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RESEARCH ARTICLE

EFFECTS OF STORAGE PERIOD AND CULTIVATED SEASON ON GRAIN QUALITY CHARACTERISTICS OF SELECTED IMPROVED AND TRADITIONAL RICE (*Oryza sativa* L.) VARIETIES IN SRI LANKA

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Abstract

The production of quality rice is determined by many properties and these properties affect the consumer preferences and commercial value of rice. Therefore, this study was done to investigate the several physical, physicochemical, and milling properties of 12 selected improved and traditional rice (*Oryza sativa* L.) varieties grown experimentally in plots using randomized complete block design, in three seasons (2022 *Yala*, 2021/22 *Maha, and* 2021 *Yala*). These rice varieties were cultivated and harvested at the Rice Research and Development Institute, Bathalagoda, Sri Lanka. Statistical analysis was done using SAS software package version 9.3. Significant ($p<0.05$) differences between rice varieties in the relevant seasons and between seasons were observed for all test parameters. The brown rice and hull percentages varied from 75-79% and 20-24%, respectively while the head rice yield varied between 56-71% for raw rice in the 2021 *Yala* season. In the 2021/22 *Maha* season, the brown rice and hull percentage varied from 74–80% and 20–25% for selected varieties. Except for the variety *suduheenati*, At 311 and At 362, the head rice yield varied between 50-67% in the 2021/22 *Maha* season. The brown rice and hull percentages varied from 75-79% and 21-25%, respectively while the head rice yield varied between 55-74% for raw rice, except for the variety At 311 and Bg 374 in the 2022 *Yala* season. Majority of rice varieties harvested in all three seasons showed an intermediate gelatinization temperature (70–74 ºC). At 362 rice variety in all three seasons showed low gelatinization temperature of 55-69ºC. Except for At 311, many varieties had high amylose contents during the 2021/22 *Maha* and 2022 *Yala* seasons. In the 2021/22 Maha season, there were significant ($p<0.05$) differences in bulk density, grain elongation, and thousand-grain weight and there was no significant ($p>0.05$) difference between the 2021 and 2022 *Yala* seasons. The information obtained can be used to choose suitable rice varieties for commercial cultivation in Sri Lanka and to plan post-harvest practices.

Keywords: Physical properties, Physicochemical properties, Storage time, Traditional rice varieties

INTRODUCTION

Rice (*Oryza sativa* L.) is the dietary staple food in Sri Lanka and the major livelihood of farmers. Rice has been grown in Sri Lanka by Indo Aryan immigrants before about 540 B.C. The annual per capita consumption of rice is 114 kg and it acts as the major source of calories and protein for the Sri Lankan population (Sinthuja *et al*. 2021). In comparison to other cereals, the amount of protein in rice is low. Even though it contains the highest digestible protein and has a good balance of amino acids (Liyanaarachchi *et al*. 2021). Rice provide a range of minerals and vitamins, dietary fibers and bioactive phytochemicals when it is consumed as the whole grains rather than the refined grains (Abeysekera *et al*. 2017). Those are important in alleviating nutritional deficiencies and non-communicable diseases par-

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ticularly in widely rice consuming countries like Sri Lanka (Abeysekera and Daya Ratnasooriya 2018). According to the department of Census and Statistics, the total land is nearly 708,000 Hectares for paddy cultivation in Sri Lanka at present. In Sri Lanka, more than 25% of the total labor force is engaged in agricultural activities mainly in rice cultivation. It is an important cereal crop contributing 7% to agricultural GDP in the country (Suresh *et al.* 2021).Rice is grown in two major seasons (*Yala* and *Maha* seasons) in Sri Lanka, based on the two different monsoonal rains. *Yala* season is normally drier and *Maha* season is a wet season. Sri Lanka's food security situation and the standard of livelihoods of a large percentage of the country's population can be improved by increasing rice productivity (Suresh *et al*. 2021). Although 0.7 million metric tons of rice imports annually due to the increased demand for rice in Sri Lanka (Suresh *et al,* 2021).

In the ancient time, Over 600 traditional rice varieties had been cultivated in Sri Lanka (Sinthuja *et al*. 2021) and those traditional rice varieties have high nutritional value, appearance, aroma, texture, and taste compared to improved rice varieties (Kariyawasam *et al*. 2016). Some traditional rice varieties had been cultivated widely compared to other varieties because of their health benefits, resistance to different abiotic stress conditions like drought, salinity, low or high temperature, and other environmental extremes (Abeysekera *et al.* 2017). Sri Lankan traditional rice varieties have obtained high demand in the market due to fully or some degree of pigmented bran layer on the grain even after milling (Sinthuja *et al.* 2021). By aiming that fact, Rice millers apply less polishing rate for pigmented brown rice than white rice during the milling process. Furthermore, Sri Lankan traditional rice varieties were richer in nutritional quality and mineral composition compared to improved white pericarp rice varieties (Kulasinghe *et al*. 2019).

With the technological developments, improved rice varieties were introduced in Sri Lanka by using bred adapting standard breeding techniques (Hafeel *et al.* 2020). The high yielding improved rice varieties with resistance to pests and diseases and acceptable grain quality are currently cultivating throughout the Island, developed by the Department of Agriculture, Sri Lanka (Honge *et al.* 2017). Another advantages of improved rice varieties are resistant to lodging due to the short plant height and erect leaves, and high milled rice yield compared to the traditional rice (Hafeel *et al*. 2020). And also improved rice varieties have high responsive rate to added fertilizer (Ekanayake 2009).

The production of quality rice is determined by many properties including physical, physicochemical, sensory and nutritional value and these properties affect the consumer preferences and commercial value of rice (Abeysekera and Daya Ratnasooriya 2018). Physical properties are shape, kernel size, milling recovery, degree of milling and grain appearance (Rebeira *et al.* 2015). Mainly Physical quality influences the final output and it determine the consumer demand which are directly affect to the farmers and millers. Physical properties mainly differ with variety, moisture content and degree of milling. Gelatinization temperature, amylose content and gel consistency are the most important physicochemical properties which influence cooking and eating characteristics of rice (Cruz and Khush 2000). And important eating qualities of cooked rice are cohesiveness, stickiness, and tenderness. Knowing of those properties is important in processing, handling, and storage of rice.

After harvesting rice, storage is done as a postharvest operation to prolong shelf-life and commercial value. During storage, rice grain quality are changed with endogenous enzymatic reactions on starch, proteins, and lipids and grain quality dependents on storage conditions like temperature, humidity, and duration (Tong *et al*. 2019). Storage temperature of rice grains and duration are significantly correlated to head rice yield and it can be caused to change in rice physicochemical properties and functionality (Tong *et al.* 2019). Furthermore, considering the importance of grain quality in the food system, this study aimed to determine the effects of storage period on grain quality characteristics of selected improved and traditional rice (O*ryza sativa* L.) varieties.

The main objectives of this study were to identify variations in physical and physico-chemical properties of selected improved and traditional rice varieties with the storage period. The specific objectives were to identify the physical and physicochemical properties of selected rice varieties, test the differences in cooking quality characteristics with storage period, and determine the effect of storage period on grain quality traits of selected rice varieties.

MATERIALS AND METHODS

Twelve Sri Lankan rice varieties including traditional and improved varieties were used in this study. Selected rice varieties obtained from Rice Research Development Institute (RRDI) at Batalagoda (Table 1). They were grown experimentally in plots using randomized complete block design during 2021 *Yala*, 2021/2022 *Maha* and 2022 *Yala* seasons. The rice varieties were selected based on their popularity in the country, consumer preference, production yield and the health benefits associated with the varieties.

Preparation of Rice for the Analysis

After leaving the rough rice for 15 months, 9 months, and 3 months respectively in ambient storage conditions, seed samples of 140g from each variety in three seasons was dehulled using a dehusking machine (Model: Satake, THU-35 B, Japan) and brown rice was obtained. By using polishing machine (Model; TM 05C, Satake, Japan) for 75 seconds removed the rice bran partially (5±2% by weight) from 100 g of brown rice.

Testing of Milling Properties

The method described by Cruz & Khush (2000) was used to determine the Milling properties (Equations 1, 2, 3). The weight of the brown rice and polished rice were recorded. Then the whole grains (head rice) were separated from the 30 g of polished rice sample and the weight of the whole grain was recorded.

Table 1: Rice varieties used and their parents/accession number, type of improvement and pericarp color

	Rice variety	Parent/Accession number	Type of improvement	Pericarp color
1	Pachchaperumal	RRDI Acc. No. 798	Traditional	Red
2	Herathbanda	RRDI Acc. No. 689	Traditional	Red
3	Madathawalu	RRDI Acc. No. 1312	Traditional	Red
4	Suduheenati		Traditional	Red
5	Bg 352	Bg 380 / Bg 367-4	New-Improved	White
6	Bg 360	3346/IR 36//Senerang	New-Improved	White
7	Bg 366	Bg 300/94-2236//Bg 300/Bg 304	New-Improved	White
8	Bg 374	Ld 12-38-1/Bg 360	New-Improved	White
9	Bg 450	Bg 12-1# / IR 42	New-Improved	White
10	At 362	At 85-2 / Bg 380	New-Improved	Red
11	At 311	At 306 / At 3-105	New-Improved	Red
12	Ld 253	selection from At 04	New-Improved	White

$$Total\ milled\ rice\% = \frac{Weight\ of\ milled\ rice}{Weight\ of\ rough\ rice} \times 100\%$$

……………………………………..Eqn 01

$$Husk\% = \frac{Weight\ of\ hull}{Weight\ of\ rough\ rice} \times 100\%$$

……………………………………..Eqn 02

$$Head\ grain\% = \frac{Weight\ of\ head\ rice}{Weight\ of\ rough\ rice} \times 100\%$$

……………………………………..Eqn 03

Testing of Physical Properties

Grain Size and Shape

Length (L) and width (W) of the milled rice kernels were measured using a micrometer. The measurements were taken from randomly selected 10 grains from each variety and it was replicated four times. Size and shape were classified according to the method described by RRDI.

Bulk Density and Weight

A random sample of 100 grains was selected from each variety, and the samples were weighed individually to determine the weights of the kernels (Vidal *et al.* 2007). The average 100 kernel weight was obtained from four replicates. After that the sample of weighed rice grains were filled into a graduated measuring cylinder and the volume occupied was recorded to determine the bulk density (ρb) (Equation 4). In here average moisture content of grains from four replicates also measured by using grain moisture meter.

$$\rho b\ \left(\frac{g}{ml}\right) = \frac{Mass\ of\ grain}{Volume\ occupied} \ \ldots\ldots$$

……………………………………......Eqn 04

1.a Improved rice varieties

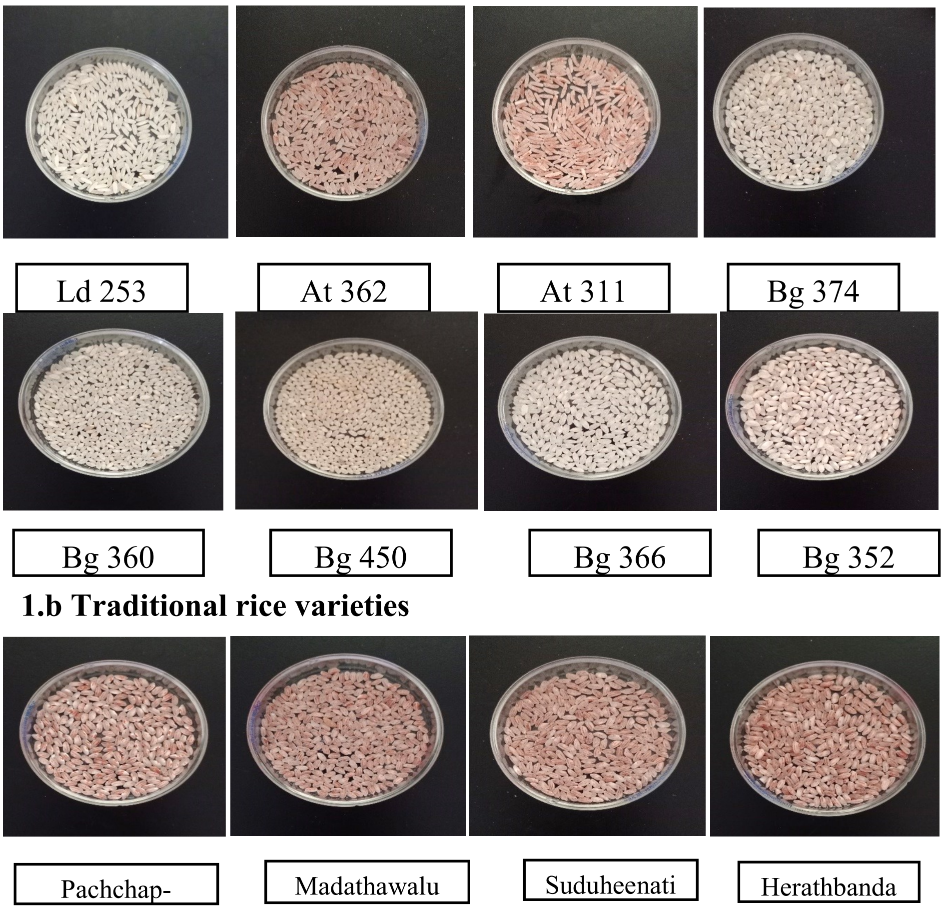


Plate 1: Whole grains of selected,
1.a) improved rice varieties in Sri Lanka , 1.b) traditional rice varieties in Sri Lanka

Testing of Cooking Properties

Physicochemical properties such as gelatinization temperature, amylose content and grain elongation also were determined for the polished rice of each variety.

Testing of Gelatinization Temperature (GT)

Alkali digestibility test and alkali spreading value were used to determine the gelatinization temperature (Cruz and Khush 2000). In which triplicate sets of 6 milled kernels (from each replicate) without cracks were selected and placed in petri dishes and the dish was covered to maintain the room temperature for 23 hours. In here 10 ml of 1.7% Potassium hydroxide (KOH) solution was added into the petri dish and after kernels were arranged to provide enough space between kernels allowing for spreading.

GT was calculated according to the scoring values given in Table 2 and below equation was used to calculate the approximate GT value for twelve rice varieties in three seasons (Bhattacharya *et al.* 1982). (Where; Y = GT and X = score in KOH solution).

$$Y = 74.54 - 1.4X \quad \text{....................Eqn 05}$$

Table 2: Numerical scale for scoring gelatinization temperature (Cruz and Kush 2000)

Score	Spreading	Alkali digestion	GT
1	Kernel not affected	Low	High
2	Kernel swollen	Low	High
3	Kernel swollen, collar complete or narrow	Low-Intermediate	High-Intermediate
4	Kernel swollen, collar complete and wide	Intermediate	Intermediate
5	Kernel split or segregated, collar complete and wide	Intermediate	Intermediate
6	Kernel dispersed, merging with collar	High	Low
7	Kernel completely dispersed and intermingled	High	Low

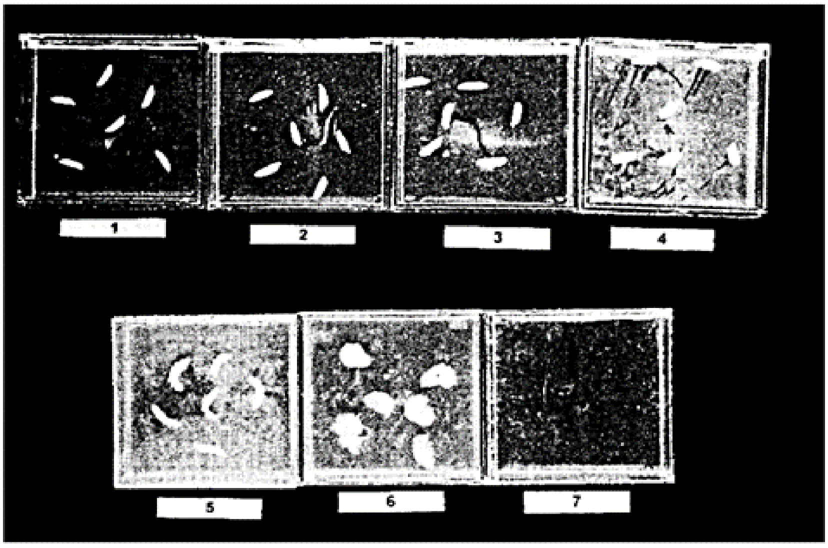


Figure 1: Alkali digestion of rice kernels and the numbers represent the scales of alkali spreading (Cruz and Khush 2000)

Testing of Amylose Content

Amylose content was determined according to the Iodine binding procedure (Perez and Juliano 1978). The absorbance of the solution is measured at 620 nm using a UV-visible spectrometer (T80+ UV/VIS Spectrometer). The amylose content of the samples was determined based on the standard curve prepared using a known amount of potato amylose (0.0571 g of purified potato amylose powder). In here, 57.1 mg of potato amylose was added into a 100 ml volumetric flask and mixed with 1 ml ethanol and 9 ml 1N sodium hydroxide. Heated for 5-10 minutes in a boiling water bath, after that cooled, and made up to volume. After that, 1, 2, 3, 4, 5 ml of solution were placed with a pipette in 100 ml volumetric flasks. The solutions were acidified with 1N acetic acid (0.2, 0.4, 0.6, 0.8, and 1.0 ml, respectively) and treated as above.

Testing of Grain Elongation

The grain elongation was measured according to the method described by Cruz and Khush (2000). The proportionate elongation was the ratio of the average length of cooked rice grains to the average length of raw rice grains.

Data Analysis

Data obtained were subjected to two-way analysis of variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) to determine the statistical differences among seasons into varieties at a significance level of $p \leq 0.05$. Then data were subjected to one-way ANOVA followed by DMRT to determine the statistical differences among varieties at a significant level of $p \leq 0.05$. Statistical analysis was done using SAS software package version 9.3.

RESULTS AND DISCUSSION

The selected Sri Lankan traditional rice varieties are still cultivated and popular among farmers. Sri Lankan improved rice varieties used in the study are the popular and widely cultivated and consumed varieties within the country. The *Yala* season in 2021 obtained comparatively higher rainfall starting from March and ending in September and 2021/22 *Maha* is the season with comparatively lower rainfall starting from October and ending in February in the Low Country Intermediate Zone of Sri Lanka. Maximum and minimum temperatures of 2021 *Yala,* 2021/22 *Maha* and 2022 *Yala* experimental seasons were 26.6 - 34.6 °C and 16.5- 28.4 °C, 25.1 - 33.6 °C and 14.9 - 26.9°C, and 26.6 - 34.6 °C and 16.5-28.4 °C, respectively. The 2022 *Yala* season is reported to have a higher ambient temperature than in 2021/22 *Maha* season and 2021 *Yala*.

Milling Properties of Rice

Both local and international markets prefer milled rice with a high head rice yield. The market value of head rice is twice higher than the broken rice (Nelson *et al*. 2011). Generally there are 20-22% of husk in rough rice, although variation of 18-26% has been recorded (Cruz and Khush 2000).The effects of controlled ambient treatment on rice quality and found a slight increase in head rice yield with the storage duration increased (Ranalli et al. 2003). Although the head rice yield varied between 56-71% for raw rice milling, in the 2021 *Yala* season for selected traditional and improved varieties. In the 2021/22 *Maha* season, head rice yield recorded within the range of 50-67%, the varieties of *suduheenati,* At 311 and At 362 gave head rice percentage of 41%,43% and 47% respectively. The head rice yield varied between 55-74% for raw rice milling, except for the variety At 311 and Bg 374 in the 2022 *Yala* season (Table 3). Traditional and improved rice varieties showed desirable milling properties over seasons, although slight increment showed in 2021 *Yala* and 2022 *Yala* compared to the 2021/22 *Maha*.

Physical Properties of Rice

Grain length, width, size and shape

Grain appearance depends on the size and shape of the kernel. The length: width ratio (L/W) ranging between 2.5 and 3.0 has been considered widely acceptable as long as the length is more than 6 mm. According to the consumers, some of them prefer short grains, although in the global markets, there is a greater demand for long- grain rice similar to Indica-type cultivars (Kordrostami *et al.* 2021). The shape of the rice grain is determined by the length: width ratio. Table (4)

Table 3: Variation of milling quality parameters of selected traditional and improved rice varieties in Sri Lanka as affected by storage period of paddy and cultivation season

Rice Variety	Season	Storage period (Months)	Brown Rice (%)	Husk (%)	Total Milled Rice (%)	Head Grain (%)	Broken Grain (%)
Traditional varieties							
Herathbanda	2021 *Yala*	15	77.99	22.01	73.56	56.10	50.68
	2021/22 *Maha*	9	77.12	22.88	70.87	54.38	47.85
	2022 *Yala*	3	76.99	23.01	73.72	70.26	45.13
Madathawalu	2021 *Yala*	15	77.37	22.63	71.37	69.18	42.29
	2021/22 *Maha*	9	77.40	22.60	70.29	50.89	48.57
	2022 *Yala*	3	78.01	21.99	73.50	71.98	44.12
Pachchaperumal	2021 *Yala*	15	78.35	21.65	73.48	70.64	44.64
	2021/22 *Maha*	9	77.44	22.56	69.45	50.49	47.64
	2022 *Yala*	3	78.04	21.96	72.99	66.62	45.61
Suduheenati	2021 *Yala*	15	78.01	21.99	70.83	68.78	41.70
	2021/22 *Maha*	9	75.90	24.10	68.84	41.42	50.79
	2022 *Yala*	3	77.89	22.11	74.79	73.57	45.28
Improved varieties							
Bg 360	2021 *Yala*	15	76.40	23.60	72.47	70.92	43.11
	2021/22 *Maha*	9	74.51	25.49	70.29	65.28	42.43
	2022 *Yala*	3	76.78	23.22	71.21	67.72	42.68
At 362	2021 *Yala*	15	78.82	21.18	73.37	69.21	45.07
	2021/22 *Maha*	9	78.56	21.44	72.61	47.27	53.08
	2022 *Yala*	3	79.05	20.95	75.56	71.48	47.18
Ld 253	2021 *Yala*	15	75.79	24.21	70.87	65.72	43.05
	2021/22 *Maha*	9	77.68	22.32	72.95	66.72	45.51
	2022 *Yala*	3	75.35	24.65	71.08	67.14	42.74

Table 3 Contd…..

Bg 366	2021 *Yala*	15	78.29	21.71	73.69	67.20	46.33
	2021/22 *Maha*	9	78.17	21.83	72.64	63.30	46.50
	2022 *Yala*	3	76.49	23.51	70.32	55.48	46.65
At 311	2021 *Yala*	15	75.46	24.54	67.88	57.00	42.69
	2021/22 *Maha*	9	76.81	23.19	70.94	43.39	52.59
	2022 *Yala*	3	76.01	23.99	69.34	46.48	49.23
Bg 374	2021 *Yala*	15	79.23	20.77	74.66	67.07	47.71
	2021/22 *Maha*	9	79.91	20.09	74.59	57.65	51.40
	2022 *Yala*	3	77.73	22.27	70.73	42.65	52.64
Bg 450	2021 *Yala*	15	77.56	22.44	75.14	66.20	48.71
	2021/22 *Maha*	9	78.26	21.74	75.29	66.78	48.68
	2022 *Yala*	3	76.84	23.16	73.22	71.26	44.02
Bg 352	2021 *Yala*	15	78.44	21.56	73.82	70.62	45.12
	2021/22 *Maha*	9	78.04	21.96	72.93	58.15	49.01
	2022 *Yala*	3	77.66	22.34	72.22	66.52	44.59

presents the mean values of grain length, grain width and grain shape as affected by rice variety, storage period and the seasons. Although, rice grain length, width, and shape are primarily determined by the variety of rice rather than the storage period. However, the cultivated season and environmental conditions can indeed have an effect on rice grain length and width. Rice is a temperature-sensitive crop. Different temperature conditions during the growing season can affect the rate of growth and maturation of the rice plants. The size and shape of the seed are influenced by the size and quantity of endosperm cells. When exposed to high temperatures, the division of these cells is blocked, resulting in a decrease in cell surface area and a reduction in the starch capacity within the endosperm (Song *et al.* 2022). This can be caused to reduce the length and width of the seed. Based on the length of kernels, all selected traditional and improved rice varieties were fallen either into short (≤5.50 mm), medium (5.51-6.60 mm) or long (6.61-7.50 mm) grain size classes (Cruz and Khush, 2000). According to the L: W ratios, grain shape subjected to the three classes such as slender (>3.0), medium (2.1 -3.0) and bold classes (≤2).

Significant ($p<0.05$) differences were observed in the length: width ratio among the tested rice varieties (Table 4). The highest kernel length of 7.04 mm was observed in variety At 311 in 2021 *Yala* season and the lowest length of 4.01 mm was observed in the variety Bg 450 in the same season. At 311 rice variety obtained highest kernel length (6.87 mm and 6.84) in 2021/22 *Maha* and 2022 *Yala,* while Bg 450 showed lowest length of 4.17 mm and 4.33 mm respectively in these seasons. Kernel length of many varieties varied from 4.5 mm to 6.0 mm while kernel width varied from 2.50 to 2.90 mm. All the tested traditional rice varieties and tested improved varieties except At 362, Ld 253 and At 311 belong to bold grain shape category, while At 311 was fallen into slender shape category and both At 362 and Ld 253 were fallen into medium shape class for all three seasons. The size and shape of grains are crucial factors that breeders consider when creating new rice varieties for commercial cultivation. Furthermore, breeders have focused their attention to develop long grain rice varieties for commercial purposes (Abeysekera & Daya Ratnasooriya 2018).

Thousand Grain Weight

Thousand grain weight of rice varieties varied significantly ($p \leq 0.05$) in 2021/22 *Maha* season and there was no significant ($p>0.05$) variation among 2021 *Yala* and 2022 *Yala*. There was no significant ($p>0.05$) variation between At 362 and Bg 352 within all three seasons, for thousand grain weight. Thousand grain weight of traditional and improved rice varieties are presented in Table 4. The traditional rice variety *Pachchaperumal* showed the highest grain weight followed by *Herathbanda* in 2022 *Yala* season. Rice variety Bg 360 showed the lowest thousand grain weight for the three seasons. The weight of a rice grain is primarily influenced by the size of the hull and the fullness of grain. High temperatures experienced during the grain-filling phase negatively impact attributes such as grain shape, the rate of grain-filling, and fullness. These temperature-induced effects lead to a reduction in grain size and a subsequent decrease in grain weight (Song *et al*. 2022). Although storage period and temperatures during grain ripening stage did have some influence, the variation in 1000-grain weight among the different rice varieties played a more dominant role. According to the Katta *et al.* (2019), 1000–grain weight is improved by cold storage due to some reductions of physiological activities and occurrence of cracked grains. These factors contribute to maintaining superior quality of the stored rice.

Grain Bulk Density

Grain bulk density is independent of its absolute dimensions and size although dependent on its density and shape (Bhattacharya *et al.* 1972). According to the Bhattacharya (2013), bulk density is inversely related to the grain slenderness (L/W ratio) and slender grains had lower bulk density while round grains had higher bulk density. Milled rice shows this

Table 4: Physical properties (mean±SD) of some selected traditional and improved rice varieties with storage period in Sri Lanka

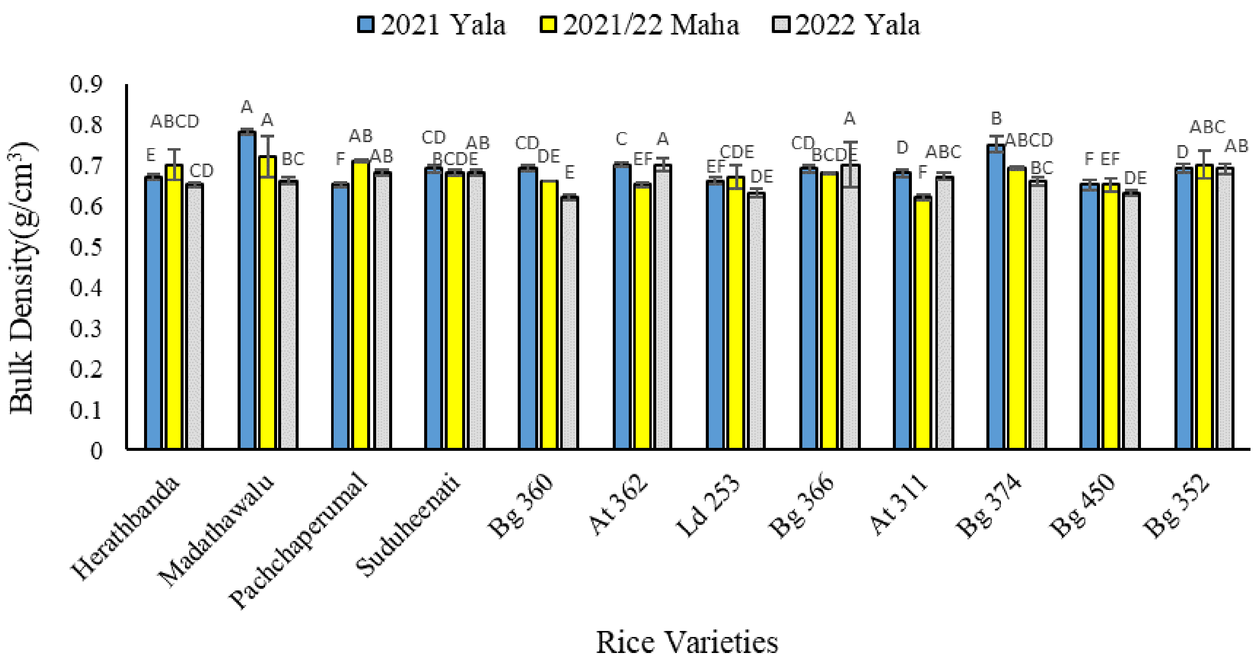
Rice variety	Season	Storage period (Months)	Length (L mm)	Grain size	Width (W mm)	L/W ratio	Grain shape	1000 grain weight (g)
Traditional varieties								
Herathbanda	2021 *Yala*	15	5.64 ±0.19	Medium	2.78±0.20	2.04^{D}±0.17	Bold	19.93^{B}±0.17
	2021/22 *Maha*	9	4.80±0.20	Short	2.89±0.12	1.67^{GH}±0.09	Bold	18.75^{A}±0.24
	2022 *Yala*	3	5.75±0.22	Medium	2.80±0.22	2.07^{D}±0.17	Bold	20.60^{A}±0.14
Madathawalu	2021 *Yala*	15	4.80±0.20	Short	2.89±0.12	1.67^{F}±0.09	Bold	15.48^{G}±0.15
	2021/22 *Maha*	9	4.79±0.24	Short	2.82±0.14	1.70^{G}±0.12	Bold	14.73^{F}±0.49
	2022 *Yala*	3	5.11±0.20	Short	2.91±0.12	1.76^{G}±0.09	Bold	15.93^{E}±0.21
Pachchaperumal	2021 *Yala*	15	5.63±0.22	Medium	2.95±0.25	1.92^{E}±0.19	Bold	20.75^{A}±0.13
	2021/22 *Maha*	9	5.39±0.25	Short	2.84±0.17	1.90^{EF}±0.16	Bold	18.40^{B}±0.08
	2022 *Yala*	3	5.59±0.28	Medium	2.88±0.14	1.95^{E}±0.13	Bold	20.28^{A}±0.19
Suduheenati	2021 *Yala*	15	5.61±0.21	Medium	2.88±0.07	1.95^{E}±0.08	Bold	18.03^{E}±0.25
	2021/22 *Maha*	9	5.61±0.20	Medium	2.77±0.10	2.03^{D}±0.09	Bold	16.20^{D}±0.14
	2022 *Yala*	3	5.60±0.40	Medium	2.89±0.06	2.04^{D}±0.14	Bold	19.10^{C}±0.22
Improved varieties								
Bg 360	2021 *Yala*	15	4.60±0.15	Short	2.43±0.04	1.89^{E}±0.08	Bold	9.68^{J}±0.10
	2021/22 *Maha*	9	4.49±0.17	Short	2.44±0.11	1.85^{F}±0.12	Bold	9.30^{I}±0.00
	2022 *Yala*	3	4.55±0.18	Short	2.46±0.33	1.87^{F}±0.16	Bold	9.83^{H}±0.10
At 362	2021 *Yala*	15	6.41±0.33	Medium	2.62±0.12	2.46^{C}±0.20	Medium	19.65^{BC}±0.21
	2021/22 *Maha*	9	6.18±0.35	Medium	2.67±0.18	2.33^{C}±0.22	Medium	18.08^{BC}±0.19
	2022 *Yala*	3	6.41±0.14	Medium	2.68±0.11	2.39^{C}±0.14	Medium	19.60^{B}±0.42
Ld 253	2021 *Yala*	15	6.21±0.33	Medium	2.41±0.14	2.59^{B}±0.20	Medium	14.48^{H}±0.19
	2021/22 *Maha*	9	5.97±0.33	Medium	2.35±0.07	2.54^{B}±0.17	Medium	13.98^{G}±0.30
	2022 *Yala*	3	6.02±0.27	Medium	2.37±0.05	2.54^{B}±0.13	Medium	13.83^{F}±0.24

Table 4 Contd...

Bg 366	2021 *Yala*	15	5.87±0.22	Medium	2.85±0.12	2.06^{D}±0.13	Bold	19.35^{CD}±0.27
	2021/22 *Maha*	9	5.23±0.96	Short	2.82±0.11	1.89^{F}±0.35	Bold	17.83^{C}±0.05
	2022 *Yala*	3	5.57±0.27	Medium	2.84±0.11	1.96^{E}±0.14	Bold	18.48^{D}±0.86
At 311	2021 *Yala*	15	7.04±0.37	Long	2.17±0.10	3.26^{A}±0.22	Slender	16.43^{F}±0.24
	2021/22 *Maha*	9	6.87±0.34	Long	2.17±0.20	3.19^{A}±0.42	Slender	14.85^{F}±0.19
	2022 *Yala*	3	6.84±0.29	Long	2.20±0.10	3.09^{A}±0.23	Slender	16.10^{E}±0.22
Bg 374	2021 *Yala*	15	5.39±0.15	Short	2.84±0.08	1.90^{E}±0.07	Bold	16.53^{F}±0.39
	2021/22 *Maha*	9	5.20±0.25	Short	2.81±0.10	1.85^{F}±0.10	Bold	15.20^{E}±0.08
	2022 *Yala*	3	5.17±0.22	Short	2.83±0.06	1.82^{F}±0.08	Bold	15.80^{E}±0.27
Bg 450	2021 *Yala*	15	4.01±0.35	Short	2.53±0.07	1.59^{G}±0.14	Bold	10.38^{I}±0.17
	2021/22 *Maha*	9	4.17±0.24	Short	2.62±0.09	1.59^{H}±0.09	Bold	10.43^{H}±0.28
	2022 *Yala*	3	4.33±0.17	Short	2.62±0.14	1.66^{H}±0.11	Bold	11.30^{G}±0.12
Bg 352	2021 *Yala*	15	5.45±0.71	Short	2.85±0.17	1.92^{E}±0.28	Bold	19.15^{D}±0.31
	2021/22 *Maha*	9	5.54±0.18	Medium	2.84±0.16	1.96^{DE}±0.14	Bold	18.83^{A}±0.30
	2022 *Yala*	3	5.40±0.26	Short	2.92±0.07	1.85^{F}±0.10	Bold	19.08^{C}±0.35

**Mean (±SD) followed by the same superscript letter in each column are not significantly different (p>0.05)*

Figure 2: Bulk density among selected traditional and improved rice varieties



relationship clearly than the rough rice. When designing grain storage silos and hoppers, the knowledge of bulk density is useful for grain handling during processing (Nalladurai *et al.* 2002).

In brown rice, bulk density decreased with increasing moisture (Bhattacharya, 2013). Bulk density varied significantly ($p < 0.05$) in the 2021/22 *Maha* season, and there was no significant ($p > 0.05$) difference between 2021 *Yala* and 2022 *Yala*. This variation can be occurred due to bulk density was ranged from 0.62±0.006 g/cm^3 to 0.70±0.015 g/cm^3 in 2022 *Yala* season. The highest bulk density of 0.70 g/cm^3 was observed in the variety At 362 and Bg 366. The range of bulk density for 2021/22 *Maha* and 2021 *Yala* was 0.62±0.008 g/cm^3 to 0.72±0.051 g/cm^3 and 0.65±0.004 g/cm^3 to 0.78±0.008 g/cm^3 respectively, and the highest grain bulk density was observed in rice variety *Madathawalu* in both seasons.

In all forms of storage, the bulk density showed that the increase in storage time reduced the grain mass. The worst density values were observed in storage silos without an aeration system (Coradi *et al*. 2020). Bulk density is an important parameter and commonly used by the agribusiness, the determination of the apparent density as a quality assessment parameter for products and helps in establishing market prices (Coradi *et al.* 2020).

Cooking Properties of Rice

Cooking and eating characteristics are determined by the properties of the starch that consists 90% of milled rice. Gelatinization temperature and amylose content are the major starch properties which influence cooking properties of rice (Cruz and Khush 2000).

Gelatinization Temperature (GT)

Gelatinization temperature (GT) is an important physicochemical property of the rice grain which affects cooking and eating qualities. The time required for cooking is depended on the GT of rice kernel starch (Cruz and Kush 2000). Environmental conditions such as temperature during grain development stage influence GT. A high ambient temperature results in starch with higher GT during grain ripening stage. The GT of selected rice varieties which was measured using the alkali digestion method is shown in Table 5. The GT of rice varieties, classified as low (55-69°C), intermediate (70-74°C), and high (>74°C) (Cruz and Khush 2000). Rice kernels which are having low GT disintegrated completely and the rice kernels with intermediate GT show only partial disintegration (Figure 1).

Rice grains with high GT remain largely unaffected in the alkali solution. Although there was positive correlation between GT and cooking time of milled rice (Cruz and Khush 2000) , most of the traditional rice varieties showed intermediate GT for all seasons except *Suduheenati* in 2021 *Yala* and 2021/22 *Maha* season. Within improved varieties except At 362 (Low GT), all other varieties recorded intermediate GT (70-74°C) for all three seasons. This indicates that a variety of low GT have a high alkali digestion. There were not high GT (above 74 ºC). The alterations in thermal characteristics of rice resulting from storage might be attributed to modifications in the composition of cell walls and properties of proteins over the storage period (Tong *et al.* 2019).

Amylose Content (AC)

Amylose content (AC) is used to predict the texture of cooked rice, and the eating quality of rice. High AC was observed in most rice varieties except for At 311 in the 2021/22 *Maha* and 2022 *Yala* seasons, which recorded an intermediate AC. Rice varieties are categorized based on the AC into waxy (0-2%), very low (3-9%), low (10-19%), intermediate (20-25%) and high (>25%) (Cruz and Kush 2000). Rice with intermediate AC is the preferred types in most of the rice-growing areas of the world, except where low-amylose japonicas are grown. Many varieties except for At 311 in the 2021/22 *Maha* and 2022 *Yala* seasons, showed high amylose content. Varieties At 311 recorded 22.84% and 23.93% AC values respectively in the 2021/22 *Maha* and 2022 *Yala* seasons and therefore, fall in to intermediate amylose group (Table 5). The traditional rice variety *Herathbanda* showed high AC within the range of 31-35 % for three seasons. These results are compatible with previously reported results by Wickramasinghe and Noda (2008). AC of Bg 450, Bg 352 reported by Wickramasinghe and Noda (2008) are comparable with the values obtained in this study. The recorded AC of At 311 shows some deviations (lower values) compared to the values found in the literature (Hafeel *et al*. 2020), for 2021/22 *Maha* and 2022 *Yala* seasons. According to the Hafeel *et al*., (2020), reported AC for improved varieties of Bg 360 and At 362, which are similar to that of the present study.

High amylose rice varieties are preferred in South Asia including Sri Lanka. Sri Lankans prefer flaky, somewhat hard non cohesive rice (Abeysekera *et al*. 2017). Most Sri Lankan traditional and improved rice varieties belonged to the high amylose group with grain AC ranging from 25 - 29% (Sinthuja *et al*. 2021). According to the study of Abeysekera *et al.* (2017), the traditional rice varieties *Pachaperumal* and *Suduheeneti* and improved variety Bg 360 showed stability of grain AC over seasons in the low country wet zone.

Storage of rice leads to the breakdown of starch molecules, resulting high amylose content and reduced the long branch-chains of amylopectin. Certain studies indicated that the amylose content in rice decreased with the increased storage period and this decline could potentially be linked to the degradation of starch caused by the activity of amylolytic enzymes. High amylose content gives more advantages for inter- or intramolecular interactions of starch with other components in rice, the formation of complexes between amylose and lipids resulted in rice that exhibited increased hardness and greater resistance to breaking apart during storage (Tong *et al*. 2019).

Grain Elongation

Grain elongation varied significantly ($p < 0.05$) in the 2021/22 *Maha* season, and there was no significant difference between 2021 *Yala* and 2022 *Yala*. Elongation of rice grains during cooking is dependent basically on rice variety and degree of milling (Mohapatra and Bal 2006).

Expansion of size in lengthwise without increase in width during cooking is considered as a highly desirable quality characteristic rice

Table 5: Alkali spreading score, alkali digestion, gelatinization temperature and amylose content of selected improved and traditional rice varieties

Variety	Storage Period (Months)	Alkali spreading score	Alkali digestion	GT(^{0}C)	GT Class	Amylose Content (%)	Group
Traditional Varieties							
Herathbanda	15	3	Low-Intermediate	70.34	Intermediate	30.85	High
	9	3	Low-Intermediate	70.34	Intermediate	32.20	High
	3	3	Low-Intermediate	70.34	Intermediate	34.53	High
Madathawalu	15	2	Low	71.74	Intermediate	31.24	High
	9	2	Low	71.74	Intermediate	29.62	High
	3	3	Low-Intermediate	70.34	Intermediate	34.10	High
Pachchaperumal	15	3	Low-Intermediate	70.34	Intermediate	30.27	High
	9	3	Low-Intermediate	70.34	Intermediate	33.68	High
	3	3	Low-Intermediate	70.34	Intermediate	31.87	High
Suduheenati	15	4	Intermediate	68.94	Low	31.18	High
	9	4	Intermediate	68.94	Low	27.94	High
	3	3	Low-Intermediate	70.34	Intermediate	34.70	High
Improved varieties							
Bg 360	15	2	Low	71.74	Intermediate	32.48	High
	9	2	Low	71.74	Intermediate	28.00	High
	3	2	Low	71.74	Intermediate	32.00	High
At 362	15	6	High	66.14	Low	39.22	High
	9	6	High	66.14	Low	30.29	High
	3	6	High	66.14	Low	32.00	High
Ld 253	15	3	Low-Intermediate	70.34	Intermediate	36.33	High
	9	3	Low-Intermediate	70.34	Intermediate	25.10	High
	3	2	Low	71.74	Intermediate	29.63	High

Table 5 Contd...

Bg 366	15	3	Low-Intermediate	70.34	Intermediate	29.76	High
	9	3	Low-Intermediate	70.34	Intermediate	28.76	High
	3	3	Low-Intermediate	70.34	Intermediate	35.90	High
At 311	15	3	Low-Intermediate	70.34	Intermediate	29.74	High
	9	2	Low	71.74	Intermediate	22.84	Intermedi-
	3	3	Low-Intermediate	70.34	Intermediate	23.93	Intermedi-
Bg 374	15	3	Low-Intermediate	70.34	Intermediate	30.12	High
	9	2	Low	71.74	Intermediate	28.51	High
	3	2	Low	71.74	Intermediate	35.23	High
Bg 450	15	3	Low-Intermediate	70.34	Intermediate	35.26	High
	9	3	Low-Intermediate	70.34	Intermediate	29.28	High
	3	3	Low-Intermediate	70.34	Intermediate	27.37	High
Bg 352	15	3	Low-Intermediate	70.34	Intermediate	34.11	High
	9	3	Low-Intermediate	70.34	Intermediate	29.04	High
	3	3	Low-Intermediate	70.34	Intermediate	35.23	High

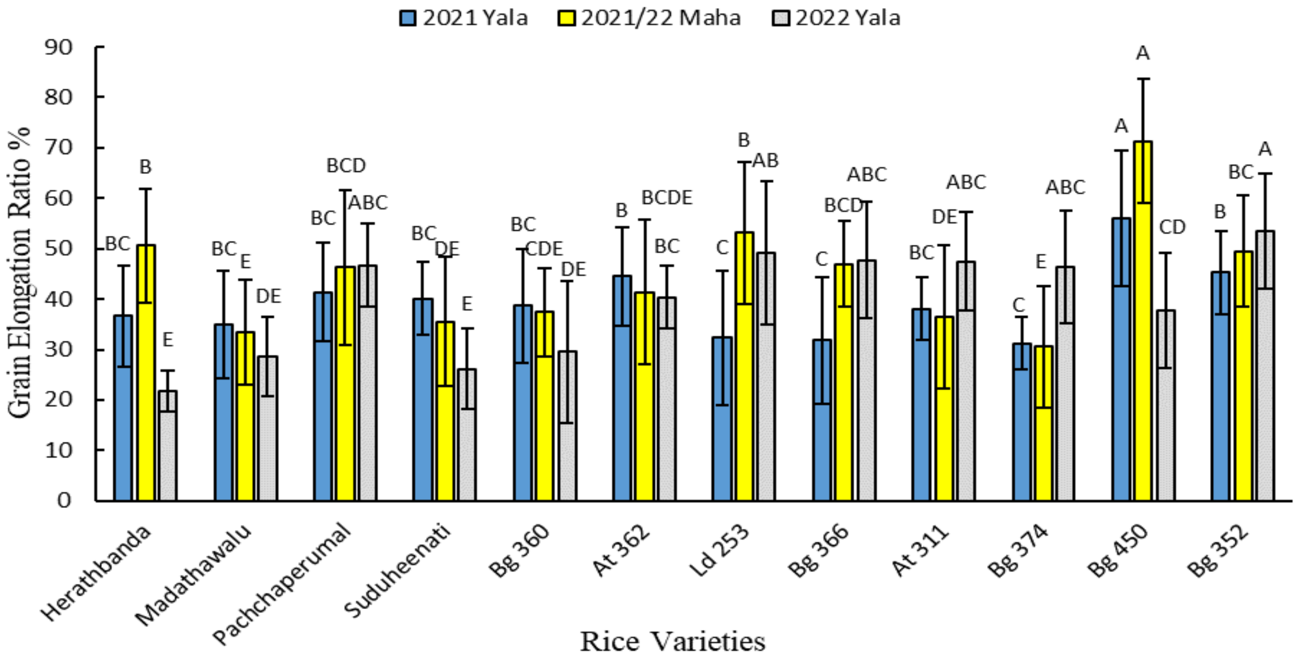


Figure 3: Variation of grain elongation ratio of selected rice varieties of Sri Lanka

grain. Bg 450 rice variety showed higher grain elongation ratio (55.95% and 71.25% respectively in 2021*Yala* and 2021/22 *Maha*) compared to 2022 *Yala* season (37.68%). The lowest grain elongation ratio was observed in Bg 374 in 2021*Yala* and 2021/22 *Maha* (31.27% and 30.54%). In 2022 *Yala*, *Herathbanda* showed the lower grain elongation ratio (21.79%). As the storage duration of milled rice prolonged, there was a decrease in water absorption and gruel solid loss. This decrease could be attributed to a reduction in α-amylase activity, lower protein solubility, and the development of amylose-lipid complexes. On the other hand, the elongation ratio of cooked rice increased during this period (Tong *et al.* 2019).

CONCLUSIONS

This study has showed that the physical properties and physicochemical properties of the different varieties of Sri Lankan rice vary significantly. The wide variation ($p< 0.05$) of bulk density, grain elongation, thousand grain weight were recorded in the 2021/22 *Maha* season, and there was no significant difference ($p>0.05$) between 2021 *Yala* and 2022 *Yala*. High amylose content was observed in many rice varieties. Varietal differences in grain amylose content over seasons in both traditional and improved varieties were also observed.

Most of the traditional rice varieties showed intermediate gelatinization temperature for all seasons except *Suduheenati* in 2021 *Yala* and 2021/22 *Maha* season. Within improved varieties except At 362, all the other varieties recorded intermediate gelatinization temperatures for all three seasons. Regardless of traditional or improved rice varieties showed desirable cooking characteristics and better physical properties for milling. The information resulted herein can be utilized in planning postharvest practices and in selecting suitable traditional rice varieties for commercial cultivation. In this study, it can be determined the effects of storage time period on grain quality characteristics of selected improved and traditional rice (*Oryza sativa* L.) varieties with the climatic changes. Furthermore, stability of amylose content of selected improved and traditional rice varieties over different storage periods can be calculated.

AUTHOR CONTRIBUTION

DMJBS, BMKS and RPNPR designed the study. HMLPH performed the experiments.

BMKS and HMLPH analyzed the data. HMLPH wrote the paper with input from all authors. All authors contributed on the results and commented on the manuscript.

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