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REGULAR ARTICLE

# Optimization of parboiling conditions for enhanced Japonica rice milling#

**Uyeh Daniel Dooyum, Seung Min Woo, Dong Hyuck Hong, Yu Shin Ha***

*Department of Bio Industrial Machinery Engineering, Kyungpook National University, Daegu 702-701, Korea*

## ABSTRACT

Indica type rice (a common staple in the world) is usually treated using the parboiling process. Loss in grain quantity and quality during this treatment is currently observed in many communities of the world. However, due to its non-availability in Korea, Japonica variety (a widely grown rice in Korea) was investigated in this study to establish optimal parboiling condition(s) for milling. The Taguchi $L_9$ ($3^4$) orthogonal array optimization method was adopted. To achieve quantity, optimal parboiling conditions peaked in moisture content of 27% after soaking; steaming temperature of 90°C for 40 minutes; and drying at a temperature of 35°C. There was a significant increase in the milling rate from 70.48% of the control to 74.97% of the best experimental result. Minitab analysis showed drying temperature to be the most significant factor for milling yield. In qualitative analyses, there were varied optimal conditions, but the conditions for quantitative analyses can be adopted since nutrients optimized at the same conditions as stated above. Nutrient analysis showed a significant increase of 2% and 1.4% in protein and amylose contents respectively when compared with the control. Findings from this study show that only a right combination of all factors can guarantee a good outcome from the parboiling process; it is better to skip the process than to perform it improperly. The degree of combination of factors is dependent on the variety. Therefore, studies should always be carried out on new developed varieties before parboiling commences.

**Keywords:** Milling; Optimization; Parboiling; Post-Harvest; Rice

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## INTRODUCTION

The process of parboiling is generally heat treatment done to paddy (Umogbai V.I., 2013). During this treatment, soaking, steaming and drying are the three steps essentially carried out. Gelatinization of starch takes place during the steaming process. This changes the physicochemical properties of rice (Kimura et al., 1991; Bhattacharya et al., 1966; Raghavendra et al., 1970; Gariboldi et al., 1972; Kimura et al., 1983; Itoh et al., 1985; Islam et al., 2001). Storage, cooking, milling, and eventually the final cooked grain are affected by this process.

Treated rice produced from high heat largely yield a colored grain. The worth of treated rice is significantly improved after parboiling at optimum conditions; but rough rice that is not properly parboiled gives lower quality product (Kimura et al., 1993; Bhattacharya, 1985). Consequently, treatment at lower heats (80 to 100°C) is recommended.

At the moment, major producers of rice in developing countries like Nigeria are also the largest consumers of parboiled rice (FAO 2016). Rice is treated by small holder farmers using rudimentary methods. They believe it increases head rice (head rice is a rice kernel possessing length equivalent to or larger than 3/4 of the average dimension of the unbroken kernel) yield and a tradition to be carried out without paying attention to other aftereffects especially loss of quantity and quality which includes non-uniformity of the final product. Other factors that cause this problem include the diversity of varieties, improper drying, etc. Many people in the world rely heavily on parboiled rice including those living below poverty threshold.

Parboiling treatment helps in preserving vitamins, minerals, losses of starch, destruction of infestation molds and insects and inactivation of lipases which further improves shelf life of rice bran (FAO 2015).

***Corresponding author:**
Yu Shin Ha, Department of Bio Industrial Machinery Engineering, Kyungpook National University, Daegu 702-701, Korea.
E-mail: yushin72@knu.ac.kr

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Using a pot made locally from mud or metal drum that has been cut into half the size, local rice processors in developing countries like Nigeria, treat paddy by steeping in cold water for a period ranging from two to three days. The grains are then steamed for an unestablished period. Drying is mostly done in a yard or any open space utilizing sunlight after which it is milled. Disadvantages such as improper gelatinization, discoloring and low market acceptability of the milled rice is recorded from this traditional method in addition to the long duration in completing this process which takes a minimum of 72 hours when there is intense sunlight and no rainfall. The method is also highly laborious, consuming a lot of man hours and energy (Obobi and Anazodo, 1987).

Rabiul et al., (2002) recommended that more studies should be done to advance conditions and equipment used for processing rice that would ensure improved grain quality, hence wider customer acceptance.

Due to the absence of the preferred variety which is usually Indica type, Japonica rice variety was used in this study. It is usually consumed raw without being parboiled. The factors mentioned above necessitates the need to optimize this process.

## MATERIALS AND METHODS

### Experimental design

The Taguchi $L_9$ ($3^4$) orthogonal array was selected for this study (Table 1). Nine experimental runs were carried out in triplicate and three control, making a total of thirty experiments.

### Sample

*Chil-bo* Japonica variety of rough rice gotten from Dalseong gun, Korea was used in this study. Indica variety of rough rice is the main type of rice used for parboiling. Due to the non-availability of this variety, Japonica variety, a widely grown rice in South Korea was adopted. The control was untreated paddy of Japonica rice variety.

### Soaking

Water bath shaker (AND, Korea) was used for steeping in tap water as described by Islam et al., (2012). Three different temperatures of 40°C, 60°C and 80°C were tested.

### Steaming

A device was fabricated to treat rice at different time and temperature combination (Figs. 1 and 2). It entails a steaming chamber with a perforated aluminum sample holder, a digital control system, a relay switch, pressure gauge, pressure valve, safety valve, water inlet and outlet points. Heat loss was reduced by insulating the parboiling device with a thick 10mm polyurethane foam. The digital control system regulated steam temperature in this stage. Pressure was controlled by pressure gauge and safety valves installed. To achieve accuracy, an analogue thermometer was installed alongside the digital thermometer. The method of steaming described by Islam et al., (2002) was adopted.

### Drying and moisture content determination

Drying was done using the hot air oven (VS-120203N, Vision scientific, Korea) referencing the recommended temperature for drying Japonica rough rice (Kim, 2009). The moisture content was determined using a single kernel moisture meter (PQ-510, Kett, Japan) as recommended by the Korean Society for Agricultural Machinery.

### Quantitative and qualitative analyses

Milling method described by Y. S Ha et al., (2002) was adopted in this study. A set of milling machine was used (Figs. 3-6). Specifications are shown (Table 2).

The Chatillon force measurement machine (LTCM100 EU, Amatek, United States) was used in this study to determine hardness as described by Islam et al., (2012). Component analyzer (AN-820, KETT, Japan) was used to determine protein and amylose content. Side stationary spectral color system (JS- 555, System Co. Ltd, Japan) was used to determine color intensity and lightness. Both were done using standard procedure recommended by the manufacturers.

### Statistical analysis

The Minitab software version 14 was used to analyze data. The impact of the different factors showing the most

**Table 1: Experimental design using Taguchi orthogonal array**

| Exp. no | M.C (%) | Steaming time (Mins) | Steaming temp (°C) | Drying temp (°C) |
|---|---|---|---|---|
| 1 | 24 | 20 | 50 | 35 |
| 2 | 24 | 40 | 70 | 45 |
| 3 | 24 | 60 | 90 | 55 |
| 4 | 27 | 20 | 70 | 55 |
| 5 | 27 | 40 | 90 | 35 |
| 6 | 27 | 60 | 50 | 45 |
| 7 | 30 | 20 | 90 | 45 |
| 8 | 30 | 40 | 50 | 55 |
| 9 | 30 | 60 | 70 | 35 |

**Table 2: Specification of huller and miller**

| Machine | Model | Manufacturer | Maximum capacity |
|---|---|---|---|
| Huller | SY-88-TH | Ssang yong (Korea) | 100 gram/round |
| Miller | | | |
| Abrasive type | TM05 | Satake (Japan) | 200 gram/round |
| Friction type | SY-92-TR | Ssang yong (Korea) | 100gram/round |

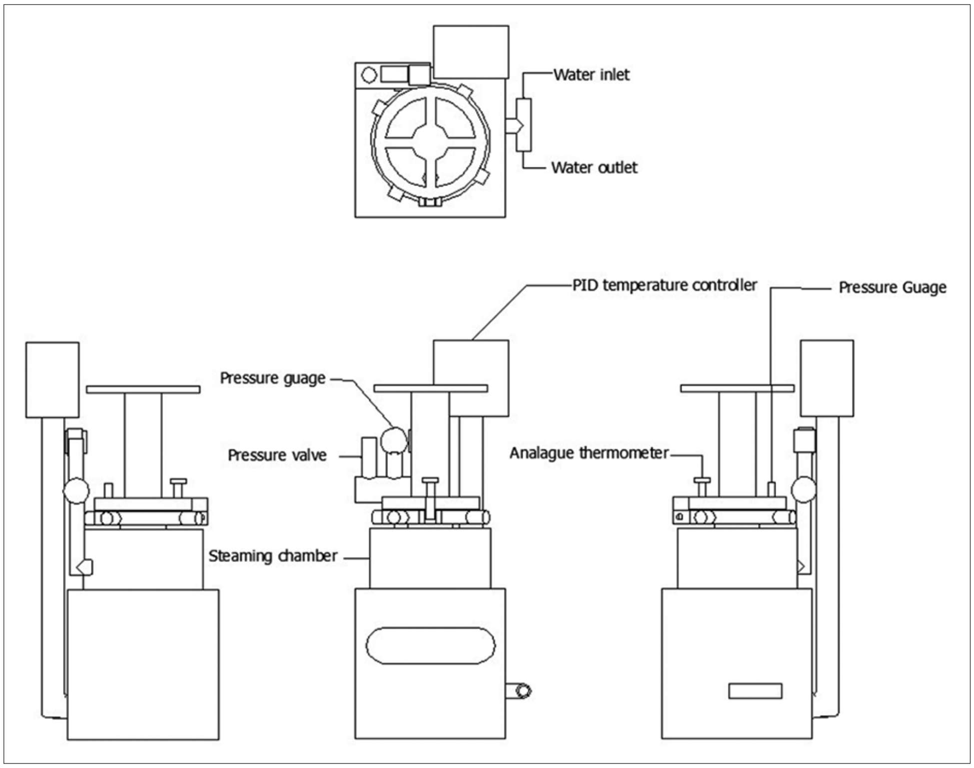


**Fig 1.** Schematic diagram of the fabricated parboil device.

**Fig 2.** Pictorial view of fabricated device.

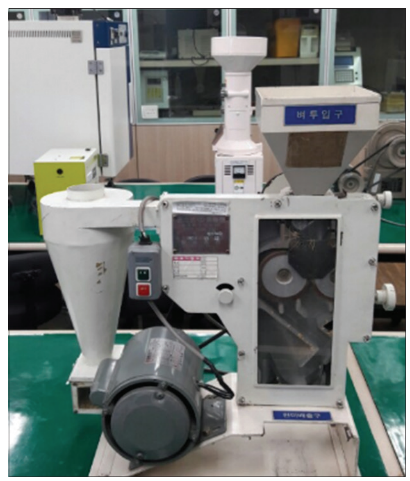

**Fig 3.** The huller.

significant to the least in order of one to four is displayed with Signal to Noise ratio (S/N) (Neter, J.et al., 1996).

## RESULTS AND DISCUSSION

The Taguchi method used in this study was effective as the quantitative and qualitative parameters of the Japonica type rice was considerably optimized at minimal experimental runs.

### Moisture content

Moisture content increased with a rise in temperature (Fig. 7). From this study, it was gathered that moisture content of Japonica paddy can be raised to between 23-30% from a moisture range of 12-14% in 30 minutes depending on the soaking temperature.

Previous studies carried out by different scholars showed that moisture content range of around 30% is needed for gelatinization of starch dependent on steeping conditions. Several studies show that steaming paddy possessing content of 25-35% moisture can be gelatinized totally without an upsurge in content of moisture. This was also observed in this study. Bhattacharya, (1985) reported that regular parboiling requires moisture content of around

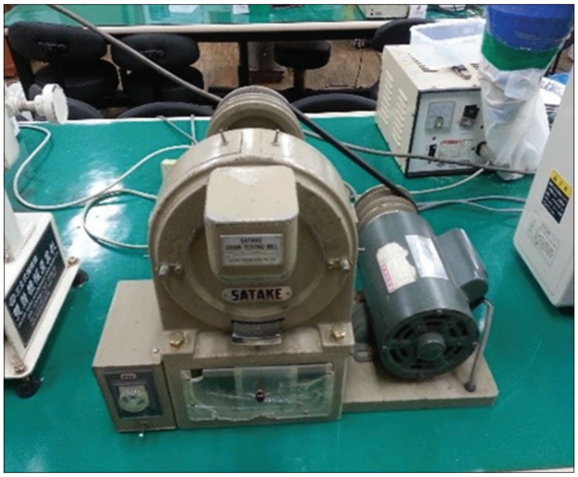


Fig 4. Abrasive type miller.

Fig 6. Cylindrical length grade.


Fig 5. Friction type miller.

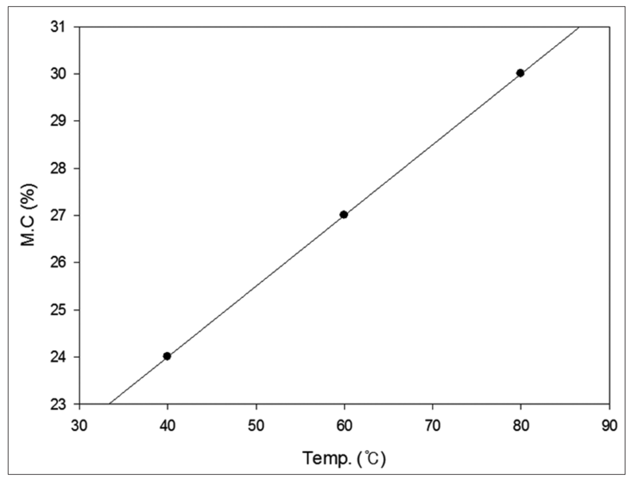


Fig 7. Hydration behavior of the Japonica rice at different temperatures.

35%. Higher moisture content lead to husk tearing apart, leading to undesirable characteristics such as deshaping of the kernel, leaching, etc. (Bhattacharya, 1985). The soaking process as observed from this study is a critical step that has to be carried out with caution. This research also showed that soaking rate is varietal dependent and this is in agreement with earlier report of Ali and Ojha, (1975).

### Quantitative analysis

Hardness and milling yield are some of the main parameters that determine quantity in milled rice.

#### *Hardness and milling yield*

Hardness is an important parameter in the process of parboiling. The results of this study fall in line with many researchers' suggestions, including a study by Islam M.R. et al., (2002) showing improved hardness with upsurge in temperatures of steaming.

Nevertheless, other experimental runs suggest that hardness is also a function of other factors such as balance of starch gelatinization, elapsed time etc. as suggested by Ali & Pandya, (1974); Pillaiyar & Mohandoss, (1981); Bhattacharya, (1985); Itoh & Kawamura, (1985); Kimura, (1991) and Islam et al., (2001) respectively.

The optimal condition was obtained in experiment 5 which had conditions of M.C. of 27, steaming at 90°C for 40 minutes and drying at 35°C (Table 3).

The relationship between hardness and milling yield was observed as shown with the same optimal condition and simultaneous increase in head rice yield with increase in hardness. Bhattacharya & SubbaRao, (1966) suggested there was a remarkable improvement in milling recovery as a result of parboiling treatment. This study showed that the claim by Bhattacharya and SubbaRao, (1966) is only true if the process is carried out at optimal conditions. In this research, it is clear that combining treatment factors improperly can rather bring a decline in milling yield as shown with a milling yield of 51.33%, 56.99%, 61.03%, 62.37%, 54.39% and 65.12% in some of the experimental runs (Table 4). Notwithstanding, the parboiling process, if done properly, hardness is impacted to the grains leading to resistance to breakage thus increasing milling yield in line with Garibaldi's, (1974) findings.

A significant increase in milling rate, a major quality parameter from 70.48% of the control and 70.7% from a reported study (Ha et al., 2002) to 74.97% of the best result was observed (Table 4).

Drying temperature was the most significant factor in milling yield with steaming temperature ranking second (Fig. 8). The optimal condition was experiment 5 (M.C. of 27, steaming at 90°C for 40 minutes and drying at 35°C).

Though the variety used in this study is different from the variety frequently used in parboiling, comparison with the situation in developing country like Nigeria, which is the largest producer in the region sub Saharan Africa (Chuma, 2005), showed that difference in the milling rate is largely significant. The 74.97% of the best experimental run shows a sharp drift from the situation obtainable and also referencing the 75% that is achievable (Tinsley, 2012).

A personal visit to local rice mills in Nigeria revealed a 40-50% head rice recovery rate indicating huge losses. This visit also found that one ton of milled rice costs about $400 at peak periods in 2015 according to the resident Rice Farmers Association. A 10% increase in head rice of 1 ton is equivalent to 0.1 tons, which costs about $40. Consequently, for every 1 ton of rice milled, $40 is lost.

This loss becomes huge as current statistics show the country has locally produced 2,709,000 metric tons of milled rice annually (USDA, 2016). Saving 10% of the total annual production can save the entire economy an estimated $108,360,000 (One hundred and eight million, three hundred and sixty thousand US dollars). It will also upsurge production and reduce imports by over 10% considering Nigeria imported 2,500,000 metric tons of milled rice in 2015 (USDA, 2015).

The Minitab software used to analyze the impact of the different factors showed from the analysis that drying temperature is the most significant factor in milling yield with steaming temperature ranking second. This is in contrast to many views by previous works that the parboiling process is totally determined by steaming temperature. A proper combination of factors which includes steaming time, soaking moisture content, drying temperature and final moisture content alone can guarantee a good milling yield. Verification was ascertained where the same steaming temperature was used with different factor combinations resulted in a very poor milling yield in the other Taguchi experimental runs.

### Qualitative analysis

Nutritional analysis and color were the parameters examined.

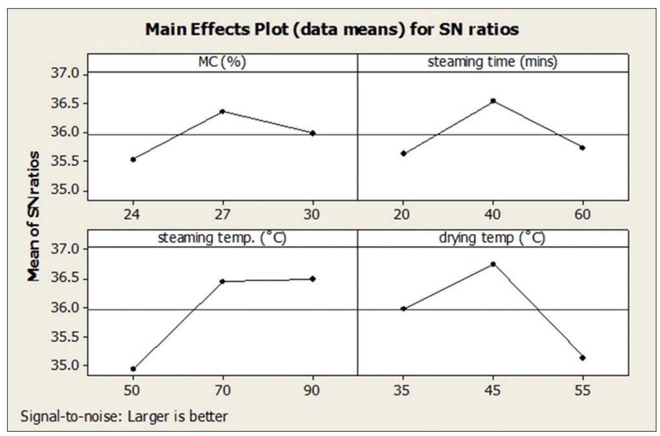


**Fig 8.** Minitab plot showing signal to noise ratio for milling yield analysis.

**Table 3: Hardness of brown rice**

| Exp. No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Result (N) | 61.20 | 83.25 | 67.93 | 69.58 | 87.54 | 70.46 | 82.65 | 66.32 | 77.45 |
| S/N (Value) | 37.73 | 38.41 | 36.64 | 36.85 | 38.84 | 36.96 | 38.34 | 36.43 | 37.78 |

**Table 4: Milled rice recovery**

| Exp. No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Result (%) | 51.88 | 73.99 | 56.36 | 61.03 | 74.97 | 62.37 | 70.47 | 54.39 | 65.12 |
| S/N (Value) | 34.21 | 37.38 | 35.02 | 35.71 | 37.50 | 35.90 | 36.96 | 34.71 | 36.27 |

**Table 5: Protein content of milled rice**

| Exp. No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Result (%) | 6.20 | 7.10 | 8.17 | 7.00 | 8.30 | 6.77 | 7.67 | 7.23 | 7.40 |
| S/N (Value) | 34.21 | 37.38 | 35.02 | 35.71 | 37.50 | 35.90 | 36.96 | 34.71 | 36.27 |

### *Nutritional analysis*

Analysis of nutritional content which has not received due attention by researchers (Ayamdoo, 2014) showed that steaming temperature played an important role in optimizing nutrient content of parboiled rice.

The optimal conditions for protein and amylose was experiment 5 which was M.C. of 27, steaming at 90°C for 40 minutes and drying at 35°C (Tables 5 and 6). This condition was the same with that of quantitative analysis of hardness and milling yield.

Minitab Taguchi analysis showed that drying temperature and steaming temperature were the most important factors in optimizing the protein and amylose content of parboiled rice respectively. This study showed a significant increase of 2% and 1.4% in protein and amylose content from the control. This depicts that temperature is very important in optimizing and denaturing nutrient (FAO/WHO, 1970; Padua and Juliano, 1974) and should therefore be applied carefully in laid down procedures. If carried out properly, this could help solve the issue of nutrient malnutrition in rice consuming countries and help solve the problem of hidden hunger in these nations.

It is worth noting that most poor and developing countries rely on rice for their daily calorie intake. They most often do not have access to other source of nutrients. The findings of this study can help improve the process of parboiling rice that will not only improve head rice recovery rate but also capture more nutrients.

Increase in rice production from postharvest technology means there will be more rice at almost the same cost of production, resulting in a better return on investment for families depending on rice for sustenance. This will give more people access to the cereal and increased nutrients intake per meal consumed without them having to increase meal rations.

### *Color*

Steaming temperature had the most significant impact on the intensity of color and lightness of the treated grain from the Minitab analysis. 25.58Wm$^{-2}$ was seen as the highest value of color intensity drifting from the 13.65Wm$^{-2}$ value of the control (Tables 7 and 8).

In this parameter, it was observed that treatment at lower temperature does not severely affect the color. This ratifies the suggestions of Bhattacharya, (1985); Kimura et al., (1993) that parboiling treatment, especially at higher temperatures directly affects the color of treated rice.

However, the major outcome usually given attention is uniformity of the grain and not whiteness of the grain as seen in the report of Tinsley, (2012) were all the parboiled grains had varied colors that were not white. Results of this study showed uniformity in the color of the grain when the triplicate analysis of the samples were done.

## CONCLUSION AND SUMMARY

Loss in grain quantity and quality during parboil treatment is currently observed in many developing countries of the world. Japonica rice variety (a widely grown rice in Korea) was subjected to a series of tests instead of Indica type rice (a common staple in the world) which is usually treated using this process. This was done to find optimal conditions for parboiling rice, by establishing problems in the process and recommending solutions. The Taguchi $L_9$ ($3^4$) orthogonal array optimization method was adopted.

This research showed that for quantitative analyses, the optimal conditions where moisture content of 27% after soaking, steaming temperature of 90°C for 40 minutes and drying at a temperature of 35°C. Qualitative analyses showed varied optimal conditions. The best condition for optimizing nutrients was different from other parameters

**Table 6: Amylose content of milled rice**

| Exp. No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Result (%) | 17.93 | 18.33 | 19.03 | 18.53 | 19.43 | 18.20 | 19.37 | 18.37 | 18.87 |
| S/N (Value) | 25.07 | 25.26 | 25.59 | 25.36 | 25.77 | 25.20 | 25.74 | 25.28 | 25.51 |

**Table 7: Color intensity of milled rice**

| Exp. No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Result (Wm$^{-2}$) | 15.83 | 20.06 | 25.58 | 17.80 | 24.02 | 16.47 | 20.46 | 20.39 | 19.09 |
| S/N (Value) | –24.08 | –26.11 | –28.16 | –25.10 | –27.62 | –24.43 | –26.27 | –26.23 | –25.66 |

**Table 8: Lightness of milled rice**

| Exp. No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Result | 75.05 | 72.10 | 66.26 | 71.15 | 64.10 | 73.51 | 66.91 | 70.88 | 68.97 |
| S/N (Value) | 37.51 | 37.16 | 36.42 | 37.04 | 36.12 | 37.33 | 36.51 | 37.01 | 36.77 |

in this analyses, however, the main parameter in qualitative analyses is nutrient content which optimized at the same condition with quantitative analyses. The whole process of parboiling from soaking to drying took a duration of about 18 hours instead of the minimum of 72 hours in the traditional system. The results obtained from this study can be summarized as follows:

a. It is better to skip the parboiling process than to perform the process improperly. Unfortunately, improper parboiling of rice is a custom in most of the developing countries where there is heavy dependence on rice.
b. Variety of rice plays a vital role in the degree to which the factors should be combined during the parboiling process. Research should always be carried out on new developed varieties before parboiling commences.
c. Parboiling process has an impact on rice in diverse ways. It affects the color intensity, lightness, impacts hardness and increases milling yield, etc.
d. Different lots of paddy with different initial moisture contents can be mixed safely for parboiling without any loss in quality or quantity.
e. Proper parboiling of rice will have significant impact on human health especially in rice consuming nations.

Conclusively, the optimal conditions for quantity can be adopted for parboiling Japonica type rice since nutrient analyses had the same optimal condition with the major parameter in quantitative analyses; milling yield. The grain also lost its whiteness, but uniformity in color was observed.

## ACKNOWLEDGEMENT

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### Authors' contributions

Uyeh Daniel Dooyum, designed the study, did analyses, and wrote the article, Seung Min Woo, designed the study, did analyses and corrected the article, Dong Hyuck Hong and Yu Shin Ha, designed the study and corrected the article.

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