Physical and nutritional characteristics of less common traditional rice ( *Oryza sativa* L.) varieties of Sri Lanka

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**ABSTRACT**

Consumption and cultivation of traditional rice varieties have increased considerably in recent years due to the increased prevalence of non-communicable diseases in our country. However, the physical properties and nutritional composition of most traditional rice have not been scientifically studied to a satisfactory level. Therefore, this study determined the physical and nutritional properties of some less common rice varieties namely Pokkali, Murugakayan, Rathdel, Madathawalu, Kuruluthuda, Pachchaperuma, Suduheenati, Suwadel and Kaluheenati without subjecting to processing treatments such as polishing and parboiling. Length, width, thickness, diameter, volume and length/width (shape) ratios as physical properties and moisture content, ash, crude fat and protein, total and digestible carbohydrate contents, resistant starch and insoluble soluble and total dietary fiber contents were determined according to standard methods. Length, width, and thickness of grains varied between 4.0-6.4 mm, 2.2-2.9 mm and 1.5-2.2 mm respectively. Diameter, volume and length-width ratio were between 2.4-3.3 mm, 3.8-10.5 mm^3^ and 1.7-2.6 respectively. Accordingly, the varieties were categorized as bold or medium. Moisture contents of varieties were between 5.4-8.3% and ash contents less than 2% (DM). Low crude fat (4.2-4.9% DM) and high protein (5.5-9.2% DM) contents were observed. Digestible carbohydrate and total carbohydrate contents ranged between 77.5-84.6% (DM) and 79.1-85.2% (DM) respectively. Resistant starch content varied between 0.4-3.2%. Corresponding insoluble, soluble and total dietary fiber contents ranged between 2.8-4.9%, 1.5-2.7% and 4.3-6.5% (DM). According to the data obtained the studied traditional rice varieties are good sources of digestible carbohydrate, protein with low fat and moisture.

**KEYWORDS:** Nutritional properties, physical properties, traditional rice

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As few studies are found in terms of quality characteristics of some traditional Sri Lankan rice (Wickramasinghe and Noda, 2008; Premakumara et al., 2013; Cruz and Khush, 2000), determining their nutritional properties would convey the potential of these rice varieties as a raw ingredient in food production in local and international rice markets. The data might also contribute to potential varietal improvements in future. Therefore, the present study was designed to determine the physical properties such as length, width, thickness, pericarp colour, diameter, volume and length/width ratio (shape) and nutritional properties such as moisture, ash, crude fat and protein, digestible carbohydrates, total carbohydrate, resistant starch (RS), insoluble (IDF), soluble (SDF) and total (TDF) dietary fiber contents of selected uncooked traditional rice varieties. Rice varieties selected for the study were namely Pokkali, Murugakayan, Rathdel, Madathawalu, Kuruluthuda, Pachchaperumal, Suduheenati, Suwadel and Kaluheenati.

2 MATERIALS AND METHODS

Less commonly consumed, paddy samples (10 kg) namely Pokkali, Murugakayan, Rathdel, Madathawalu, Kuruluthuda, Pachchaperumal, Suduheenati, Suwadel and Kaluheenati harvested during Yala season (2017), were collected from Rice Research Institute (RRI), Bathalegoda. Paddy samples were collected into polythene bags, sealed, labelled and transported on the same day to the laboratory and stored under temperature-
controlled conditions until processed. The paddy samples were photographed, cleaned and dehusked (SATAKE, JAPAN) and not subjected to any other treatments such as polishing. Grain classifications of rice varieties were made according to the International Rice Research Institute (IRRI) recommendation (Rice Knowledge Bank, 2019). Rice grains with lengths 5.51-6.6 or 5.5 mm or less were categorized as medium or short respectively.

2.1 Physical properties of grains

Colour of the pericarp, length, width, thickness, diameter, grain volume and shape of the grains were determined as stated below.

2.1.1 Pericarp colour of rice grains

Pericarp colour of the selected traditional Sri Lankan rice was evaluated by visual inspection (Abeysekera et al., 2017).

2.1.2 Length, width and thickness of rice grains

Length (L), width (W) and thickness (T) of each rice variety (five replicates of ten grains each) were determined by slide calliper. The grain was kept between the two jaws along sides and fixed. Reading was taken of the main scale and Vernier calliper collectively.

2.1.3 Equivalent diameter and grain volume

The above values were used to determine the equivalent diameter (D) and grain volume (V) of rice grain respectively (Hettiarachchiet al., 2016)

2.1.5 Grain shape

Rice grain shape was obtained by the ratio of length and width according to the classification of IRRI (Rice Knowledge Bank, 2019) where 1.1-2 and 2.1-3.0 ratios were considered as bold and medium respectively.

2.2 Rice flour preparation

Dehusked rice was cleaned and washed using tap water. Rice was dried under the sun for 2-3 days, each day for six hours and in an oven at 55 °C for 3-4 hours before milling. Dried rice was milled (IKA ® A11 basic, New Zealand), sieved (100 mesh size) and stored (0-4°C) in airtight containers until used for analyses.

2.3 Nutrient composition determination

Moisture content, ash, crude protein (AOAC, 2000) and crude fat (Croon and Fuchs, 1980 with modifications) were determined by standard methods. Carbohydrate contents (digestible carbohydrate, total carbohydrate and resistant starch) were determined according to AOAC Official Method 996.11 by Megazyme kits, Ireland (enzymatic assays). The total carbohydrate content was determined by the phenol sulphuric assay method (Dubois et al., 1956). Dietary fiber including insoluble and soluble dietary fiber was determined by total dietary fiber assay kit (TDF 100A-1KT, Sigma Aldrich, USA).
2.4 Statistical analysis

Data are presented as mean±SD for physical properties and nutrient composition of rice varieties. Significances were analyzed using ANOVA at 95% confidence interval with SPSS software package and Microsoft office excel 2010.

3 RESULTS AND DISCUSSION

3.1 Physical properties of traditional rice grains

Physical characteristics reflect the appearance of the rice grain and are considered as key parameters of varietal purity by breeders, sellers and consumers to select the desired variety. Physical properties of selected traditional rice are stated in table 1. Rice grains obtained after dehulling without milling and polishing were used to obtain these parameters.

Values obtained for length, width and thickness of rice varieties varied between 4.0-6.4 mm, 2.2-2.9 mm and 1.5-2.2 mm respectively. When considering the physical parameters (Table 1), Rathdel was the smallest (P≤ 0.05) rice variety out of the nine varieties studied. The highest length and width were observed in Suduheenati and Kuruluthuda respectively (P≤0.05). Thickness was highest (P≤ 0.05) in Pachchaperumal and Kaluheenati. The diameter of the rice grains varied between 2.4-3.3 mm where Rathdel had significantly (P≤ 0.05) lower diameter while both Pachchaperumal and Kaluheenati had significantly higher diameters (P≤0.05) among these varieties. The volume of the rice varieties was between 3.8-10.5 mm^3 with lowest (P≤0.05) in Rathdel which was the smallest variety with the lowest length, width, thickness and diameter. Variety Kaluheenati had the highest volume with higher thickness and diameter compared to other varieties studied. Length to width ratio which determines the shape of the rice varied between 1.7-2.6. Selected rice varieties were either medium or bold in shape irrespective of varying lengths and widths. Out of the nine varieties, two varieties were white in colour (Rathdel and Suwadel) and smallest while others were red (Figure 1).
Table 1. Physical properties of rice grains

| Rice varieties | Length ±SD* (mm) | Width ±SD* (mm) | Thickness ±SD* (mm) | Diameter ±SD* (mm) | Volume ±SD* (mm³) | Length/Width ±SD* | Shape* | Pericarp colour |
|----------------|------------------|-----------------|---------------------|--------------------|-------------------|-------------------|--------|----------------|
| **Pokkali**    | 6.1±0.0 a         | 2.5±0.0 a       | 1.7±0.0 a           | 3.0±0.0 a          | 7.4±0.0 a         | 2.5±0.0          | Medium Red |
| **Murugakayan**| 6.2±0.0 b         | 2.5±0.0 a       | 1.8±0.0 b           | 3.0±0.0 a          | 8.0±0.1 b         | 2.5±0.0          | Medium Red |
| **Rathdel**    | 4.0±0.0 c         | 2.2±0.0 b       | 1.5±0.0 c           | 2.4±0.0 b          | 3.8±0.0 c         | 1.9±0.0          | Bold White |
| **Madathawalu**| 5.2±0.0 d         | 2.5±0.0 a       | 1.8±0.0 b           | 2.9±0.0 b          | 6.7±0.0 d         | 2.1±0.0          | Medium Red |
| **Kuruluthuda**| 5.3±0.0 e         | 2.9±0.0 c       | 1.8±0.0 b           | 3.1±0.0 d          | 8.3±0.1 e         | 1.9±0.0          | Bold Red |
| **Pachchaperumal** | 5.7±0.0 f        | 2.8±0.0 d       | 2.2±0.0 d           | 3.3±0.0 e          | 10.1±0.0 f        | 2.0±0.0          | Bold Red |
| **Suduheenati**| 6.4±0.0 g         | 2.5±0.0 a       | 1.7±0.0 a           | 3.1±0.0 d          | 8.4±0.0 g         | 2.6±0.0          | Medium Red |
| **Suwadel**    | 4.1±0.0 h         | 2.5±0.0 a       | 1.6±0.0 e           | 2.6±0.0 f          | 4.9±0.0 h         | 1.7±0.0          | Bold White |
| **Kaluheenati**| 6.0±0.0 i         | 2.8±0.0 d       | 2.2±0.0 d           | 3.3±0.0 e          | 10.5±0.1 i        | 2.1±0.0          | Medium Red |

*N=10x5; SD-Standard Deviation; #-Classified according to IRRI; Different superscripts in columns indicate significances at 95% confidence interval
Figure 1: Paddy and dehulled grains of selected traditional rice

All of the selected rice varieties of this study were either medium (5.51-6.6 mm) or short (<5.50 mm) in length (Table 1) according to the classification adopted by IRRI (Rice Knowledge Bank, 2019). Thilakarathna et al. (2018) for Suwadel and Abeysekera et al. (2017) for Rathdel, Madathawalu, Pachchaperumal, Suduheenati and Kaluheenati reported similar results. However, the results obtained for physical properties in the present study were different from the results of Hettiarachchi et al. (2017) and Rebeira et al. (2015) for Pachchaperumal and Kaluheenati (short grains) and Madathawalu (medium grain). In the present study classification of Pachchaperumal and Kaluheenati was as medium and Madathawalu as short, similar to Thilakarathna et al. (2018) and Abeysekera et al. (2017). Some Bangladesh and Thai rice varieties were of medium and long length (6.6-7.5 mm) and all the varieties belonged to either slender or bold shape according to length/width ratio (Chapagai et al., 2017). Varieties Pokkali, Murugakayan, Suduheenati and Kaluheenati would be more popular as medium grains are more preferred in countries of Southeast Asia including Sri Lanka (Juliano, 1985; Juliano 2003).

Significant positive correlations between length and diameter (P= 0.001) and length and shape (P= 0.001) were observed. A positive correlation of grain length with shape was reported by Wadchararat et al. (2006), Thongbam et al. (2010) and Rasool et al. (2015). These results indicate that increased length is associated with the slender shape.

Table 2. Moisture, ash, crude fat and protein of selected rice flour (g/100g dry weight)

| Traditional rice variety | Moisture±SD*% | Ash±SD*% | Crude fat±SD**% | Crude protein±SD***% |
|--------------------------|---------------|----------|-----------------|---------------------|
| Pokkali                  | 6.6±0.2       | 1.2±0.1  | 4.7±0.3         | 9.2±0.2             |
| Murugakayan              | 6.7±0.4       | 1.2±0.1  | 4.8±0.3         | 6.2±0.2             |
| Rathdel                  | 6.8±0.1       | 1.3±0.1  | 4.9±0.2         | 7.1±0.3             |
| Madathawalu              | 5.4±0.1       | 1.6±0.1  | 4.6±0.0         | 7.7±0.1             |
| Kuruluthuda              | 7.0±0.4       | 1.2±0.1  | 4.2±0.1         | 8.6±0.3             |
| Pachchaperumal           | 5.0±0.2       | 1.4±0.1  | 4.3±0.1         | 6.7±0.2             |
| Suduheenati              | 8.3±0.0       | 1.2±0.1  | 4.4±0.2         | 5.5±0.2             |
| Suwadel                  | 8.6±0.3       | 1.3±0.1  | 4.6±0.2         | 8.4±0.2             |
| Kaluheenati              | 6.8±0.2       | 1.4±0.1  | 4.2±0.3         | 8.1±0.2             |

*n=6; **n=5; ***n=3; SD: Standard Deviation; Different superscripts in columns indicate significances at 95% confidence interval

3.2 Proximate composition of rice
Moisture, ash, crude fat and protein of the studied rice varieties are stated in table 2. The moisture content of rice flour varied between 5.0-8.6%. Varieties Pachchaperumal and Madathawalu contained least (P≤0.05) moisture whereas Suwadel and Suduheenati had the highest moisture (P≤0.05) contents among these varieties. The moisture content of the rice grain is an essential parameter which determines the keeping quality, milling quality and cooking and processing qualities of rice (Juliano, 2003). For storage moisture content must be kept lower than 14% or else the grain quality deteriorates (Juliano, 1985; Juliano, 2003). In the present study, the moisture contents of studied rice flour were less than 14%. Thus these varieties have the added advantage of being able to be stored for longer periods. According to Kulasinghe et al. (2019), Abeysekera et al. (2017) and Kariyawasam et al. (2016) the moisture contents of air-dried rice were more than 11% for selected traditional rice varieties which is higher than the moisture of the present study. In the present study, the rice grains have been dried in the oven for a few hours following air drying and prior to milling. Studies of Hettiarachchi et al. (2014) and Gunathilaka and Ekanayake, (2015) reported moisture contents more or less similar to the present study although the rice varieties were high yielding and basmati types.

Ash content which reflects the mineral content of uncooked rice flour varied between 1.2-1.6%. Values obtained for ash content of traditional rice by Kariyawasam et al. (2016) and Samaranayake et al. (2017) correlate with present study data. Both traditional and high yielding rice varieties have exhibited similar ash values (Kulasinghe et al., 2019; Samaranayake et al., 2017), except for Kuruluthuda (2.95%) and Madathawalu (2.16%). However, in the present study also Madathawalu contained the highest ash (P≤0.05) among the nine varieties. The ash contents by Abeysekera et al. (2017) for the same varieties were slightly higher. The mineral content of rice could vary due to soil conditions and also the fertilizer application (Syafutri et al., 2016).

The crude fat content of rice varieties varied within a small range (4.2-4.9% DM) and was less than 5% DM. The smallest rice, Rathdel and Murugakayan and Pokkali varieties had the highest (P≤ 0.05) crude fat contents out of the studied varieties. In the present study, crude fat values obtained were higher compared to other reported studies. Values for lipid content vary with the method of analysis (Zhou et al., 2002). In the present study, the discontinuous solvent extraction method was used to determine fat while many other researchers have used soxhlet extraction. Soxhlet extraction uses continuous flow and needs more time to extract under heating (Doria et al., 2009) where some fat could be oxidized/evaporated. The crude fat content of most reported studies on the fat content of rice that did not exceed 3% (Kulasinghe et al., 2019; Kariyawasam et al., 2016; Abeysekera et al., 2017 Gunaratne et al., 2011) were determined using the soxhlet method. Further, unmilled rice retains both the bran and germ which accommodate fat
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present in the grain (Chapagai et al., 2017). Thai rice varieties have shown similar amount of crude fat for rice flour (3.63-4.51g/100g) as in the present study but have obtained lower results for Sri Lankan red rice obtained from the market where the fat content was determined by gravimetric method (Sompong et al., 2011). The lower value could be due to the market rice being polished.

Lowest and highest (P≤0.05) crude protein contents were in Suduheenati (5.5%) and Pokkali (9.2%) respectively (Table 2). The protein content of rice flour of the present study was similar to Kulasinghe et al. (2019) and Samaranayake et al. (2017). However, according to Kariyawasam et al. (2016), Pokkali and Kaluheenati varieties had higher quantities of crude protein than observed in the present study. Crude protein contents of traditional rice including some varieties studied in the present study were higher (11-13.5%) than observed in the present study (Abeysekera et al., 2017). Gunaratne et al. (2011) have stated that traditional varieties contain more protein than improved varieties. This was apparent according to the results of Wathupola, (2017), Hettiaratchi et al. (2009) and Nisanka and Ekanayake, (2016) where high yielding varieties had lower protein than traditional varieties. Further, depending on the degree of polishing protein content decreases from raw rice at least by 6.7% due to removal of the aleurone layer (Juliano, 1985).

Digestible and un-digestible carbohydrates comprised more than 80% of the grain weights. Digestible carbohydrate was the major nutrient in all the traditional rice varieties (Table 3) and varied between 77.5-84.6%. Varieties Pokkali, Rathdel and Pachchaperumal had the highest (P≤0.05) content of digestible carbohydrate. The total carbohydrate content of rice varied between 78.7-85.2% when determined by both enzymatic digestion and phenol sulphuric (chemical) methods. Highest (P≤0.05) total carbohydrate contents were observed in Pokkali (85.2%), Rathdel and Pachchaperumal similar to digestible carbohydrate contents whereas Suwadel had the least (79.1%) total carbohydrate content (P≤0.05). Carbohydrate content of un-processed traditional rice determined by difference varied between 72.0-82.74% (Samaranayake et al., 2017; Kulasinghe et al., 2019). Samaranayake et al. (2017) reported higher values while Kulasinghe et al. (2019) reported lower values compared to the present study. The variations could be due to the difference in estimating carbohydrate content (by difference). The digestible carbohydrate content of several traditional rice varieties determined using enzymatic assay had more or less similar results to the present study (Gunaratne et al., 2011). The digestible and total carbohydrate content of high yielding raw and parboiled rice flour obtained by the same method of analyses were lower (Darandakumbura, 2013) when compared to the traditional rice studied in the present study. Basmati varieties had comparable digestible carbohydrate contents to the present study which had been determined using
enzymatic digestion (Gunathilaka and Ekanayake, 2015).

**Table 3.** Digestible carbohydrate, total carbohydrate, resistant starch, insoluble, soluble and total fiber contents of rice flour (g/100g dry weight)*

\*n=4; SD-Standard Deviation; ED-enzymatic digestion method; PS-Phenol sulphuric method

| Traditional rice variety | Digestible carbohydrate ± SD% | Total carbohydrate ± SD% (ED) % | Resistant starch ± SD% | Total carbohydrate ±SD% (PS)% | Insoluble fiber ± SD% | Soluble fiber ±SD% | Total fiber ± SD% |
|--------------------------|--------------------------------|---------------------------------|------------------------|-------------------------------|----------------------|-------------------|-----------------|
| **Pokkali**              | 84.6±0.6a                      | 85.2±0.2a                       | 0.7±0.2a               | 83.1±0.7ac                   | 2.8±0.2a             | 1.5±0.2a         | 4.3±0.1a        |
| **Murugakayan**          | 82.3±0.9b                      | 83.5±0.6b                       | 1.3±0.4ba              | 82.1±1.0ac                   | 4.0±0.6bc            | 1.5±0.2a         | 5.4±0.5b        |
| **Rathdel**              | 84.0±0.3a                      | 84.9±0.1a                       | 0.8±0.1ab              | 83.3±0.9a                    | 3.4±0.3bd            | 1.9±0.1b         | 5.3±0.4b        |
| **Madathawalu**          | 79.1±0.9c                      | 79.8±0.1c                       | 0.8±0.1ab              | 78.7±1.3b                    | 4.4±0.8bc            | 1.8±0.5ab        | 6.2±0.6bc       |
| **Kuruluthuda**          | 78.9±1.1cd                     | 79.3±0.1d                       | 0.4±0.2a               | 80.5±1.7ab                   | 4.9±0.5c             | 1.6±0.3ab        | 6.5±0.5c        |
| **Pachchaperumal**       | 84.0±0.6a                      | 84.7±0.3a                       | 0.7±0.1a               | 83.1±1.6a                    | 3.7±0.3bd            | 2.7±0.1c         | 6.5±0.2c        |
| **Suduheenati**          | 77.5±1.3cd                     | 80.6±0.6e                       | 3.2±0.6c               | 80.8±0.8b                    | 3.9±0.2b             | 1.9±0.3b         | 5.8±0.5bc       |
| **Suwadel**              | 78.1±0.6d                      | 79.1±0.4d                       | 1.0±0.3ab              | 79.7±1.4cd                   | 3.3±0.1d             | 2.4±0.4ab        | 5.7±0.4bc       |
| **Kaluheenati**          | 80.2±2.3bcd                    | 81.6±0.1e                       | 1.4±0.1b               | 80.3±1.0ab                   | 3.5±0.3bd            | 1.8±0.4ab        | 5.3±0.4b        |

for total carbohydrate; Different superscripts in columns indicate significances at 95% confidence interval

Resistant starch (RS) contents of rice flour ranged between 0.4- 3.2% where **Suduheenati** contained the highest (P≤ 0.05) amount. Except for **Murugakayan, Suduheenati, Suwadel** and **Kaluheenati** other varieties had less than 1% of RS. Varieties **Rathdel, Suduheenati** and **Suwadel** had similar RS values with reported data but **Kuruluthuda, Pachchaperumal** and **Kaluheenati** had higher values (Abeysekera et al., 2017) than reported in the present study where the RS content had been determined directly. Rice samples for this study had
been obtained from experimental fields of Rice Research and Development Center, Bombuwala. Improved rice varieties had more than 4% RS when analyzed according to the same method as in the present study (Gunaratne et al., 2013). The different geographical locations from which the rice has been obtained and the level of polishing the rice subjected to may have contributed to the observed differences.

The total dietary fiber contents of studied rice were more than 4% (Table 3). Insoluble dietary fiber content varied between 2.8- 4.9% (DM) whereas soluble fiber content varied between 1.5-2.7% (DM). Varieties Kuruluthuda (4.9%) and Pachchaperumal (2.7%) scored the highest values for insoluble and soluble fiber respectively and contained the highest dietary fiber among the varieties studied. Dietary fiber contents of Kuruluthuda (4.88%) and Suwadel (6.28%) determined by the same method as used in this study were similar to the data of the present study. These varieties have been obtained from a private institute (Samaranayake et al., 2017). The total dietary fiber content of Rathdel was similar but higher in Suduheenati (Abeysekera et al., 2017). However, some rice obtained from the market (Thailand, China and Sri Lankan red rice) had similar dietary fiber contents (Sompong et al., 2011) for other varieties whereas lower values were obtained for Sri Lankan rice which could be due to the polishing of the market rice.

4 CONCLUSIONS

The selected rice varieties in the present study were dehulled and not subjected to any other treatment. Shapes of the raw grains of the studied varieties were either medium or bold. The increased length was associated more with slender shape. When considering the nutritional potential the results indicated that the selected traditional rice varieties are good sources of carbohydrate and protein with low fat and moisture. Thus consumption of whole rice will be nutritionally advantageous. The low moisture increases the duration of storage of these varieties. Therefore, these rice varieties have the potential to be utilized as flour in the production of low-fat food products or replace wheat flour to a certain extent.

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