Optimization of Parboiling Conditions of Local Rice Varieties in the Philippines

Andres M. Tuates Jr.[*], Shiela Marie A. Villota, Aileen R. Ligisan, and Ofero A. Caparino

Bioprocess Engineering Division
Philippine Center for Postharvest Development and Mechanization
CLSU Compound, Science City of Munoz, Nueva Ecija. Philippines

[*]*Corresponding author's email: amtuates [AT] yahoo.com*

ABSTRACT---- ***Parboiling is a hydro thermal treatment of paddy before milling. It consists of three steps: 1) Soaking of rough rice, 2) steaming of soaked rice and 3) drying of steamed rice. Parboiling changes the physical and chemical modifications in the grain, fills the void spaces and cements the cracks inside the endosperm, making the grain harder, hence, minimizing internal fissure and breakage during milling.***

Eleven (11) rice sample varieties, namely: NSIC:Rc 118, NSIC:Rc 254H, NSIC 238, Selection 64, Rc 158, 75 days, NSIC 216, Japonica, Rc 18, PHB 77 and Rc 218 were collected from four (4) provinces of Agusan del Sur, North Cotabato, Palawan and Orriental Mindoro. Three (3) soaking temperature settings (40^{o}C, 50^{o}C, 60^{o}C) and three (3) soaking time (1 hour, 2 hours, 3 hours) were applied followed by steaming at 121°C for 5 minutes using autoclave. The parboiled rice was dried to a mositure content of 14% (wb) before milling. The physical qualities of parboiled rice kernel were evaluated in terms of milling recovery, percent head rice and whiteness.

Results showed that the quality of parboiled rice was significantly affected by the parboiling process such as soaking temperature and exposure time. The suitable soaking temperature for the selected rice varieties is 60℃. The soaking time of 2 hours was recommended for NSIC:Rc 254H, NSIC 238, Rc 18, and PHB-77 while 3 hours for NSIC:Rc 118, Selection 64, Rc 158, 75 days, NSIC 216, Japonica and Rc 218. Through parboiling process, the milling and head rice recovery of selected rice varieties significantly increased (P< 0.05) from 73.24% to 78.64% and 79.13% to 99.54%, respectively. However, a slight decrease in the whiteness value from 70.56 to 59.70 was observed.

Keywords--- optimization, parboiling, milling recovery, head rice recovery, lightness

1. INTRODUCTION

Rice (*Oryza sativa* L.) is considered as a main staple food and a major source of nutrients of Filipinos. The increasing trend of rice consumption and huge postharvest losses of the total rice production, the country has continuously relied on importation from other countries such as Thailand, Vietnam and China to satisfy its requirements and ensure enough buffer stocks.

In this period of rice deficit, it is ironic to spend more money on well-polished rice even if it is less nutritious and healthy than its cheaper variety. Indeed, we use up more electricity to polish rice and get rid of the nourishing parts of its grains. Similarly, the rice consumers nowadays are more health conscious and thereby cautious on the quality of food they eat. This awareness and sophistication have created the expectation for improved quality in consumer food products. Parboiled rice is an excellent alternative food to satisfy those expectations because during parboiling vitamins and mineral salts are retained inside the rice kernel.

Parboiling is a hydro thermal treatment of paddy before milling. It consists of three steps: 1) Soaking of rough rice, 2) steaming of soaked rice and 3) drying of steamed rice (Gariboldi, 1972; Bhattacharya, 1985; Pillaiyar, 1988). Parboiling prevents loss of nutrients during milling and saves wet or damaged paddy. It causes physical and chemical modifications in the grain, fills the void spaces and cements the cracks inside the endosperm, making the grain harder resulting to minimal breakage during milling (Correa *et al.*, 2006). In terms of marketability, parboiled rice can command premium price because of its potential to obtain high percentage head rice e.g. ≥ 95% (NFA, 2002).

Parboiling process has been practiced elsewhere in commercial proportion among Southeast Asian countries including Sri Lanka, Thailand, China, Bangladesh, Japan and Nepal (Parnsakhorn & Noomhorm, 2008). However, it is neither common nor a familiar activity in the local settings.

In 1987, National Food Authority (NFA) was a recipient of a commercial parboiling plant granted by the Food and Agriculture Organization (FAO) of the United Nations. The installation of the parboiling does not imply a commercial production for domestic sclae but rather to learn the technology involved in this process and evantually indulge in the actual exportation of the processed commodity. Del Rosario (1987) recommended that further work on the parboiling process be done to improve the product quality and eventually attract and encourage rice consumers. Hence, there is a need to determine the most appropriate combination of soaking and steaming conditions applicable for the production of good quality parboiled rice.

2. MATERIALS AND METHODS

Selection and preparation of samples

Fifty (50) kilograms of newly harvested paddy from two to three commonly rice varieties in each of the four (4) provinces were selected and used in the experiments. Parboiling of freshly harvested paddy with moisture content ranging from 19% to 32% is recommended (Coronel, 1978).

The impurities considerably affect the results of parboiling. Prior to parboiling, rough rice was subjected to floatation in cold water to remove the impurities and immature rice kernels, and washed the grains simultanously.

Parboiling procedure

Soaking

The purpose of soaking is to absorb the rough rice with water up to 40 % by weight to facilitate cooking and heat transfer. Three soaking temperature settings (40^{o}C, 50^{o}C, 60^{o}C) and three soaking time (1 hour, 2 hours, 3 hours). Aluminum containers were used for soaking the samples. A fluke data logger was used to monitor the temperature setting.

Steaming

Soaked rough rice was taken out in the aluminum container and drained to remove the excess water. The drained samples were placed inside the autoclave and exposed to a steam at a temperature of 121°C for 5 minutes. The purpose of steaming is to complete the parboiling process and gelatinization of rice starch (Cherati *et. al.*, 2012).

Drying

Steamed rough rice was spread evenly on a tray and allowed to cool and air dry for five minutes. After air drying, the samples were dried using a combination of sundrying and laboratory mechanical dryer. The parboiled rice was thinly spread in a thin layer and mixed frequently to prevent kernel damage caused by rapid drying. Drying continued until the moisture content of the samples is down to 14% (wb) ready for milling. Samples were then packed in a polyethylene bag and labeled properly. The moisture content of the samples was measured using SHEGA (PHilMech, Phil.) moisture meter.

Milling and Polishing

The dried parboiled rice was milled using a laboratory rice mill (JLGJJ, China). Three (3) 100 grams of the parboiled rice were dehulled separately. After hulling, the paddy, head rice and broken rice were classified and weighed. The head rice (brown rice) was then polished for 60 seconds for milled rice analysis. The head rice and broken rice were segregated manually and weighed.

Color analysis

The color parameter *L* of parboiled rice was measured using color meter (Gardner, USA). The value of '*L*' is a measure of the brightness or whiteness from black (0) to white (100).

Experimental Design and Data Analysis

A 3 x 3 factorial in completely randomized design was used in this experiment to determine the factors that provide optimum responses in the parboiling process. The variables are soaking temperature and soaking time. ANOVA table was utilized to determine the level of significant among treatments. The difference among means was analyzed using DMRT.

3. RESULTS AND DISCUSSION

Characteristics of the parboiled rice samples

A total of eleven (11) rice varieties with moisture content ranging from 19.57 – 26.60% (wb) were collected from four (4) provinces of Agusan del Sur, North Cotabato, Palawan and Orriental Mindoro. Prior to parboiling experiment, all the samples were characterized in terms of variety, type, moisture content and purity (Table 1).

Table 1. Physical properties of the paddy samples

Variety	Type	Source of samples	Date of harvest	Purity, %	Initial MC, %
1. NSIC:Rc 118	Inbred	Agusan del Sur	6/5/2013	82.50±0.19	22.80±0.08
2. NSIC:Rc 254H	Hybrid	Agusan del Sur	6/5/2013	83.50±0.28	20.10±0.10
3. NSIC 238	Inbred	North Cotabato	8/13/2013	88.30±0.23	21.50±0.06
4. Selection 64	Inbred	North Cotabato	8/12/2013	86.40±0.06	20.10±0.13
5. Rc 158	Inbred	North Cotabato	8/13/2013	85.40±0.22	24.77±0.08
6. 75 days	Inbred	Palawan	7/22/2013	86.30±0.21	22.70±0.09
7. NSIC 216	Inbred	Palawan	7/23/2013	89.60±0.17	22.80±0.11
8. Japonica	Upland	Palawan	7/23/2013	87.10±0.32	26.60±0.07
9. Rc 18	Inbred	Orriental Mindoro	10/20/2013	83.00±0.15	21.03±0.10
10. PHB-77	Hybrid	Orriental Mindoro	10/20/2013	88.30±0.24	19.57±0.06
11. Rc 218	Inbred	Orriental Mindoro	10/20/2013	91.00±0.12	20.40±0.05

Effect of parboiling conditions on the physical quality of parboiled rice

The effect of different parboiling conditions in terms of the physical qualities e.g. milling recovery, percent head rice and whiteness were evaluated.

Milling recovery

Milling recovery is the amount of brown or milled rice (including brokens) obtained from a paddy sample. Table 2 shows the milling recovery of the parboiled brown rice after hulling. The rice varieties that yielded higher milling recoveries after parboiling include: NSIC:Rc 118=79.26% and NSIC:Rc-254H=77.20% (Agusan del Sur); NSIC 238=79.90%, Selection 64=78.46% and Rc 158=79.78% (North Cotabato); 75 days=75.74%, NSIC 216=79.01%, Japonica=79.69% (Palawan) and Rc 18=79.97%, PHB 77=79.90% and Rc 218=79.61% (Orriental Mindoro). The milling recovery increases as the soaking temperature and time increases. This can be attributed to the effect of gelatinization, which allows the husks to split more readily during milling. This confirms the results of Miah *et. al.* (2002) that gelatinization in rice has affected the physical quality of parboiled rice.

Table 2. Milling recovery of parboiled rice samples, %

Source/ Variety/ Soaking Temperature	Soaking Time, hr			AVERAGE
	1	2	3	
		Agusan del Sur		
NSIC:Rc 118				
40^{0}C	77.38±0.64	78.07±0.38	78.49±0.28	**77.98±0.46^b**
50^{0}C	77.52±0.45	78.36±0.48	78.65±0.28	**78.18±0.48^a**
60^{0}C	78.00±0.51	79.19±0.26	79.26±0.43	**78.82±0.58^a**
AVERAGE	**77.63±0.27^b**	**78.54±0.47^a**	**78.80±0.33^a**	
NSIC:Rc 254H				
40^{0}C	75.18±0.20	75.37±0.25	75.66±0.23	**75.40±0.20^b**
50^{0}C	75.48±0.19	75.85±0.40	76.12±0.47	**75.82±0.26^b**
60^{0}C	75.98±0.06	76.76±0.61	77.20±0.54	**76.65±0.50^a**
AVERAGE	**75.55±0.33^b**	**75.99±0.57^{ab}**	**76.33±0.64^a**	
		North Cotabato		
NSIC 238				
40^{0}C	76.85±0.51	78.59±0.72	78.79±0.24	**78.08±0.87^b**
50^{0}C	78.17±0.24	78.95±0.15	78.98±0.10	**78.70±0.38^b**
60^{0}C	78.79±0.79	79.56±0.31	79.90±0.05	**79.42±0.47^a**
AVERAGE	**77.94±0.81^b**	**79.03±0.40^a**	**79.22±0.49^a**	
Selection 64				
40^{0}C	77.35±0.25	77.63±0.22	77.92±0.59	**77.63±0.23^b**
50^{0}C	77.42±0.20	77.9±0.25	78.04±0.30	**77.81±0.28^b**
60^{0}C	77.66±0.29	78.44±0.16	78.46±0.14	**78.19±0.37^a**
AVERAGE	**77.48±0.13^b**	**78.01±0.33^a**	**78.14±0.23^a**	
Rc 158				
40^{0}C	77.36±0.08	78.17±0.23	78.33±0.26	**77.95±0.43^b**
50^{0}C	78.21±0.65	78.82±0.17	79.20±0.42	**78.74±0.41^b**
60^{0}C	78.65±0.39	79.16±0.27	79.78±0.08	**79.20±0.46^a**
AVERAGE	**78.07±0.54^b**	**78.72±0.41^a**	**79.10±0.51^a**	
		Palawan		
75 days				
40^{0}C	74.39±0.39	74.58±0.32	75.13±0.69	**74.70±0.31^b**
50^{0}C	74.50±0.28	74.94±0.35	75.46±0.12	**74.97±0.39^{ab}**
60^{0}C	74.83±0.47	75.27±0.24	75.74±0.15	**75.28±0.37^a**
AVERAGE	**74.57±0.19^b**	**74.93±0.28^{ab}**	**75.44±0.25^a**	
NSIC 216				
40^{0}C	75.29±0.13	75.65±0.23	75.83±0.43	**75.59±0.23^c**
50^{0}C	76.47±0.28	76.82±0.57	77.11±0.54	**76.80±0.26^b**
60^{0}C	77.73±0.31	78.18±0.86	79.01±0.30	**78.31±0.53^a**
AVERAGE	**76.50±1.00^b**	**76.88±1.03^{ab}**	**77.32±1.31^a**	
Japonica				
40^{0}C	77.62±0.29	78.38±0.37	78.83±0.17	**78.28±0.38^b**
50^{0}C	78.15±0.41	78.66±0.26	79.12±0.37	**78.64±0.25^{ab}**
60^{0}C	78.43±0.25	78.99±0.59	79.69±0.17	**79.04±0.28^a**
AVERAGE	**78.06±0.34^c**	**78.68±0.25^b**	**79.21±0.36^a**	
		Orriental Mindoro		
Rc 18				
40^{0}C	78.09±0.46	78.53±0.23	79.16±0.17	**78.59±0.44^b**
50^{0}C	78.25±0.22	78.68±0.05	79.59±0.16	**78.84±0.56^{ab}**
60^{0}C	78.64±0.18	79.08±0.42	79.97±0.01	**79.23±0.55^a**
AVERAGE	**78.33±0.23^b**	**78.76±0.23^b**	**79.57±0.33^a**	
PHB-77				
40^{0}C	77.25±0.06	77.44±0.24	77.80±0.31	**77.50±0.23c**
50^{0}C	78.02±0.31	78.5±0.25	79.16±0.20	**78.56±0.47b**
60^{0}C	78.51±0.17	79.49±0.41	79.90±0.05	**79.30±0.58a**
AVERAGE	**77.93±0.52^c**	**78.47±0.84^b**	**78.95±0.87^a**	
Rc 218				
40^{0}C	77.86±0.15	78.53±0.23	78.85±0.24	**78.41±0.41^b**
50^{0}C	77.99±0.48	78.87±0.21	79.30±0.24	**78.72±0.54^{ab}**
60^{0}C	78.52±0.17	78.96±0.41	79.61±0.11	**79.03±0.45^b**
AVERAGE	**78.12±0.29^b**	**78.78±0.19^a**	**79.25±0.31^a**	

Average of 3 replications. Means followed by the same letter(s) are not significantly different at 5% level using DMRT.

Results of analysis of variance revealed that there significant difference in the soaking temperature and period of soaking in all parboiled rice samples.

Percent Head rice

The percent head rice is equivalent to the weight of head grain or whole kernels including broken kernels with at least 75-80% of the whole kernel. This parameter is one of the most important criteria in measuring the quality of rice.

Table 3. Percent head rice of parboiled milled rice samples

Source/ Variety/ Soaking Temperature	Soaking Time, hr			AVERAGE
	1	2	3	
		Agusan del Sur		
NSIC:Rc 118				
40^0C	96.40±0.52	97.81±0.41	99.32±0.26	**97.84±1.19^b**
50^0C	97.79±0.19	98.48±0.29	99.52±0.19	**98.60±0.71^b**
60^0C	99.05±0.25	99.71±0.16	99.92±0.03	**99.56±0.37^a**
AVERAGE	**97.75±1.08^c**	**98.67±0.79^b**	**99.59±0.25^a**	
NSIC:Rc 254H				
40^0C	97.77±0.49	98.84±0.30	98.92±0.26	**98.51±0.52^b**
50^0C	98.09±0.47	98.92±0.32	99.16±0.13	**98.72±0.46^b**
60^0C	98.75±0.21	99.25±0.13	99.60±0.36	**99.20±0.35^a**
AVERAGE	**98.20±0.41^b**	**99.00±0.18^a**	**99.23±0.28^a**	
		North Cotabato		
NSIC 238				
40^0C	87.27±0.78	95.63±0.34	96.15±0.46	**93.02±4.07^c**
50^0C	89.35±0.15	96.74±0.93	97.24±0.12	**94.44±3.61^b**
60^0C	91.78±0.92	97.81±0.21	98.22±0.13	**95.94±2.94^a**
AVERAGE	**89.47±1.84^b**	**96.73±0.89^a**	**97.20±0.85^a**	
Selection 64				
40^0C	94.82±0.57	97.31±0.76	98.35±0.67	**96.83±1.48^c**
50^0C	96.97±0.72	98.06±0.45	99.15±0.31	**98.06±0.89^b**
60^0C	98.81±0.21	99.10±0.73	99.92±0.04	**99.28±0.47^a**
AVERAGE	**96.87±1.63^c**	**98.16±0.73^b**	**99.14±0.64^a**	
Rc 158				
40^0C	96.48±0.36	97.23±0.06	98.56±0.38	**97.42±0.86^c**
50^0C	97.86±0.21	98.38±0.21	99.11±0.23	**98.45±0.51^b**
60^0C	99.06±0.17	99.30±0.22	99.84±0.12	**99.40±0.33^a**
AVERAGE	**97.80±1.05^c**	**98.30±0.85^b**	**99.17±0.52^a**	
		Palawan		
75 days				
40^0C	99.49±0.10	99.63±0.04	99.79±0.04	**99.64±0.12^c**
50^0C	99.69±0.07	99.79±0.09	99.91±0.03	**99.80±0.09^b**
60^0C	99.89±0.02	99.95±0.02	99.98±0.02	**99.94±0.03^a**
AVERAGE	**99.69±0.17^c**	**99.79±0.13^b**	**99.89±0.08^a**	
NSIC 216				
40^0C	98.27±0.39	98.61±0.36	99.08±0.35	**98.66±0.17^c**
50^0C	98.54±0.16	98.99±0.30	99.56±0.2	**99.03±0.22^b**
60^0C	99.12±0.08	99.61±0.33	99.90±0.07	**99.54±0.24^a**
AVERAGE	**98.65±0.36^c**	**99.07±0.41^b**	**99.51±0.33^a**	
Japonica				
40^0C	99.19±0.15	99.64±0.07	99.79±0.06	**99.57±0.22^c**
50^0C	99.50±0.09	99.78±0.07	99.89±0.05	**99.73±0.14^b**
60^0C	99.69±0.12	99.92±0.01	99.98±0.01	**99.85±0.11^a**
AVERAGE	**99.46±0.21^c**	**99.78±0.12^b**	**99.92±0.08^a**	
		Orriental Mindoro		
Rc 18				
40^0C	98.66±0.08	98.72±0.43	99.16±0.07	**98.85±0.22^b**
50^0C	99.33±0.07	99.43±0.28	99.69±0.13	**99.49±0.15^a**
60^0C	99.48±0.44	99.82±0.14	99.87±0.11	**99.72±0.17^a**
AVERAGE	**99.16±0.36^b**	**99.33±0.46^{ab}**	**99.57±0.30^a**	
PHB-77				
40^0C	99.36±0.21	99.48±0.11	99.64±0.07	**99.49±0.11^b**
50^0C	99.44±0.14	99.60±0.04	99.73±0.18	**99.59±0.12^{ab}**
60^0C	99.57±0.08	99.68±0.17	99.84±0.08	**99.70±0.11^a**
AVERAGE	**99.46±0.09^b**	**99.59±0.08^{ab}**	**99.74±0.08^a**	
Rc 218				
40^0C	92.35±0.21	94.35±0.28	97.76±0.09	**94.82±2.23^c**
50^0C	93.22±0.76	95.88±0.04	98.74±0.55	**95.94±2.26^b**
60^0C	95.56±0.43	97.38±0.75	99.23±0.51	**97.39±1.50^a**
AVERAGE	**93.71±1.36^c**	**95.87±1.24^b**	**98.58±0.61^a**	

Average of 3 replications. Means followed by the same letter(s) are not significantly different at 5% level using DMRT.

As shown in Table 3, the rice varieties that yielded higher percent head rice after polishing include: NSIC:Rc 118=99.92% and NSIC:Rc 254H=99.60% (Agusan Del Sur); NSIC 238=98.22%, Selection 64=99.92%, and Rc 158=99.84% (North Cotabato); 75 days=99.98%, NSIC 216=99.90% and Japonica=99.98% (Palawan) and Rc 18=99.87%, PHB 77=99.84% and Rc 218=99.23% (Orriental Mindoro). The percent head rice recovery increases as the soaking temperature and time increases. This can be attributed to the degree of gelatinization of the rice kernel. Islam *et. al.* (2002) and Sareepuang *et. al.* (2008) described that during parboiling process, the starch and protein expand and fill in the internal spaces between granules. The starch granules are then closely compressed and create strong cohesion between them, resulting in reduction of fissures and cracks within the grains thereby producing higher percent head rice.

Table 4. *L*-Value (Whiteness) of parboiled milled rice samples

Source/ Variety/ Soaking Temperature	Soaking Time, hr			AVERAGE
	1	2	3	
		Agusan del Sur		
NSIC:Rc 118				
40^{0}C	64.01±0.51	63.39±0.30	62.1±0.56	**63.17±0.80^a**
50^{0}C	63.38±0.46	62.74±0.23	61.15±0.36	**62.42±0.94^b**
60^{0}C	62.69±0.36	61.98±0.20	60.93±0.34	**61.87±0.72^c**
AVERAGE	**63.36±0.54^a**	**62.70±0.58^b**	**61.39±0.51c**	
NSIC:Rc 254H				
40^{0}C	58.94±0.31	57.73±0.25	56.35±0.41	**57.67±1.06^a**
50^{0}C	55.35±0.32	54.21±0.35	53.79±0.24	**54.45±0.66^b**
60^{0}C	52.94±0.31	51.73±0.75	50.35±0.42	**51.67±1.06^c**
AVERAGE	**55.74±2.47^a**	**54.56±2.46^b**	**53.50±2.46^c**	
		North Cotabato		
NSIC 238				
40^{0}C	65.09±0.39	64.93±0.60	64.32±0.42	**64.78±0.33^a**
50^{0}C	64.61±0.46	64.43±0.51	63.26±0.51	**64.10±0.60^b**
60^{0}C	63.97±0.24	63.78±0.39	62.68±0.27	**63.48±0.57^c**
AVERAGE	**64.56±0.46^a**	**64.38±0.47^a**	**63.42±0.68^b**	
Selection 64				
40^{0}C	63.77±0.96	61.52±0.64	60.38±0.48	**61.89±1.41^a**
50^{0}C	62.28±0.47	60.58±0.54	60.00±0.02	**60.95±0.97^{ab}**
60^{0}C	60.52±0.93	59.91±0.59	59.43±0.65	**59.95±0.45^b**
AVERAGE	**62.19±1.33^a**	**60.67±0.66^b**	**59.94**±0.39^b	
Rc 158				
40^{0}C	63.62±0.24	63.14±0.36	62.87±0.24	**63.21±0.31^a**
50^{0}C	63.18±0.03	62.74±0.07	62.30±0.65	**62.74±0.36^{ab}**
60^{0}C	62.90±0.65	62.39±0.25	61.88±0.49	**62.39±0.42^b**
AVERAGE	**63.23±0.30^a**	**62.76±0.31^{ab}**	**62.35±0.41^b**	
		Palawan		
75 days				
40^{0}C	62.19±0.52	60.95±0.46	57.69±0.59	**60.28±0.62^a**
50^{0}C	59.91±0.24	58.88±0.18	56.95±0.15	**58.58±0.51^b**
60^{0}C	58.03±0.47	56.96±0.31	56.12±0.32	**57.03±0.54^c**
AVERAGE	**60.04±1.70^a**	**58.93±1.63^b**	**56.92±0.64^c**	
NSIC 216				
40^{0}C	64.44±0.35	63.17±0.63	62.21±0.62	**63.27±0.64^a**
50^{0}C	63.31±0.24	62.74±0.03	61.06±0.66	**62.37±0.28^b**
60^{0}C	62.49±0.62	62.34±0.16	60.49±0.22	**61.77±0.08^c**
AVERAGE	**63.41±0.80^a**	**62.75±0.34^b**	**61.25±0.72^c**	
Japonica				
40^{0}C	61.87±0.40	61.69±0.38	61.42±0.17	**61.66±0.09^a**
50^{0}C	61.20±0.02	61.08±0.09	60.58±0.50	**60.95±0.06^b**
60^{0}C	60.66±0.25	60.30±0.58	59.79±0.30	**60.25±0.18^c**
AVERAGE	**61.24±0.49^a**	**61.02±0.57^b**	**60.60±0.67^c**	
		Orriental Mindoro		
Rc 18				
40^{0}C	63.23±0.59	62.74±0.16	61.96±0.38	**62.64±0.24^a**
50^{0}C	62.56±0.34	61.60±0.45	61.17±0.75	**61.78±0.48^b**
60^{0}C	61.12±0.74	60.22±0.23	59.95±0.01	**60.43±0.45^b**
AVERAGE	**62.30±0.88^a**	**61.52±1.03^{ab}**	**61.03±0.83^b**	
PHB-77				
40^{0}C	61.60±0.32	60.79±0.46	59.58±0.49	**60.66±0.83^a**
50^{0}C	60.86±0.78	60.20±0.18	58.92±0.03	**59.99±0.81^b**
60^{0}C	59.97±0.46	59.43±0.57	58.19±0.19	**59.20±0.75^c**
AVERAGE	**60.81±0.67^a**	**60.14±0.56^b**	**58.90±0.57^c**	
Rc 218				
40^{0}C	62.67±0.39	62.18±0.20	61.80±0.27	**62.67±0.24^a**
50^{0}C	62.08±0.41	61.81±0.11	61.27±0.75	**62.08±0.13^b**
60^{0}C	61.61±0.11	61.02±0.45	60.73±0.22	**61.61±0.29^c**
AVERAGE	**62.12±0.44^a**	**61.67±0.49^{ab}**	**61.27±0.44^b**	

Average of 3 replications. Means followed by the same letter(s) are not significantly different at 5% level using DMRT.

Results of analysis of variance revealed that there significant difference in the soaking temperature and period of soaking in all parboiled rice samples.

L-Value (Whiteness)

One factor that influences the price of milled rice is its degree of whiteness. Whitening of rice is done by removing the silver skin and the bran layer during rice milling and polishing.

Table 4 shows the rice varieties which obtained the higher *L* values after polishing indicating higher degree of whiteness, include: NSIC:Rc 118=64.01 and NSIC:Rc 254H=58.94 (Agusan del Sur); NSIC 238=65.09, Selection 64=63.77 and Rc 158=63.62 (North Cotabato); 75 days=62.19, NSIC 216=64.44 and Japonica=61.87 (Palawan) and Rc 18=63.23, PHB 77=61.60 and Rc 218=62.67 (Orriental Mindoro). The *L* values of parboiled milled rice samples decreases as the soaking temperature and time increases. This revealed that lower soaking temperature and period of soaking were favorable to produce a whiter quality of parboiled rice. This result is in agreement with the observations of Islam *et. al.* (2002) who reported similar trend. Likewise, the present study corroborated with the report of Lu (1980), Kimura *et. al.* (1993) and Bhattacharaya *et. al.* (1996) who concluded that increasing the temperature and period of soaking significantly influence the discoloration of parboiled rice.

Results of analysis of variance revealed that there significant difference in the soaking temperature and period of soaking in all parboiled rice samples.

Comparison of the physical quality of parboiled rice and non-parboiled rice

The physical quality of the optimum parboiling conditions of the eleven rice varieties were selected and compared to non-parboiled rice as presented in Figure 1. Parboiling process significantly increases the milling and head rice recovery from 73.24% to 78.64% and 79.13% to 99.54%, respectively. The increase in the recovery can be associated in the increase of tensile strenght of kernel by starch granules inside the rice kernel after gelatinization, resulting reduction of grain breakage during milling operation. However, the whiteness value is decreased from 70.56 to 59.70 due to the discoloration of grains.

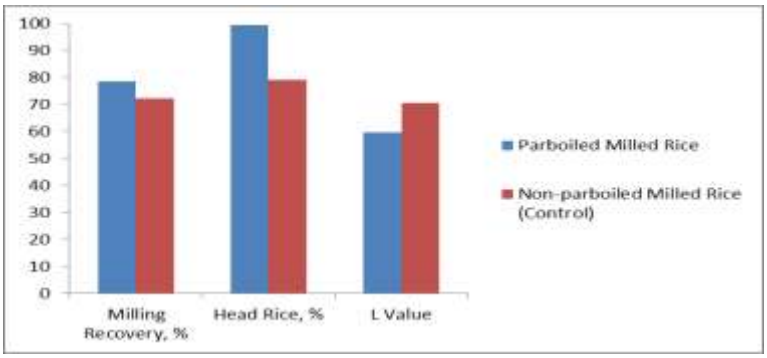

Figure 1. Percent milling recovery (a), percent head rice recovery (b), and *L* values (whiteness) (c) of parboiled and non-parboiled rice.

4. CONCLUSIONS

The parboiling process increases the milling and head rice recovery of selected rice varieties from 73.24% to 78.64% and 79.13% to 99.54%, respectively. However, a slight decrease in the whiteness value from 70.56 to 59.70 was observed.

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