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Physicochemical and nutritional properties of twenty three traditional rice (*Oryza sativa* L.) varieties of Sri Lanka

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ABSTRACT

Objective: To evaluate the physicochemical and nutritional properties of selected traditional rice varieties of Sri Lanka.
Methods: Twenty three rice varieties were selected. All the varieties were studied for grain colour, grain size and shape as physicochemical properties, while for nutritional properties, moisture, crude ash, crude protein, crude fat and total carbohydrate contents were studied. Only selected set of varieties were studied for total, soluble and insoluble dietary fiber. These properties were studied using internationally accepted standard techniques.
Results: The results showed significant ($P < 0.05$) difference in the physicochemical and nutritional properties of the studied varieties. Out of 23 varieties tested, 20 varieties were red rices, while the rest were white rices. The grain size and shape were mostly medium bold (30%) and short bold (56%). The mean moisture, crude ash, crude protein, crude fat and total carbohydrate contents of selected varieties varied from (10.42 ± 0.25)% to (12.33 ± 0.02)%, (1.30 ± 0.14)% to (1.92 ± 0.05)%, (10.59 ± 0.12)% to (13.27 ± 0.32)%, (2.18 ± 0.10)% to (4.12 ± 0.28)% and (81.42 ± 0.25)% to (85.66 ± 0.24)%, respectively. The selected varieties had total, soluble and insoluble dietary fiber contents in the range of 4.2%–6.9%, 0.8%–2.1% and 3.1%–4.8%, respectively. The varieties Pachchaperumal, Suduru samba, Wanni Dahanala, Gonabaru and Sudu Heeneti had the highest crude protein, crude fat, crude ash, total carbohydrate and dietary fiber contents, respectively.
Conclusions: Selected traditional rice varieties of Sri Lanka had physicochemical properties preferred by consumers and nutritional properties with dietary importance.

1. Introduction

Rice (*Oryza sativa* L.) is one of the principle food crops in the world and the staple food for more than half of the world's population. It is mainly consumed as the cooked grain kernels, thus physicochemical properties of the rice grain are of primary important parameters for consumer's acceptance[1-5]. The main physicochemical properties which influence the consumer acceptance include grain color, grain size, grain shape, amylose content and gelatinization characteristics[1-3]. Apart from the physicochemical properties, nutritional properties of the rice grain are also of great importance to the rice consumers[1,2,6,7]. This is mainly because of significant contribution of rice to the dietary energy, protein and fat supply especially in the countries where rice is the staple food[8-11]. Rice is also reported to provide a range of minerals and vitamins, variety of bioactive phytochemicals and dietary fibers when it is consumed as the whole grains rather than the refined grains[1,2,6,12-15]. However, physicochemical and nutritional properties of rice vary significantly among different varieties cultivated in different regions of the world[1,2,5-7]. Research findings have clearly shown three to four times greater nutrient

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densities in certain varieties compared to the reported average[16]. Therefore, it is important to identify such rice varieties along with desirable physicochemical properties as those can be used as vehicles to improve the nutritional and health status of the people especially in countries where rice is the staple food.

In Sri Lanka rice is also the staple food and the rice cultivation in the country has a very long history[17,18]. During this period the country was known as the Granary of the East and existence of about 2 000 indigenous or the traditional rice varieties had been reported[16,17]. However, among these thousands of traditional rice varieties, some had been cultivated widely than the other varieties because of their health benefits, adaptability to problematic soils and resistance to different abiotic stress conditions[17,19]. Recent research conducted in the country scientifically showed range of medically important health benefits of some Sri Lankan traditional rice varieties[19-22]. These findings were able to uplift the traditional rice industry in the country immensely. If these varieties also contain high nutritional values and dietary important physicochemical properties, they can be marketed in the local and international trade easily. Current trend in the food industry is also to identify and introduce health foods as there is a rising incidence of nutritional deficiencies and non communicable diseases worldwide[23,24]. The rice varieties having physicochemical and nutritional properties preferred by consumers can be effectively used as vehicles to address such problems especially in countries where rice is the staple food. Although health benefits of some of the Sri Lankan traditional rice varieties were recently reported, their physicochemical and nutritional properties are still not well documented. Hence this study was conducted to investigate the dietary important physicochemical properties of traditional rice varieties of Sri Lanka.

2. Materials and methods

2.1. Rice samples

Twenty three Sri Lankan traditional rice varieties were used in this study. Selected rice varieties were obtained from Regional Rice Research and Development Center (RRRDC), Bombuwala, Sri Lanka. Rice varieties had been cultivated in experimental plots (plot size of 1.9 m × 1.2 m and spacing of 20 cm × 15 cm) using randomized complete block design (RCBD) during 2006–2007 Maha season. Figure 1 shows the twenty three Sri Lankan traditional rice varieties selected for the study.

2.2. Sample preparation

Rice seeds were dehulled using laboratory dehuller (THU 35B, Satake, Hiroshima, Japan). Dehulled grains were polished in a laboratory miller (TM-05c, Satake, Hiroshima, Japan). The whole grains and the milled grains were stored at 8 °C in a cold room until used for the analysis. Preparation of rice flour from whole grains was performed using an ultra centrifugal mill with a 0.25 mm sieve, and the rice flour was used for the evaluation of nutritional properties of the rice grains.

2.3. Physicochemical properties of selected traditional rice varieties of Sri Lanka

2.3.1. Pericarp color

Pericarp color of the selected Sri Lankan traditional rice was evaluated by visual observation[1].

2.3.2. Grain size

Grain size was evaluated according to the method described by Juliano[1,2]. Briefly, 10 milled undamaged rice grains were arranged lengthwise and the cumulative measurements (mm) were taken using a ruler. Then, length of the rice grains was calculated by dividing the cumulative length of the rice grains by 10. Mean value of 5 replications was used. Rice grains were classified according to the classification adapted by Philippines[25].

2.3.3. Grain shape

Grain shape was evaluated according to the method described by Juliano[1,2]. Briefly, 10 milled undamaged rice grains were arranged lengthwise and widthwise and the cumulative measurements (mm) were taken using a ruler. The ratio of length to width was calculated. The grain shape was classified according to the classification adapted by the Philippines[26]. Mean value of 5 replications was used.

2.4. Nutritional properties of selected traditional rice varieties of Sri Lanka

2.4.1. Proximate composition

Moisture content, crude ash, crude protein and crude fat contents (n = 4) of selected whole grain rice varieties were determined according to the methods described by Association of Official Analytical Chemists[27]. Total carbohydrate content was determined by subtracting the sum of the values of crude protein, crude fat and ash content (% dry weight) of the sample from 100[6].

2.4.2. Total, soluble and insoluble dietary fiber contents

Total, soluble and insoluble dietary fiber contents were estimated by enzymatic gravimetric method of Asp *et al*.[28]. One gram of rice flour (to the nearest 0.1 mg) was added to 25 mL of 0.1 mol/L sodium phosphate buffer (pH = 6) and 100 µL of heat stable α-amylase was added and incubated in a boiling water bath for 15 min. The digest was allowed to cool and the pH of the samples was adjusted to 1.5 ± 0.1 using HCl. Then, 100 mg of pepsin was added to each sample and incubated at 40 °C for 1 h with agitation. After the digestion, samples were allowed to cool and pH was adjusted to 6.8 ± 0.1 using NaOH. Then, samples were incubated at 40 °C for 1 h with agitation with the addition of 100 mg of pancreatin. Finally, pH of the samples was adjusted to 4.5 with 1 mol/L HCl and whole digest was directly precipitated with 4 volumes of 95% ethanol and filtered through a dry and weighed crucible (porosity 2) containing 0.5 g of dry celite as the filter aid. Residue was washed with 2 × 10 mL of 78% ethanol, 2 × 10 mL of 95% ethanol and 2 × 10 mL of acetone. Residue was dried at 105 °C overnight and weighed after cooling in a desiccator. It was incinerated at 550 °C until a constant weight was obtained. Nitrogen in the dietary fiber fractions was

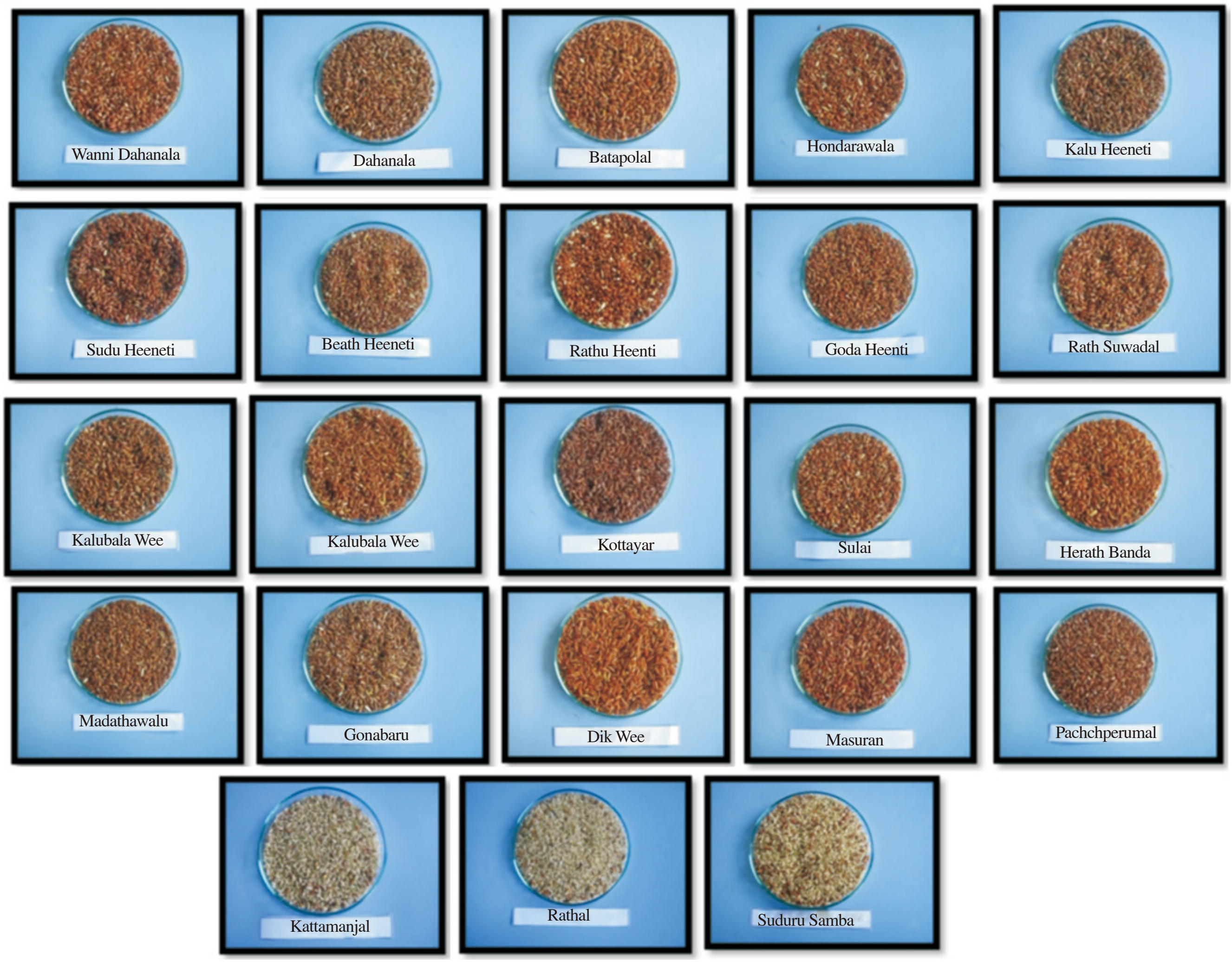

Figure 1. Whole grains of twenty three selected traditional rice varieties of Sri Lanka.

determined using the Kjeldahl method and transferred to protein by multiplication with 6.25 (indigestible proteins). The blank was assayed in the same way without the sample. The indigestible protein was subtracted from the dietary fiber values to calculate total dietary fiber content of the rice samples. For the determination of insoluble dietary fiber content, the sample was filtered through a dry and weighed crucible (porosity 2) containing 0.5 g of dry celite after the pancreatic digestion step and pH was adjusted to 4.5 with 1 mol/L HCl. The resulting filtrate contained the soluble dietary fibers and it was directly precipitated with 4 volumes of 95% ethanol and filtered through a dry and weighed crucible (porosity 2) containing 0.5 g of dry celite as the filter aid. Then, same procedure was followed as described in the determination of total dietary fiber contents of the samples.

2.5. Statistical analysis

Results were represented as mean ± SE. Data of each experiment were statistically analyzed using SAS version 6.12. One-way ANOVA and the Duncan's multiple range test (DMRT) were used to determine the differences among means. $P < 0.05$ was regarded as significant.

3. Results

3.1. Physicochemical properties of selected traditional rice varieties of Sri Lanka

3.1.1. Pericarp color

Pericarp color of the selected rice varieties is given in Table 1. Pericarp colors of the selected Sri Lankan traditional rice varieties were either red or white. Among the selected rice varieties, Suduru Samba, Kattamanjal and Rathal were white rices, while the rest of the varieties were red rices. However, different intensities of red color were observed among the red varieties.

3.1.2. Grain size

Grain length of the rice varieties ranged from (4.12 ± 0.10) to (5.98 ± 0.10) mm. Selected rice varieties were medium or short grains according to the grain size classification used. The varieties having medium grains were Masuran, Hondarawalu, Dik Wee, Kalu Heeneti, Sudu Heeneti, Sulai, Gonabaru and Pachchaperumal, while the rest of the rice varieties had short grains. All white rice varieties (Rathal, Suduru Samba and Kattamanjal) used in this study were of short grains. Grain size of selected rice varieties is given in Table 1.

Table 1

Physicochemical properties of selected traditional rice varieties of Sri Lanka.

Rice variety	Pericarp color	Length (mm)	Grain size	Width (mm)	Length:width	Grain shape
Masuran	Red	5.98 ± 0.10	Medium	2.36 ± 0.00	2.53 ± 0.00	Bold
Hondarawalu	Red	5.74 ± 0.10	Medium	2.42 ± 0.10	2.38 ± 0.00	Bold
Dik Wee	Red	5.70 ± 0.10	Medium	1.88 ± 0.00	3.03 ± 0.00	Slender
Kalu Heeneti	Red	5.62 ± 0.10	Medium	2.30 ± 0.10	2.45 ± 0.00	Bold
Sudu Heeneti	Red	5.62 ± 0.10	Medium	2.48 ± 0.10	2.27 ± 0.00	Bold
Sulai	Red	5.60 ± 0.10	Medium	2.68 ± 0.10	2.09 ± 0.00	Bold
Gonabaru	Red	5.60 ± 0.10	Medium	2.34 ± 0.00	2.39 ± 0.00	Bold
Pachchaperumal	Red	5.56 ± 0.00	Medium	2.46 ± 0.00	2.26 ± 0.00	Bold
Wanni Dahanala	Red	5.48 ± 0.00	Short	2.48 ± 0.00	2.21 ± 0.00	Bold
Dahanala	Red	5.42 ± 0.10	Short	2.28 ± 0.10	2.38 ± 0.00	Bold
Kalu Bala Wee	Red	5.40 ± 0.10	Short	2.28 ± 0.10	2.37 ± 0.00	Bold
Rath Suwadal	Red	5.32 ± 0.10	Short	2.44 ± 0.00	2.18 ± 0.00	Bold
Kahata Wee	Red	5.30 ± 0.10	Short	2.18 ± 0.00	2.43 ± 0.00	Bold
Herath banda	Red	5.26 ± 0.00	Short	2.48 ± 0.10	2.12 ± 0.00	Bold
Batapolal	Red	5.22 ± 0.10	Short	2.32 ± 0.20	2.26 ± 0.00	Bold
Goda Heeneti	Red	5.16 ± 0.00	Short	2.46 ± 0.00	2.10 ± 0.00	Bold
Kottayar	Red	5.14 ± 0.10	Short	2.42 ± 0.10	2.13 ± 0.00	Bold
Madathawalu	Red	4.88 ± 0.10	Short	2.44 ± 0.00	2.00 ± 0.00	Bold
Suduru Samba	White	4.78 ± 0.10	Short	2.12 ± 0.10	2.26 ± 0.00	Bold
Rathal	White	4.48 ± 0.10	Short	2.08 ± 0.10	2.16 ± 0.00	Bold
Rathu Heeneti	Red	4.44 ± 0.00	Short	2.46 ± 0.00	1.81 ± 0.00	Round
Beheth Heeneti	Red	4.22 ± 0.10	Short	2.26 ± 0.00	1.87 ± 0.00	Round
Kattamanjal	White	4.12 ± 0.10	Short	2.02 ± 0.00	2.04 ± 0.00	Bold

Data were expressed as mean ± SE ($n = 5$). Size classification: short (< 5.5 mm); medium (5.5–6.3 mm). Shape classification: Round (length to width ratio < 2.0); bold (ratio 2.0–3.0); slender (ratio > 3.0).

3.1.3. Grain shape

Length to width ratio of rice varieties ranged from 1.81 ± 0.00 to 3.03 ± 0.00. Selected rice varieties had slender, bold and round shapes according to the grain shape classification used. However, 20 varieties out of 23 varieties had bold shape. Among the rice varieties tested, only Dik Wee had slender shape and Rathu Heeneti and Beheth Heeneti had round shape. The three white rice varieties Rathal, Suduru Samba and Kattamanjal selected for the study had the grain shape of bold. Grain shape of selected rice varieties is given in Table 1.

3.2. Nutritional properties of selected traditional rice varieties of Sri Lanka

Proximate composition of selected rice varieties is given in Table 2. Results showed that moisture, crude ash, crude protein, crude fat and total carbohydrate contents varied significantly ($P < 0.05$) among the rice varieties tested. The mean moisture, crude ash, crude protein, crude fat and total carbohydrate contents varied from (10.42 ± 0.25)% to (12.33 ± 0.02)%, (1.30 ± 0.14)% to (1.92 ± 0.05)%, (10.59 ± 0.12)% to (13.27 ± 0.32)%, (2.18 ± 0.10)% to (4.12 ± 0.28)% and (81.42 ± 0.25)% to (85.66 ± 0.24)%, respectively among the rice varieties tested in this study. The details of each nutritional properties are given in the following sections.

3.2.1. Moisture content

The mean moisture content of selected Sri Lankan traditional rice varieties is given in Table 2. Among the rice varieties tested, Madathawalu had the highest moisture content while Herath Banda had the lowest. Beheth Heeneti, Masuran, Dik Wee and Herath Banda had the moisture content < 11%, while Madathawalu, Pachchaperumal, Sulai and Suduru Samba had moisture content > 12%. The rest of the rice varieties had moisture content within 11%–12%.

3.2.2. Crude protein content

The mean crude protein content of selected Sri Lankan traditional rice varieties is given in Table 2. All the selected rice varieties had protein content > 10%. The red rice Pachchaperumal had the highest protein content. The lowest protein content was observed in the variety Gonabaru. Red rice varieties Pachchaperumal (13.27% ± 0.32%) and Wanni Dahanala (13.14% ± 0.12%) and white rice variety Suduru Samaba (13.16% ± 0.05%) had protein content > 13% and these varieties were the highest protein-containing varieties in this study.

3.2.3. Crude fat content

Mean crude fat content of selected rices is given in Table 2. Crude fat content ranged from (2.18 ± 0.10)% to (4.12 ± 0.28)% among the rice varieties tested. White rice varieties had significantly higher ($P < 0.05$) fat content than red rice varieties tested in this study. White rice variety Suduru Samba had the highest fat content (4.12% ± 0.28%) among all the rice varieties studied. Kattamanjal (3.25% ± 0.09%) and Rathu Heeneti (3.08% ± 0.37%) had fat content > 3% and the rest of the rice varieties had fat content in the range of (2.18 ± 0.10)% to (2.97 ± 0.03)%.

3.2.4. Crude ash content

Mean ash content of selected rices is given in Table 2. Crude ash contents were in the range of (1.30 ± 0.14)% to (1.92 ± 0.05)% among all rice varieties tested. Red rice variety Wanni Dahanala had the highest ash content (1.92% ± 0.05%) while white rice variety Suduru Samba had the lowest.

Table 2

Proximate composition of selected traditional rice varieties of Sri Lanka (% dry weight).

Rice variety	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Total carbohydrate (%)
Madathawalu	12.33 ± 0.02^{a}	11.52 ± 0.07^{defgh}	2.97 ± 0.03^{bcd}	1.50 ± 0.20^{efg}	84.01 ± 0.13^{defg}
Pachchaperumal	12.13 ± 0.52^{ab}	13.27 ± 0.32^{a}	2.75 ± 0.17^{cdef}	1.70 ± 0.07^{abcde}	82.28 ± 0.42^{j}
Sulai	12.11 ± 0.26^{ab}	10.72 ± 0.04^{gh}	2.54 ± 0.06^{defgh}	1.62 ± 0.03^{bcdef}	85.12 ± 0.09^{abc}
Suduru Samba	12.10 ± 0.08^{ab}	13.16 ± 0.05^{ab}	4.12 ± 0.28^{a}	1.30 ± 0.14^{g}	81.42 ± 0.25^{k}
Kalubala Wee	11.80 ± 0.22^{abc}	12.49 ± 0.55^{abcd}	2.67 ± 0.10^{cdefgh}	1.79 ± 0.07^{abcd}	83.05 ± 0.60^{hij}
Sudu Heeneti	11.70 ± 0.09^{abc}	12.08 ± 0.03^{cdef}	2.63 ± 0.17^{cdefgh}	1.60 ± 0.05^{cdef}	83.69 ± 0.17^{fghi}
Rathu Heeneti	11.66 ± 0.51^{abc}	10.94 ± 0.28^{gh}	3.08 ± 0.37^{bc}	1.59 ± 0.03^{cdef}	84.38 ± 0.40^{bcdef}
Hondarawalu	11.47 ± 0.13^{abc}	11.35 ± 0.27^{efgh}	2.49 ± 0.18^{defgh}	1.42 ± 0.09^{fg}	84.75 ± 0.45^{abcde}
Wanni Dahanala	11.45 ± 0.22^{abc}	13.14 ± 0.12^{ab}	2.45 ± 0.07^{efgh}	1.92 ± 0.05^{a}	82.48 ± 0.08^{j}
Rathal	11.43 ± 0.24^{abc}	11.09 ± 0.11^{fgh}	2.89 ± 0.17^{bcde}	1.61 ± 0.03^{bcdef}	84.41 ± 0.23^{bcdef}
Kottayar	11.41 ± 0.50^{bc}	12.20 ± 0.05^{bcde}	2.50 ± 0.08^{defgh}	1.63 ± 0.05^{bcdef}	83.67 ± 0.05^{fghi}
Kalu Heeneti	11.33 ± 0.30^{bcd}	11.40 ± 0.30^{efgh}	2.72 ± 0.11^{cdefg}	1.87 ± 0.10^{ab}	84.02 ± 0.32^{defg}
Rath Suwadal	11.21 ± 0.14^{bcd}	12.86 ± 0.34^{abc}	2.63 ± 0.26^{cdefgh}	1.67 ± 0.03^{abcdef}	82.84 ± 0.57^{ij}
Batapolal	11.14 ± 0.37^{cd}	11.10 ± 0.20^{fgh}	2.50 ± 0.06^{defgh}	1.48 ± 0.06^{efg}	84.93 ± 0.06^{abcd}
Kattamanjal	11.12 ± 0.12^{cd}	12.21 ± 0.54^{bcde}	3.25 ± 0.09^{b}	1.69 ± 0.07^{abcde}	82.84 ± 0.51^{ij}
Gonabaru	11.11 ± 0.45^{cd}	10.59 ± 0.12^{h}	2.21 ± 0.07^{gh}	1.54 ± 0.16^{defg}	85.66 ± 0.24^{a}
Goda Heeneti	11.10 ± 0.05^{cd}	12.20 ± 0.02^{bcde}	2.18 ± 0.10^{h}	1.81 ± 0.04^{abc}	83.81 ± 0.08^{efgh}
Dahanala	11.05 ± 0.22^{cd}	12.37 ± 0.24^{abcde}	2.61 ± 0.03^{cdefgh}	1.87 ± 0.05^{ab}	83.16 ± 0.25^{ghij}
Kahata Wee	11.03 ± 0.20^{cd}	11.02 ± 0.04^{abcde}	2.70 ± 0.24^{cdefgh}	1.63 ± 0.03^{bcdef}	84.61 ± 0.29^{bcdef}
Beheth Heeneti	10.99 ± 0.70^{cd}	11.39 ± 0.14^{efgh}	2.74 ± 0.16^{cdef}	1.80 ± 0.08^{abcd}	84.07 ± 0.24^{defg}
Masuran	10.93 ± 0.40^{cd}	10.63 ± 0.63^{h}	2.71 ± 0.35^{cdefg}	1.45 ± 0.08^{efg}	85.22 ± 0.73^{abc}
Dik Wee	10.90 ± 0.12^{cd}	11.70 ± 0.08^{defg}	2.39 ± 0.12^{efgh}	1.61 ± 0.18^{bcdef}	84.30 ± 0.18^{cdef}
Herath Banda	10.42 ± 0.25^{d}	10.90 ± 0.28^{gh}	2.30 ± 0.12^{fgh}	1.44 ± 0.04^{efg}	85.36 ± 0.30^{ab}

Data were expressed as mean ± SE (n = 4 each). Mean values in a column with different superscripted letters are significantly different at $P < 0.05$.

3.2.5. Total carbohydrate content

Mean total carbohydrate content of selected rices is given in Table 2. Total carbohydrate contents of selected rice varieties varied from (81.42 ± 0.25)% to (85.66 ± 0.24)%. Red rice variety Gonabaru had the highest total carbohydrate content while white rice variety Suduru Samba had the lowest. Among the rice varieties tested Gonabaru (85.66% ± 0.24%), Herath Banda (85.36% ± 0.30%), Masuran (85.22% ± 0.73%) and Sulai (85.12% ± 0.09%) had total carbohydrate content > 85%, while the rest of the rice varieties had total carbohydrate content in the range of 81%– 84%.

3.2.6. Total, soluble and insoluble dietary fiber contents

Total, soluble and insoluble dietary fiber contents of selected rices are given in Table 3. Selected rice varieties had total, soluble and insoluble dietary fiber contents in the range of 4.2%–6.9%, 0.8%–2.1% and 3.1%–4.8% respectively. Among the rice varieties studied, red rice variety Sudu Heeneti exhibited the highest total and insoluble dietary fiber contents, while red rice variety Beheth Heeneti had the highest soluble dietary fiber contents.

Table 3

Total, soluble and insoluble dietary fiber contents of selected traditional rice varieties of Sri Lanka (% dry weight).

Rice variety	Pericarp color	TDF	SDF	IDF	Sum of SDF & IDF[a]
Sudu Heeneti	Red	6.9	1.8	4.8	6.7
Rathu Heeneti	Red	6.5	1.2	4.7	5.9
Beheth Heeneti	Red	6.0	2.1	3.5	5.6
Hondarawala	Red	5.7	1.6	4.0	5.7
Rathal	White	5.5	1.9	3.5	5.4
Dik Wee	Red	5.0	0.8	3.6	4.4
Suduru Samba	White	4.9	1.9	3.1	4.9
Gonabaru	Red	4.6	0.9	3.1	4.0
Molligoda	Red	4.2	1.2	3.9	5.1

TDF: Total dietary fiber; SDF: Soluble dietary fiber; IDF: Insoluble dietary fiber. [a]: TDF as sum of SDF & IDF.

4. Discussion

Twenty three traditional rice varieties of Sri Lanka were studied for physicochemical properties using internationally accepted standard techniques. These varieties were selected based on the health claims in the Sri Lankan traditional knowledge and the findings of our previous researches[17,19-22]. Physicochemical properties of the rice grain are important rice grain quality attributes which influence the consumers' acceptance[1,2,4,5]. In this study, grain color, grain size and shape were studied as physicochemical properties of the rice grain. Out of 23 varieties tested in this study, 20 varieties were red rices and the rest of the varieties were white rices (3 varieties). The grain size and shape of the varieties studied were mostly medium bold or short bold, while Dik Wee was the only rice variety which had medium size and slender shape. Colored or pigmented rices are popular in some countries and are reported as special rices. Such rices are reported to have variety of health benefits compared to non-pigmented rices[6,7,19-22,29]. Our previous researches on health benefits of traditional rice varieties of Sri Lanka showed high antioxidant, anti-diabetic, anti-inflammatory and cytotoxic effects on human cancer cell lines in brans of red rices in contrast to brans of white rices[19-22]. Thus, consumption of traditional red rice varieties may be important in prevention and dietary management of such chronic diseases. Preference for grain size and shape varies among consumers and in general long grains have a high demand in the international trade[1-3,30]. As Dik Wee is a slender variety and proved to have medically important health food properties from our previous studies, it may have the potential to be marketed in the international trade as a special rice variety. In countries of Southeast Asia, the medium to medium long grain rices are mostly preferred[1-3,30]. Thus, the rest of the rice varieties tested in this study are much suitable for Sri Lankans as well as the consumers in Southeast Asia.

Proximate composition (moisture, crude protein, crude fat, crude ash and total carbohydrate) for all the rice varieties and dietary fibers (soluble, insoluble and total dietary fiber) only for selected rice varieties were studied as nutritional properties of the rice grain. These properties were studied for the whole grains as consumption of whole grains is widely known for variety of health benefits compared to refined grains[1,2,6,12-15]. Protein is a major nutrient in rice and selected rice varieties in the present study had protein content in the range of (10.59 ± 0.12)%–(13.27 ± 0.32)%. Analysis of 2674 rice varieties by the International Rice Research Institute (IRRI) showed that protein content of *Oryza sativa* varieties ranged from 4.5% to 15.9%[16]. Thus, our findings are in agreement with those of IRRI. However, according to the most of the studies conducted, protein content of rice varieties worldwide were < 13%[1,2,6,31-33]. Thus, rice varieties which had protein content > 13% can be considered as high protein-containing varieties. Rice accounts for 14% protein supply globally and in developing countries it contributes to up to 20% daily protein requirement[9]. In Sri Lanka, contribution of rice to the daily protein requirement is nearly 37%[9]. Therefore, consumption of especially whole grains of Pachchaperumal, Suduru Samba and Wanni Dahanala rice varieties may be beneficial in obtaining significant amount of recommended daily protein requirement.

Contribution of fat from rice to the dietary fat supply varies significantly from country to country. In the countries in Southeast Asia (high per capita consumption) such as Bangladesh (150 kg), Laos (172 kg), Viet Nam (165 kg), Myanmar (213 kg) and Cambodia (169 kg) where rice is heavily consumed, contribution of rice to the dietary fat is nearly 17%–26%[9,34]. In Sri Lanka, contribution of rice to the dietary fat supply is about 2.7%. In the present study Suduru Samba, Kattamanjal and Rathu Heeneti showed high fat content. It is reported that the outer layers of the rice grain (rice bran) contain more mono- and polyunsaturated fatty acids, which are considered as good-quality dietary fat[1,2]. Thus, although contribution of rice to the dietary fat supply is low in Sri Lanka, consumption of these varieties as whole grains helps in obtaining good-quality dietary fat.

The ash content is an indication of the mineral content of the rice grain. Among selected rice varieties, 5 varieties had ash content < 1.5%, 13 varieties had 1.5%–1.8% ash content and 5 varieties had 1.8%–1.92% ash content. Among minerals, iron and zinc are considered as important minerals. A recent study conducted on micronutrient contents of traditional rice varieties of Sri Lanka showed that Kalubala Wee, Pachchaperumal, Dahanala, Rathu Heeneti, Kattamanjal and Rathal had high iron contents (2.25–3.73 mg/100 g), while Kalu Bala Wee, Wanni Dahanala, Rathu Heeneti, Dahanala, Rathal and Kalu Heeneti had high zinc (2.51–3.91 mg/100 g) contents[35,36]. Therefore, consumption of such varieties may be helpful in obtaining significant amount of iron and zinc.

Carbohydrate is the major component of the rice grain. It varied from (81.42 ± 0.25)% to (85.36 ± 0.30)% among the varieties and it was within the range of other published data. Rice is the predominant staple for 15 countries in Asia and the Pacific, 10 countries in Latin America and the Caribbean, 7 countries in Sub-Saharan Africa and one country in North Africa[9,34]. In developing countries, rice accounts for about 27% of dietary energy supply, while in Southeast Asian countries where rice is heavily consumed, the contribution of rice is more than 50% to the per capita dietary energy[11,34]. In Sri Lanka, rice is reported to contribute 45% to the per capita dietary energy[37]. Foods containing generally high carbohydrate contents are associated with high glycaemic index[38]. As prevalence of diabetes and prediabetes in the country is on an increasing trend[39], it is important to identify rice varieties having low glycaemic indices. Presence of high dietary fiber, amylose contents and inhibitors of carbohydrate digestion enzymes reduces glycemic index of a food[38]. The present study showed that Sudu Heeneti, Rathu Heeneti and Beheth Heeneti had high dietary fiber content. Furthermore, our previous studies showed that all the selected rice varieties (except Suduru Samba with intermediate amylose content) had high amylose contents (> 25%)[40,41] and brans of Sudu Heeneti, Masuran, Goda Heeneti and Dik Wee had high α-amylase inhibitory activity[20]. Furthermore, whole grains of Sudu Heeneti, Masuran and Dik Wee had low *in vitro* starch hydrolysis rate (indication of glycemic index)[19,20,22]. Thus consumption of such rices may be important in managing diabetes and prediabetes.

A healthy Sri Lankan adult generally consumes 275 g of rice per day on average[37]. As an example consumption of Pachchaperumal (one of the best varieties in terms of nutritional properties) 275 g/day can provide nearly 66% protein (35 g from 275 g), 25% fat (6.9 g from 275 g) and 32% iron (5.8 mg from 275 g) for the total daily requirement of nutrients[42]. Thus, traditional rice varieties of Sri Lanka are super staple foods to enhance the nutritional and health status of the people in the country.

In conclusion, selected traditional rice varieties of Sri Lanka had physicochemical properties preferred by consumers. For the nutritional properties, the best varieties were Pachchaperumal, Wanni Dahanala, Rathu Heeneti, Kalubala Wee, Dahanala (red rice), Suduru Samba, Kattamanjal and Rathal (white rice) in terms of protein, fat, iron and zinc contents.

Conflict of interest statement

We declare that we have no conflict of interest.

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