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Original Research Article

Study on the Potential of MARDI Specialty Rice for the Production of Local Parboiled Rice

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Abstract: Producing specialty rice varieties with unique qualities is an essential research focus at MARDI. Additionally, producing parboiled rice from local specialty varieties adds value to the rice industry. This study evaluated two local specialty rice varieties, MRQ 107 and MRQ 111, for their potential in parboiled rice production. Optimal processing parameters for both varieties resulted in a high milling rice recovery (MRR) percentage of 68-69%. The physical quality analysis showed that head rice yield (HRY) reached 97%, with only 3% broken rice. A study on the effect of storage duration indicated that the physicochemical characteristics of the parboiled rice fell into the soft category for gel consistency, meaning the cooked rice had a tender and cohesive texture. The cooking time for the parboiled rice was 23 minutes, with a lower solid loss than the control sample. Nutritional analysis revealed that the local specialty parboiled rice had increased protein and mineral content, including calcium and magnesium. Additionally, the content of folic acid, resistant starch, and dietary fiber was double that of the control samples.

Keywords: Specialty rice; MRQ 107; MRQ 111; parboiled rice; physical quality; physicochemical characterization; nutritional analysis

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1. Introduction

In Malaysia, the paddy and rice industry is a crucial agricultural subsector that the government has prioritized due to its impact on food supply and security. Additionally, paddy cultivation and rice production are significant sources of income for many farmers in the country. To meet the population's dietary needs, Malaysia imports 30% to 40% of its rice from foreign countries, including specialty rice varieties. The import volume of specialty rice has steadily increased, from 154,000 metric tons in 2010 to 279,000 metric tons in 2020, with demand growing at an average rate of 5.56% annually (Nik Rahimah *et al*., 2020). Socio-economic changes drive this rise as consumers seek high-quality, nutritious, healthy food options. Since the early 1990s, MARDI has focused on developing specialty rice varieties with distinctive qualities. These varieties include rice that elongates when cooked, like Basmati, and soft-textured, aromatic varieties akin to Jasmine rice. MARDI has developed over ten specialty rice varieties, including glutinous and coloured rice (Site Noorzuraini *et al*.,2020). Producing parboiled rice from these varieties is seen as introducing value-added, premium products to diversify further and maximise the potential of local specialty rice varieties. This aligns with Malaysians' growing preference for health-conscious diets and diverse flavours. Parboiled rice is well-known for its superior nutritional value to ordinary white rice. Globally, approximately 130 million tonnes of paddy are parboiled annually, with 3–4 million tonnes of high-value parboiled rice entering international trade (Kwofi *et al*., 2016). In 2015 Malaysia imported 18,582 metric tons of parboiled rice to meet domestic demand (DOA, 2015) while exporting 2,347 metric tons of well-milled parboiled rice. In line with the National Agri-Food Policy 2021–2030 (DAN 2.0), which aims to capitalize on local specialty rice varieties, MARDI has conducted a study to produce premium parboiled rice from two specialty rice varieties: MRQ 107 and MRQ 111.

2. Materials and Methods

2.1. Parboiled Rice Production

Parboiled rice production differs slightly from whole-milled white rice processing, involving two additional stages: soaking and steaming. The detailed processing for both MRQ 107 and MRQ 111 is described below:

2.1.1. MRQ 107 and MRQ 111 harvesting

MRQ 107 and MRQ 111 paddy samples were harvested from research plots in MARDI Seberang Perai, Pulau Pinang. The harvested samples were collected at 85% maturity, which means that 80−85% of the grains are straw with yellow-coloured (IRRI, 2013). The paddy sample was then cleaned by separating from its straw and foreign matter using an aspirator machine before drying in a cabinet dryer at <45ºC. This temperature is used since it does not affect rice's cooking and eating qualities (Inprasit *et al*., 2006). The drying process stops once the moisture reaches 12.0–13.5% before storing in the cold room at 5ºC–10ºC for further processing.

2.1.2. Soaking process and steaming process

135g of MRQ 107 and MRQ 111 paddy was soaked with clean water at different water temperatures (65–75ºC) for 2–4 hours, then steamed for 15–45 minutes at 110ºC.

2.1.3. Second stage drying

The paddy samples underwent a second drying stage using the same parameters as the first, as mentioned in 2.1.1. with a drying temperature of 45ºC in a cabinet dryer. This process ensured that the samples reached the ideal moisture content of 12.0–13.5% before proceeding to storage.

2.1.4. Milling processing

The dried paddy was ready for the subsequent milling process to produce parboiled rice. The milling process consists of several stages of dehusking using a dehusking machine (THU35B, Satake, Japan), whitening and polishing by using a polishing machine (TM05C, Satake, Japan) and grading process using a cylindrical grading machine (TRG05B, Satake, Japan). Meanwhile, the brown rice was also produced by dehusking the paddy using a rice dehusker machine, a similar model as mentioned above.

2.2. Storage Study

The storage study of MRQ 107 and MRQ 111 parboiled rice was conducted using two different packaging techniques, vacuum and non-vacuum, in nylon-PE packaging material with a 0.08 mm thickness. The storage conditions were cold and ambient. Each sample, weighing 500 g, was stored for up to 6 months. The rice's physical quality and physicochemical characteristics were evaluated at 0, 2, 4, and 6 months during the storage period.

2.3. Physical Quality, Physicochemical Properties, and Nutritional Analysis

2.3.1. Determination of physical quality

The milling rice recovery (MRR) and head rice yield (HRY) were evaluated. The parboiled rice (200 g) was produced following the methodology in 2.1.5. The rice yield was calculated based on the formula below:

Milling Rice Recovery, MRR (%) = Weight of rice / weight of paddy x 100 (1)

Head Rice Yield, HRY (%) = Weight of head rice / weight of rice x 100 (2)

2.3.2. Determination of physicochemical properties

2.3.2.1. Gel Consistency

Gel consistency was achieved using the referring method suggested by Cagambang *et al*. (1973), where 0.1 g of rice powder was treated with 0.2 ml of 95% ethanol and 0.025% thymol blue. All the content was thoroughly mixed by vortex, and 2.0ml of 0.2N potassium hydroxide (KOH) was immediately before their vortex. The reaction mixture was placed in boiling water for 8–10 minutes and cooled down in ice for 15–20 minutes. The gel length was measured by laying the tube with the reaction mixture over graph paper after 30–60 minutes.

2.3.2.2. Cooking time

Five grams of head rice was put in 250 ml distilled water and was heated. After 10 min, 10 grains of head rice were checked every minute to ensure they were thoroughly cooked. This was done by observing the head rice become soft and elongated. The rice's cooking time was recorded, and the test was done in triplicate.

2.3.2.3. Total solid loss (TSL)

The total solid loss (also known as the degree of agglutination) is the rate of solid loss during cooking. This was done by taking 10 ml of the water used when cooking rice and placing it in a pre-weighed crucible. The crucible was then placed in an oven UF160 (Memmert, USA) at 110°C for 2.5 hours and cooled in a desiccator for one hour before recording its weight.

Total Solid loss = (weight of dried solid + crucible) - empty crucible (3)

The entire test on physical quality and physicochemical characterization data was analyzed using the software Statistical Analysis System (SAS) version 9.4. ANOVA analysis of variance was applied, and the means were compared based on the Least Significant Difference (LSD) test at $p = 0.05$ probability level.

2.3.2. Nutritional analysis

Nutritional analysis that has been implemented includes assessing the proximate components of rice grains, such as moisture content and ash, as well as the nutritional content.

The analysis was measured by following standard procedures described by the American Association of Cereal Chemists and Association of Official Agricultural Chemists protocols (Horwitz,1982).

3. Results and Discussions

3.1. Production of MRQ 107 and MRQ 111 Parboiled Rice

Parboiled rice processing using the involved parameters of soaking and steaming time together with different temperatures has contributed to the quality of parboiled rice milling, as shown in Table 1. This data displayed the optimal processing parameter from a series of analyses described in 2.1.2 (soaking and steaming method). The result shown for MRQ 107 at a temperature of 70ºC with a soaking time of 4 hours and a steaming time of 45 minutes has produced 76.00% brown rice yield with a milling recovery percentage of 69.36%. Furthermore, the yield fractions for head rice yield (HRY) and the broken rice were 96.62% and 3.38%, respectively. For MRQ 111, parboiled rice processed at a temperature of 75ºC, with a soaking time of 2 hours and a steaming duration of 45 minutes, resulted in a brown rice yield of 74.67% and a milled rice recovery of 68.47%. A high percentage of head rice exceeding 97% with broken rice at a minimum of 2.27% has also been achieved from processing parboiled rice using the ideal parameters determined for MRQ 111.

Table 1. Parameters for Processing Parboiled Rice Using Varieties MRQ 107 and MRQ 111.

Variety	Temp (°C)	Soaking Time (hours)	Steaming Time (minutes)	Brown Rice Yield (%)	Milling Recovery (%)	Head Rice Yield (%)	Broken Rice (%)
MRQ 107	70	4	45	76.00 ± 0.48	69.36 ± 0.44	96.62 ±0.76	3.38 ± 0.76
MRQ 111	75	2	45	74.67 ±1.30	68.47 ± 1.62	97.73 ±0.28	2.27 ± 0.28

3.2. Effect of Storage Period on the Physicochemical Characteristics of Parboiled Rice

Table 2 shows the physicochemical characteristics of MRQ 107 and MRQ111 parboiled rice. In the initial storage period (0 months), a comparison of physicochemical characteristics between parboiled rice and the control sample (white milled rice) was also conducted. A significant difference between the gel consistency (GC) values for parboiled rice and the white rice control sample for MRQ 107 and MRQ 111 has been recorded.

Table 2. Physicochemical characteristics of parboiled rice MRQ 107 and MRQ 111 over storage period and techniques

Storage duration	**Sample/ Parameter**	**MRQ 107** Gel Consistency (mm)	Cooking Time (min)	Total Solid Loss (g/100g)	**MRQ 111** Gel Consistency (mm)	Cooking Time (min)	Total Solid Loss (g/100g)
0 Month	White Milled Rice (Control)	44.00 ± 0.00^{c}	18.15 ± 0.01^{b}	0.63 ± 0.00^{a}	53.00 ± 0.00^{d}	20.30 ± 0.00^{b}	0.79 ± 0.01^{a}
	Parboiled Rice	70.00 ± 0.00^{a}	23.45 ± 0.01^{a}	0.53 ± 0.01^{b}	66.67 ± 0.01^{c}	23.35 ± 0.00^{a}	0.50 ± 0.01^{c}
2 Month	NV-Cold	68.67 ± 0.00^{b}	23.40 ± 0.00^{a}	0.50 ± 0.04^{b}	60.00 ± 0.02^{c}	23.45 ± 0.09^{a}	0.65 ± 0.02^{b}
	NV-Ambient	68.00 ± 0.00^{b}	23.35 ± 0.01^{a}	0.54 ± 0.01^{b}	70.67 ± 0.01^{b}	23.45 ± 0.00^{a}	0.66 ± 0.01^{b}
	Vacuum-Cold	68.67 ± 0.03^{b}	23.45 ± 0.00^{a}	0.58 ± 0.02^{b}	70.66 ± 0.01^{b}	23.35 ± 0.02^{a}	0.65 ± 0.00^{b}
	Vacuum-Ambient	72.67 ± 0.01^{a}	23.45 ± 0.00^{a}	0.50 ± 0.01^{bc}	70.00 ± 0.00^{b}	23.40 ± 0.04^{a}	0.66 ± 0.00^{b}
4 Month	NV-Cold	73.30 ± 0.00^{ab}	23.45 ± 0.00^{a}	0.57 ± 0.00^{b}	80.00 ± 0.02^{a}	23.35 ± 0.01^{a}	0.60 ± 0.01^{b}
	NV-Ambient	74.67 ± 0.00^{ab}	23.45 ± 0.00^{a}	0.41 ± 0.00^{c}	75.33 ± 0.03^{a}	23.92 ± 0.01^{a}	0.63 ± 0.01^{b}
	Vacuum-Cold	72.00 ± 0.00^{b}	23.40 ± 0.01^{a}	0.62 ± 0.01^{c}	80.00 ± 0.01^{a}	23.4 ± 0.00^{a}	0.56 ± 0.02^{bc}
	Vacuum-Ambient	60.00 ± 0.02^{b}	23.40 ± 0.00^{a}	0.40 ± 0.00^{c}	74.3 ± 0.02^{ab}	23.45 ± 0.02^{a}	0.59 ± 0.01^{b}
6 Month	NV-Cold	78.67 ± 0.01^{a}	23.68 ± 0.02^{a}	0.60 ± 0.00^{a}	71.22 ± 0.03^{b}	23.91± 0.01^{a}	0.59 ± 0.00^{b}
	NV-Ambient	75.30 ± 0.01^{a}	23.68 ± 0.01^{a}	0.64 ± 0.00^{a}	78.30 ± 0.06^{a}	23.92 ± 0.05^{a}	0.53 ± 0.00^{c}
	Vacuum-Cold	74.60±0.00^{ab}	23.68 ± 0.01^{a}	0.39 ± 0.01^{c}	67.20 ± 0.00^{c}	23.92 ± 0.01^{a}	0.53 ± 0.01^{c}
	Vacuum-Ambient	68.67 ±0.00b	23.92 ± 0.01^{a}	0.62 ± 0.00^{a}	69.00 ± 0.03^{b}	23.68 ± 0.03^{a}	0.57 ± 0.01^{c}

The means within a factor and column followed by different letters differ significantly at $p < 0.05$ using the LSD test.

The gel consistency (GC) values for parboiled rice MRQ 107 and MRQ 111 were 70.00 ± 0.00 mm and 66.67 ± 0.01 mm, respectively, falling under the soft gel consistency category. In contrast, white rice MRQ 107 and MRQ 111 are classified as having medium GC, with values of 44.00 ± 0.00 mm and 53.00 ± 0.00 mm, respectively. This result indicated that parboiled and white rice have different textures and firmness, which is related to the starch gelatinization within the rice grain upon cooking (Juliano & Bechtel, 1985). Parboiled rice with soft GC displayed that it suggested becoming tender and sticky and absorbing more water while easily breaking down during cook due to the soft texture. Meanwhile, white rice with medium GC exhibited a firmer texture since it can absorb less water. The rice is less sticky, and the grain can retain more shape after cooking

Regarding cooking time, it was observed that the white rice as control samples and parboiled rice takes time within 20–23 minutes. Parboiled rice takes slightly longer to cook than white rice. This is assumed because parboiled rice is steamed with the husk and bran intact and then dried. After drying, the husk is removed, but some bran remains, making it a middle ground between brown and white rice, thus contributing to longer cooking than white rice and probably less time than brown rice. The total solid loss (TSL) values also showed significant differences, with parboiled rice showing lower TSL values at 0.53 ± 0.01 (for parboiled rice MRQ 107) and 0.50 ± 0.01 (for boiled rice MRQ 111) compared to white rice, which at 0.63 ± 0.00 (for white rice MRQ 107) and 0.50 ± 0.01 (for white rice MRQ 111), respectively. For the storage period after 2 months, parboiled rice MRQ 107 showed GC values exceeding 61 mm, indicating a soft gel consistency (GC in the range of 61-100 mm) in all storage conditions. Cooking time also showed no significant changes, with consistent cooking times ranging from 23.35 ± 0.01 to 23.45 ± 0.00 minutes. TSL values were also not significantly different since the value ranged from 0.50 ± 0.01 (g/100g) to 0.58 ± 0.02 (g/100g). Parboiled rice MRQ 111 also showed GC values with the same trend as parboiled rice MRQ 107, with all samples reaching values above 61.00 mm. Significant differences can be seen in samples stored in PE-Nylon packaging at cold temperatures, which recorded GC values at 60.00 ± 0.02 mm compared to other storage conditions that remained consistent at 70.00 mm. Parboiled rice MRQ 111 showed no significant differences in cooking time and TSL values in all storage conditions.

For the 4-month storage period, GC values for vacuum-packed parboiled rice MRQ 107 at ambient temperature showed significant differences compared to other packaging conditions. GC values in this packaging condition were below 61.00 mm and categorized as medium GC (range of 41-60 mm). This differs from parboiled rice in other packaging conditions, maintaining a soft texture with consistent GC values above 70.00 mm. No significant differences were observed in cooking time. However, TSL values in samples stored in PE-Nylon packaging at cold temperatures showed significantly different TSL values than other packaging conditions. GC for parboiled rice MRQ 111 also showed differences in vacuum packaging storage at room temperature compared to others, although the overall GC values were above 70.00 mm. There were no significant differences in cooking time after 4 months of storage, which was at 23 minutes, and solid loss was in the range of 0.56g/100g to 0.63g/100g. A similar trend in results can be observed after a storage period of 6 months. Parboiled rice MRQ 107 showed significant differences in vacuum packaging at room temperature, compared with all packaging conditions, showing GC values exceeding 61.00 mm. GC values for parboiled rice MRQ 111 also exceeded 61.00 mm, with no significant differences in cooking time for both parboiled rice, with an average cooking time of 23 minutes. TSL values for MRQ 107 were in the range of 0.39g/100g to 0.64g/100g, while for MRQ 111, they were in the range of 0.53g/100g to 0.59g/100g. This result showed that the storage study for MRQ 107 and MRQ 111 parboiled rice shows no apparent difference in physicochemical characteristics. Both showed physicochemical characteristics on high GC values, moderate cooking time, and the minimum TSL value recorded upon storage duration. This characteristic showed that parboiled rice offers a soft texture with reasonable cooking time and retains nutrients well during cooking.

3.3. Nutritional Analysis of Parboiled Rice

Nutritional analysis for determining the nutritional content of parboiled rice MRQ 107 and MRQ 111 involves several nutritional elements, as shown in Table 3.

Generally, brown rice contains higher levels of fibre, vitamins, minerals, and protein than white rice because it retains the bran layer, which contains these nutrients. Although the fiber content of parboiled rice is not as high as brown rice, it has more nutrients than white rice. White rice has a lower nutritional profile than brown and parboiled rice because the bran layer is removed during processing, resulting in lower levels of vitamins, minerals, and fibre. Parboiled rice of MRQ107 and MRQ111 has shown that their carbohydrate content is between 78.5–78.6 g/100 g, higher than brown rice 77.0–77.2 g/100 g. Fat content is in the range between 1.1–1.2 g/100 g, lower than brown rice (1.5–1.7 g/100 g), and free fatty acids are 0.10–0.12 g/100 g, lower than white and brown rice (0.21–0.37 g/100 g). Protein sources show 8.9–9.0 g/100 g, higher than white rice (6.7–7.9 g/100 g). Calcium, Phosphorus, Sodium, Magnesium, Iron, and silica are essential minerals found in various types of rice.

According to the result, parboiled rice contains lower mineral content than white and brown rice except for iron content, which is between 2.3–2.5 mg/100 g compared to 1.9–2.1 mg/100 g for parboiled rice and brown rice. Magnesium content, 38–41 mg/100 g, is also higher than white rice (26–27 mg/100 g). Furthermore, parboiled rice shows higher vitamin content than white and brown rice because it is retained through the boiling process, which involves pre-cooking rice activity within its husk before husking. This can be seen that for evaluation of Vitamin B, the thiamine content has shown a value of 0.10–0.11 mg/100 g, riboflavin (vitamin B2) 0.08–009 mg/100 g, Niacin (vitamin B3) 1.43–1.85 mg/100 g and Pyridoxine (vitamin B6) 0.26–0.28 mg/100 g. Folic acid, one of the primary sources of amino acid functionality, has also increased by over 50% in parboiled rice with a value of 207–212 μg/100 g. Resistant starch content has also increased from 0.3 g/100 g in control rice to 0.5g/100 g in parboiled rice, and the same trend was found for dietary fiber content, which doubled from 0.8–0.9g/100 g in control rice to 1.7–1.8g/100 g in parboiled rice for both varieties.

Table 3. Comparison of Nutritional Content of Specialty Parboiled Rice with Specialty White Rice and Specialty Brown Rice

Sample / Parameter	White Rice		Parboiled Rice		Brown Rice	
	MRQ 107	**MRQ 111**	**MRQ 107**	**MRQ 111**	**MRQ 107**	**MRQ 111**
Moisture Content (g)	10.1	11.8	10.2	10.5	10.4	10.6
Carbohydrate (g/100 g)	80.5	80.2	77.2	77.0	78.6	78.5
Protein (g/100 g)	7.9	6.7	9.8	9.6	8.9	9.0
Fat (g/100 g)	0.8	0.7	1.5	1.7	1.2	1.1
FFA (g/100 g)	0.4	0.3	0.2	0.2	0.1	0.1
Ash (g/100 g)	0.7	0.6	1.3	1.2	0.9	0.8
Crude Fibre (g/100 g)	0.4	0.4	0.7	0.6	0.4	0.3
Energy (kcal)	361.0	354.0	362.0	362.0	361.0	360.0
Calsium (mg/100 g)	7.2	6.8	18.0	17.0	5.6	5.8
Phosphorus (mg/100 g)	76.0	73.0	178.0	182.0	72.0	74.0
Sodium (mg/100 g)	5.0	5.0	4.0	5.0	4.0	4.0
Magnesium (mg/100 g)	26.0	27.0	90.0	87.0	41.0	38.0
Iron (mg/100 g)	2.0	2.1	1.9	1.9	2.3	2.5
Silica (mg/100 g)	0.4	0.4	0.6	0.7	0.2	0.2
Thiamine (mg/100 g)	0.1	0.1	0.1	0.1	0.1	0.1
Riboflavin (mg/100 g)	0.1	0.1	0.1	0.1	0.1	0.1

Sample / Parameter	White Rice		Parboiled Rice		Brown Rice	
	MRQ 107	MRQ 111	MRQ 107	MRQ 111	MRQ 107	MRQ 111
Niacin (mg/100 g)	1.1	1.2	1.8	1.6	1.9	1.4
Pyridoxine (mg/100 g)	0.1	0.1	0.2	0.2	0.3	0.3
Folic Acid (μg/100 g)	126.0	131.0	207.0	171.0	212.0	207.0
Dietary Fibre (g/100 g)	0.8	0.9	1.8	1.7	0.6	0.6
Resistant Starch (g/100 g)	0.3	0.3	0.5	0.5	0.2	0.2

4. Conclusions

A study on local specialty parboiled rice production involves two (2) speciality rice varieties, namely MRQ 107 and MRQ 111. The series of parameters for processing parboiled rice has been tested with parameters obtained for MRQ 107 parboiled, including the temperature of 70ºC, soaking time of 4 hours, and a steaming time of 45 minutes that has resulted in milling recovery of 69.36%, with 96.62% head rice yield (HRY) and 3.38% broken rice. For MRQ 111, the optimal parameters are a temperature of 75ºC, a soaking time of 2 hours, and a steaming time of 45 minutes, yielding a milling recovery of 68.47%, with over 97% HRY and with a minimum of 2.27% broken rice produced. Physicochemical characteristics of parboiled rice were also studied during a storage period of 0-6 months, revealing that the local specialty parboiled rice exhibited good physicochemical properties. These include a high gel consistency value, explicitly falling within the GC soft category (61–100 mm). Both local parboiled rice also showed a consistent cooking time of 23 minutes and lower total solid loss (TSL) than the control sample. Nutritional content analysis has compared parboiled rice, brown rice, and regular whited-milled rice from both varieties. The result showed increased protein and mineral content, such as calcium and magnesium, compared to the control rice. Similarly, the content of folic acid, resistant starch, and dietary fiber also increased twice, from 0.8–0.9g/100g in control rice to 1.7–1.8g/100g for both MRQ 107 and MRQ 111 parboiled rice.

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