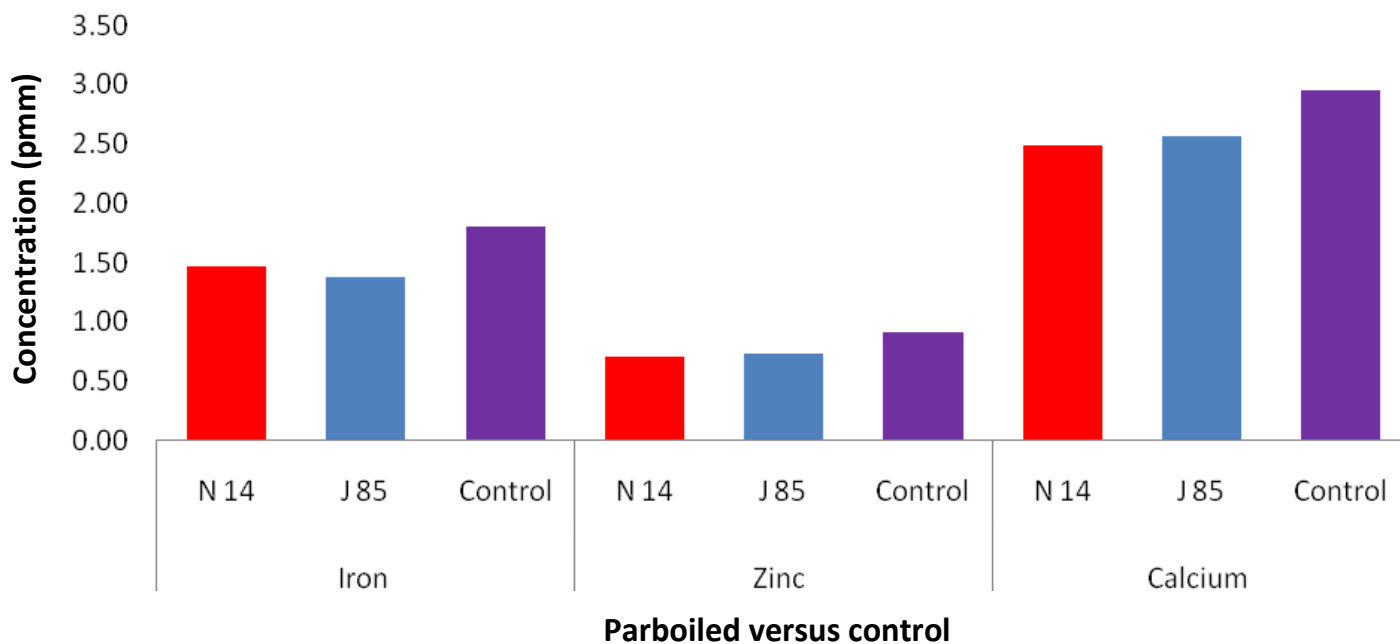


Figure 3. Iron, Zinc and Calcium concentrations in both varieties after parboiling as against control.

extractable fraction) tended to increase, with the increase being more prevalent on the batches parboiled under severe conditions. Oil and protein bodies are known to diffuse outwards during parboiling process and this might be the reason for fewer lipids in parboiled rice. Kato et al. (1983) observed an increase in lipids bound to starch and protein and a decrease in unbound lipids due to parboiling. The results suggested that parboiling enhanced the interaction of bran lipids with endosperm starch and protein. This in turn, makes the lipid fraction of the aleurone layer more difficult to remove on milling (Patindol et al., 2008).

Ash content

The ash content of any agricultural material is the inorganic residue remaining after the organic material has been burnt off (Pearson, 1976). It is also the inorganic residue after the organic carbonaceous portion and other volatiles have been oxidized and evaporated. Ash content showed significant effects from varietal differences as well as parboiling conditions. Mild parboiling (6 h soak; 40 min steam) resulted in parboiled rice with high ash content and this may be due to less heat at mild parboiling that did not disassociate starch molecules much hence molecular mass of the individual starch grains remains same. As soaking and steaming time increases the ash content tend to decrease because of losses of matter from the kernel through dissolution

and leakage which can be quiet high to reflect in the ash content of samples.

Minerals concentration

The minerals concentration after parboiling decreased when compared to the minerals levels in control (raw) samples. This can be largely attributed to accompanied losses in leached starch during prolong steaming operations especially where kernel ruptures and exude endosperm starch. The mild parboiled rice (6 h soak; 40 min steam) that did not experience too much heat gave appreciable minerals content values when compared to the well parboiled rice (20 and 24 h soak; 60 min steam) minerals concentration. Aside this, the concentration of these minerals, Iron, Zinc, Calcium, Manganese, Potassium and Sodium vary slightly amongst the different parboiling levels. From the analysis it was clear that Nerica-14 variety gave higher concentration of minerals than Jasmine-85 in all the parboiled conditions (Figure 3 and 4) and this could be due to genetic differences.

CONCLUSION AND RECOMMENDATIONS

This study points to the fact that parboiling affects nutritional quality of paddy rice. Crude protein shows an increase at moderate parboiling (20 - 24 h soak; 60 min steaming) but decrease when parboiled beyond this level.

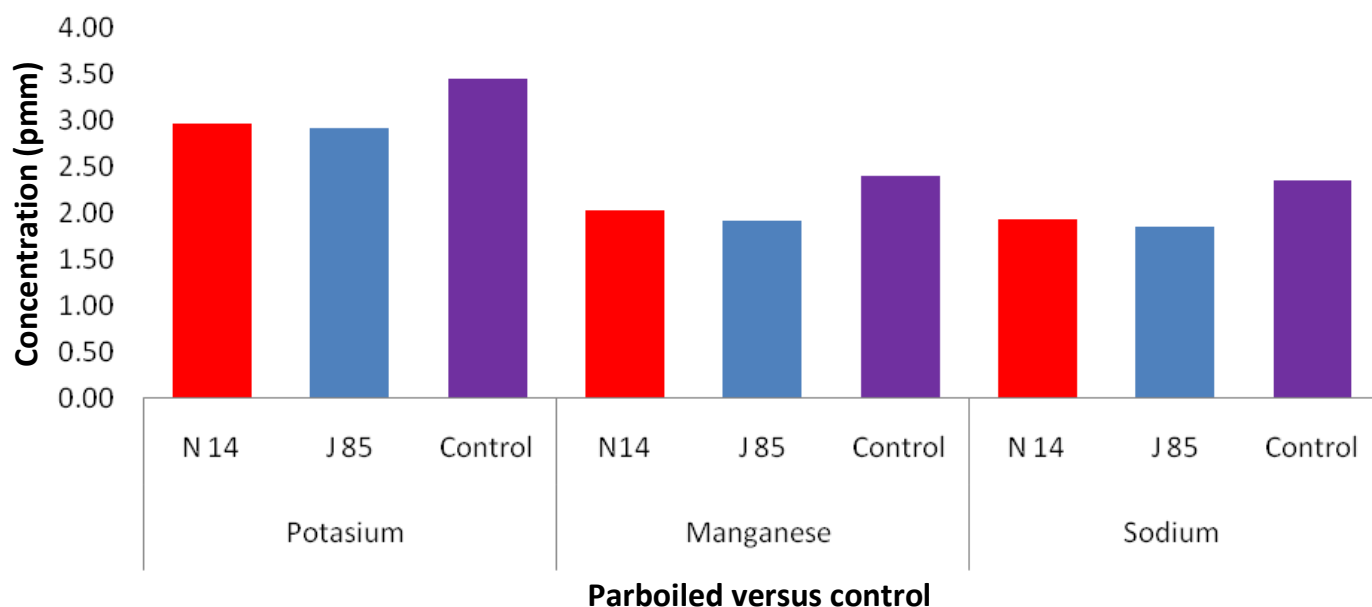


Figure 4. Potassium, Manganese and Sodium concentrations in both varieties after parboiling.

Minerals' content was also affected by the different durations of heating due to parboiling. The slight reductions of some nutrients such as carbohydrate, lipids, ash and minerals after parboiling are compensated for by improved physical qualities such as easy hulling, less breakage, good head rice yield, colour, proper gelatinization etc. usually associated with parboiling paddy rice.

From the outcome of this study it's necessary that paddy rice be soaked and steamed at the right time period in order to retain maximum nutrients after parboiling. It is ideal that paddy rice be moderately parboiled by soaking in warm water of 40°C for 20 – 24 h and then steamed for 60 min. For optimum nutrients and minerals content, 20 h soak and 60 min steam is recommended to reduce the waste incurred on time and resources by soaking to 24th hour.

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