Research Paper

Nutrient Composition and *In-Vitro* Starch Digestibility of Selected Rice Varieties (*Oryza sativa* L.) in Sri Lanka

S.P. Rebeira[1*], B.M.K.S. Menike[2], A. Bentota[2], D.M.J.B. Senanayake[2], B.D.R. Prasantha[3], N.D.V. Champika[2], D.K. Padmalatha[2], K.M.K. Kumarihamy[2]

[1] *Food Research Unit, Gannoruwa, Sri Lanka*

[2] *Rice Research and Development Institute, Batalagoda, Sri Lanka*

[3] *Department of Food Science & Technology , Faculty of Agriculture, University of Peradeniya, Sri Lanka*

**Corresponding author: srikanthi.rebeira@yahoo.com*

ARTICLE INFO

Article history:
Received: 27 May 2021
Revised version received: 27 October 2021
Accepted: 10 December 2021

Citation:
Rebeira, S.P., Menike, B.M.K.S., Bentota, A., Senanayake, D.M.J.B., Prasantha, B.D.R., Champika, N.D.V., Padmalatha, D.K., Kumarihamy, K.M.K. (2022). Nutrient composition and *in-vitro* starch digestibility of selected rice varieties (*Oryza sativa* L.) in Sri Lanka. *Tropical Agriculturist*, 170 (2), 1-11.

Abstract

Knowledge on nutritional value and digestibility of rice varieties can assist consumers to select the right variety according to their dietary requirement. Twenty popular traditional and improved rice varieties were evaluated with the objective of generating information on their nutrient composition, *in-vitro* starch digestibility and physicochemical properties. The highest values for crude protein, total ash, crude fat total dietary fiber contents (% w/w) were observed in At 373 (11.04± 0.01), *Kalu Heenati* (1.25±0.01), *Kalu Heenati* (2.13±0.03) and At 311 (3.93± 0.02), respectively. The lowest digestion rate, total and available carbohydrates contents (% w/w, TCHO and ACHO) were observed in Bg 94-1 (56.86±1.88) and At 373 (TCHO=72.88±0.09; ACHO=69.80±0.24), respectively. New and old improved varieties were predominantly grouped in high amylose category while traditional cultivars in intermediate amylose category. An intermediate gelatinization temperature was prominent among evaluated varieties. Pigmented rice showed higher contents of total ash, fat, total dietary fiber when compared to non–pigmented rice but no difference in analysed nutrient composition was found between evaluated improved and traditional varieties.

Keywords: Cooking quality, Nutritional quality, Starch digestibility

Introduction

Rice (*Oryza sativa* L.) is the staple food and the single most important crop in Sri Lanka in terms of area cultivated, production, number of farming families engaged and political sensitivity (Wickramasinghe and Noda, 2008). Vast genetic diversity of rice can be found in Sri Lanka with traditional, old and new improved varieties of pigmented and non–pigmented rice. Almost 99% of the rice land is cultivated with new–improved rice varieties and 1% is occupied by old improved varieties and traditional cultivars (AgStat, 2018). However, traditional cultivars have an increasing demand owing to their nutritive and medicinal value recognized from the ancient time (Wickramasinghe and Noda, 2008; Abeysekera *et al*., 2017b). Even though non–pigmented rice is popularly consumed in the world, pigmented rice is also demanded in some Asian countries including Sri Lanka (Somaratne *et al*., 2017). Pigmented rice have become more popular and accounts roughly 30–40% of the total rice consumption in Sri Lanka. Pigmented rice showed potential health benefits due to their high dietary fiber content, which could reduce the risk of type 2–diabetes by controlling blood glucose level (Babu *et al*., 2009).

Starch is the major component of cereals and starch digestibility of a food is an important factor, specially for the people with diabetic concerns. *In-vitro* starch hydrolysis method has been suggested for predicting *in-vivo* glycemic response or Glycemic Index (GI) of a food (Englyst *et al*.,1999; Frei *et al*., 2003; Gunaratne *et al*., 2020). Limited facts are avaialble on starch digestibility and glycemic responses of Sri Lankan rice. Hence, identification of varieties with low digestion rates is beneficial to individuals with impaired glucose tolerance (Englyst *et al*., 1999; Wolever and Mchling, 2002). Rice is the main source of carbohydrates, besides it provides 20% protein, 3% fat and a considerable portion of dietary minerals and fiber requirement of a person in developing countries (Kennedy and Burlingame, 2003). Rice protein comprises of a good balance of amino acids and has the highest digestibility over other cereal proteins (Liyanaarachchi *et al*., 2021). Consumption of rice fat is beneficial due to its antioxidant components such as tocopherols, tocotrinols and orizanolas well as the presence of unsaturated fatty acids such as oleic and linoleic acid (Xu *et al*., 2001; Samaranayake *et al.*, 2017). Consuming rice as a source of dietary fiber can reduce the risk of coronary heart diseases, diabetes, obesity, and cancer (Ahmed *et al*., 2000; Young and Woodside, 2001).

Milled or polished rice is popularly consumed even though brown rice with its bran layer considered to be more nutritious. Rice may be milled up to 8–10% wt/wt to reach optimum whiteness despite the fact that low amounts of nutrients; protein, fiber, oil, minerals, vitamins, and phytochemicals are retained (Somaratne *et al*., 2017). Lack of scientific data on nutrient composition, digestibility of Sri Lankan rice has failed to provide a proper guidance to select rice varieties for individuals with different health concerns. Some previous studies have reported nutritional properties of unpolished rice regardless the fact that polished rice is the most demanded type by a regular consumer. Physicochemical properties such as amylose content and gelatinization temperature are also considered as important quality parameters, which determine cooking and eating quality. With the above concern, the present investigation was commenced with the objective of identifying the nutrient composition and starch digestibility of milled rice of the selected popular new and old improved varieties and traditional cultivars along with assessment of their physico chemical properties.

Materials and Methods

Twenty selected rice varieties including six traditional cultivars (Pigmented: *Madathawalu, Kalu Heenati, Murungakayan, Pokkali, Sudu Heenati* and non–pigmented: *Suwandel*), one old improved variety (H4: pigmented) and thirteen new improved varieties (Pigmented:Bw 272–6B, At 362, At 311 and non–pigmented:Bg 358, Bg 360, Bw 367, Bg 352, Bg 359, Bg 300, Bg 94–1, At 373, Bg 379–2, Bg 366) were cultivated at the field of the Rice Research and Development Institute, Batalagoda, Sri Lanka under recommended management practices. Harvested grains at physiological maturity were shade dried. The grains stored for six weeks were dehulled (laboratory huller: THU 358, Satake, Hiroshima, Japan) and polished upto 7% weight reduction (polishing machine: THO 50, Satake, Hiroshima, Japan). Moisture content, total ash, crude protein, crude fat and total carbohydrate contents were determined according to the methods described by Association of Official Analytical Chemists (2000). Total dietary fiber content was determined according to the method described by Abeysekera *et al*. (2017a). Total available carbohydrate content was determined subtracting total dietary fiber content from total carbohydrate content. *In vitro* starch digestibility rate was determined according to the method described by Panlasigui *et al*. (1991). Digestion and dialysis were carried out for the reference sample; white bread. Portion (1 ml) of each dialysate samples were taken hourly within 3 hours and analyzed for sugars using dinitrosalicylic acid.

Amylose content (AC) was estimated by the simplified spectrophotometric method (Juliano, 1971) and varieties were classified as high AC (25–33%), intermediate AC (20–25%) and low AC (12–20%). Gelatinization Temperature (GT) was determined by alkali digestibility test and according to the alkali spreading value (Cruz & Khush, 2000) and classified as high GT (74.5–80 °C), intermediate GT (70–74 °C) and low GT (<70 °C). Data on each parameter were statistically analyzed using SAS version 6.12. One-way analysis of variance (ANOVA) was performed with all tested parameters. Duncan's new Multiple–Range Test (DMRT) was used for mean comparisons at $P < 0.05$.

Results and Discussion

Chemical composition

The variation of moisture and crude protein contents of evaluated varieties were illustrated in Figure 1.

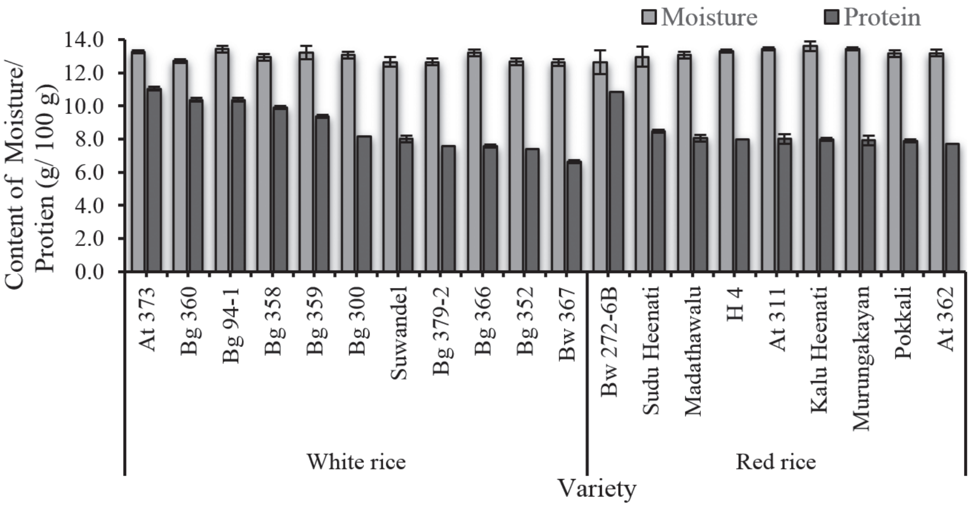

Figure 1. Mean values of moisture content and crude protein content (g/ 100g raw rice) in selected rice varieties under 70% polishing level.

Moisture content varied from 12.61 ±0.21 g/100g (in Bw 367) to 13.61±0.21g/100g (in *Kalu Heenati*). The highest crude protein content (CPC) was reported in At 373; an aromatic improved variety commonly known as "*Suwanda samba*" (11.04 ±0.01g/100g) and Bw 272–6B (10.84 ±0.20 g/100g). The lowest CPC was observed in Bw 367 (6.64 ±0.11g/100g), which is known to be a high yielding improved variety with a good appearance quality. Previous studies have reported that approximately 9 g/100g of CPC in market samples of Sri Lankan rice (Sompong *et al*., 2011). Gunaratne *et al*. (2013) reported that CPC of brown rice flour ranges from 6.15 to 10.1 g/100g in 11 selected rice varieties. Although CPC is mainly influenced by genetic variability it may be affected by agronomic practices, climatic conditions, fertilizer application and cultivation season (Rajapakse *et al*., 2011; Liyanaarachchi *et al*., 2021). In general, milling results in a reduction in protein content therefore, higher degree of polishing results in lower CPC (Sandhu *et al*., 2018). Even after 70% polishing, new improved varieties, At 373, Bw 272–6B, Bg 360, Bg 94–1 and Bg 358 showed significantly high ($P<0.05$) CPC values (11.04 ± 0.00, 10.84 ± 0.20, 10.37 ± 0.30, 10.37 ± 0.10 and 9.90 ± 0.10 g/100g, respectively) among evaluated 20 varieties.

Figure 2 represents the total ash content (TAC), which indicates the macro and micro mineral contents of rice, crude fatcontent (FC) and total dietary fibercontent (TDF). The highest TAC was reported in *Kalu Heenati* (1.25 ±0.01g/100g), *Murungakayan* (1.25 ±0.02g/100g) followed by *Pokkali* (1.24±0.02 g/100g), *Suwandel* (1.24±0.00 g/100g), *Madathwalu* (1.23±0.01 g/100g) and At 373 (1.22±0.01 g/100g) while the lowest was in Bw 367 (0.59 ±0.10 g/100g). Abesekara *et al*. (2017a) reported higher crude ash contents ranging from 1.30–1.92 g/100g in brown rice of 23 traditional cultivars.

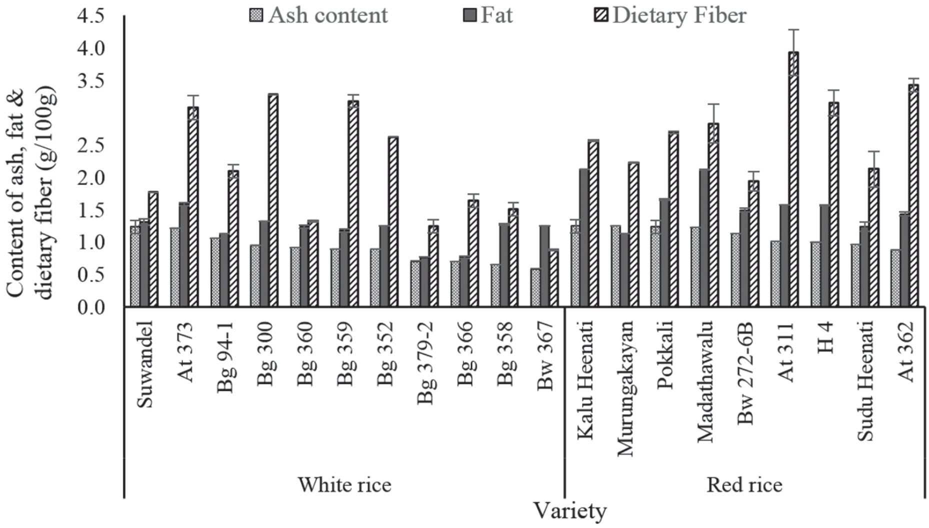

Figure 2. Mean values of total ash, crude fat and total dietary fiber contents (g/100g raw rice) in selected rice varieties under 70% polishing level.

Milling process removes considerable portion of bran layer, which contributes to the total ash content. Sandhu *et al*. (2018) reported that reduction of TAC was more than 50% at 80% milling rate. Even with the bran removal, majority of the traditional cultivars and improved varieties; H4, At 373, Bw 272–6B, At 311, Bg 94–1 reported more than 1 g/100g of TAC. Herath *et al*. (2018) reported that the mineral contents (Ca, Mg, Mn, and Zn) of improved rice varieties can be strengthen by the application of inorganic fertilizers due to their high fertilizer response.

Crude fat content ranged from 0.77 ±0.10 g/100 g in Bg 366 and Bg 379–2 where as in *Kalu Heenati* it was 2.13 ±0.03 g/100 g. *Madathawalu* contained FC similar to *Kalu Heenati* (2.12 ±0.01 g/ 100 g).Previous studies have reported that the FC of 80% milled rice was less than one fourth of unpolished brown rice (Sandhu *et al*., 2018). Even if the milling results in a loss of fats, evaluated varieties reported mean FC of 1.4 g/100g at 70% polishing rate. Besides the low contribution in quantity wise it is still beneficial to consume the rice fat due to its nutritional quality (Abeysekera *et al*., 2017a).

Total dietary fiber content of the evaluated varieties varied from 0.88 ±0.00% (Bw 367) to 3.93 ±0.02% (At 311) with mean value of 2.38 ±0.86%. At 362, Bg 300, Bg 359, H4, At 373 reported TDF> 3 g/100g. Abeysekera *et al*. (2017a) reported 4.2–6.9 g/100g TDF in traditional brown rice, which is comparatively higher than the TDF values recorded in this study. There is lack of data on TDF of milled rice even though milled rice is consumed by the majority of the consumers in Sri Lanka. There are some records on crude fiber contents in brown and milled rice. Brown rice of selected 11 improved varieties and traditional cultivars showed crude fiber content between 0.2–0.9 g/100g (Gunaratne *et al*., 2013) while crude fiber content in milled rice of 39 improved varieties and traditional cultivars varied between 0.089–0.97 g/100g (Hafeel *et al*., 2020).

Figure 3 shows the mean vales of total carbohydrate content (TCHO), total available carbohydrate content (ACHO) and *in-vitro* starch digestion rates (DR) of evaluated varieties. Mean TCHO was 76.01 ±1.5 g/ 100 g varying from72.88 ±0.09 (At 373) to 78. 91 ±0.01g/100g (Bw 367). Bw 272–6B and Bg 94–1 reported comparatively low levels of TCHO (P<0.05). Abesekara *et al*. (2017a) reported TCHO in the range 81.42–85.66 g/100 g on dry basis (71.57–76.14 g/100 g brown rice) in 23 traditional cultivars in Sri Lanka.

Mean ACHO ranged from 69.80 ± 0.29 (At 373) to 78.04 ±0.03 g/100 g (Bw 367) and the average ACHO for 20 evaluated varieties was 73.64 ±1.90 g/100g. Hafeel *et al*. (2020) reported higher levels of ACHO ranging from 87.33 to 92.74 g/100g (at 80% polishing) while Somaratne *et al*. (2017) reported 82.83 g/100g in white Basmati (at 100% polishing). Somaratne *et al*. (2017) and Prasantha (2018) reported that rice provides 45% of the per capita dietary energy in Sri Lanka. Hence, rice carbohydrate is an important source of energy.

The highest *In-vitro* starch digestion rate (DR) was reported in Bg 359 (93.98 ±7.10) and the lowestin Bg 94–1(56.86 ±1.88). Except for Bg 94–1, varieties Bg 358, Bw 272–6B, Bg 366, H4, *Sudu Heenati*, At 362 showed comparatively lower (P<0.05) DR (DR<65) than other tested varieties. Gunaratne *et al.* (2020) reported that hydrolysis index varied in the range 88.4–96.1 in six new improved rice varieties. Starch digestion may be affected by various factors; cultivar, cooking time, storage and processing, chemical components such as protein, fat, dietary fiber, amylose, and antioxidant contents (Sagum and Arcot, 2000; Frei *et al*, 2003; Leeman *et al,* 2006;

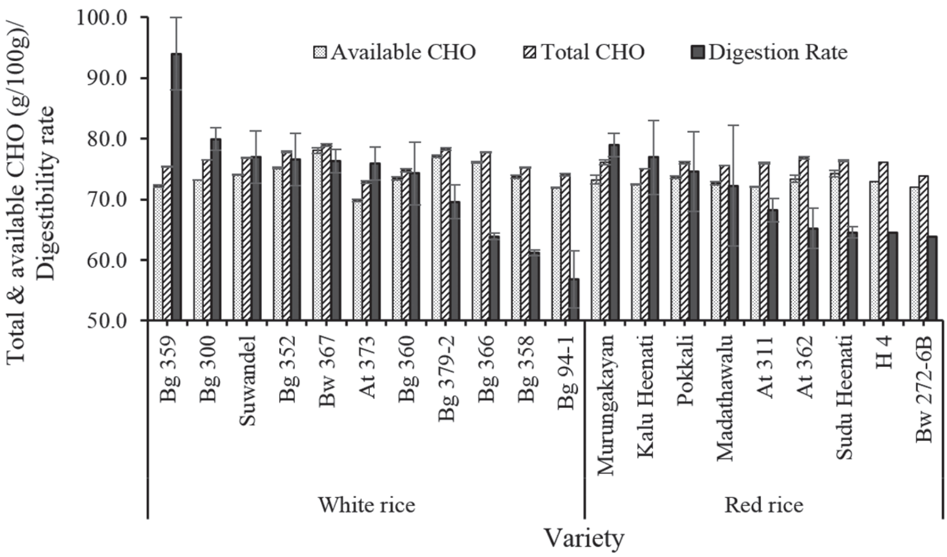

Figure 3. Contents of total and total available carbohydrates (g/100g raw rice) and rate of *in-vitro* starch digestion in selected riceunder 70% polishing level.
*(*Reference to in-vitro starch digestion rate of white bread and it considered as 100)*

Somaratne *et al*., 2017; Prasantha, 2018; Barros *et al*., 2012).

Physicochemical properties

Amylose content (AC) and gelatinization temperature (GT) are the most important physicochemical properties, which determines the cooking and eating quality. Rice with soft and slightly moist nature after cooking is generally preferred and such qualities are provided by intermediate AC and moderate GT (Wicramasinghe and Noda, 2008). All the evaluated improved varieties and traditional *Kalu Heenati* were classified under high AC category (25–33%) where as all the other traditional cultivars in intermediate amylose category (Table 1). Only Bw 272–6B, At 362 and H4 were classified in low GT group and all the other varieties were in intermediate GT group. Results reveal that majority of evaluated varieties consisted of preferred gelatinization characters although most of varieties reported high amylose content.

Comparison of chemical composition and *in-vitro* starch digestion rate between pigmentedand non–pigmented rice and between traditional and improved rice among selected varieties is shown in the Table 2.

Table 1. Categorizing of selected varieties according to amylose content and alkali spread value.

AC category	Varieties
High	Bw 272–6B, At 362,At 311, Bg358, Bg 360, Bw 367, Bg 352, Bg359, Bg 300, Bg 94–1, At 373, Bg 379–2, Bg 366, H4, Kalu Heenati
Intermediate	Madathawalu, Pokkali, Murungakayan, Sudu Heenati, Suwandel
GT category	**Varieties**
Intermediate	At 311, Bg358, Bg 360, Bw 367, Bg 352, Bg 359, Bg 300, Bg 94–1, At 373, Bg 379–2, Bg 366, H4, Madathawalu, Kalu Heenati, Murungakayan, Pokkali, Sudu Heenati, Suwandel
Low	Bw 272–6B, At 362, H4

AC: amylose content; GT: gelatinization temperature.

Table 2. Variation of chemical composition and *in-vitro* starch digestion rate between pigmented upon non–pigmented and new/ old improved upon traditional rice.

	MC	TAC	CPC	FC	TCHO	TDF	ACHO	SDR
Pericarp color								
Non–pigmented	12.94^{b}	0.90^{b}	8.77^{a}	1.19^{b}	76.21^{a}	2.06^{b}	74.15^{a}	73.22^{a}
Pigmented	13.20^{a}	1.11^{a}	8.32^{a}	1.60^{a}	75.78^{a}	2.84^{a}	72.94^{b}	69.90^{a}
Type of variety								
NIV	13.00^{a}	0.89^{b}	8.84^{a}	1.25^{b}	76.01^{a}	2.37^{a}	73.64^{a}	71.22^{a}
OIV	13.15^{a}	1.20^{a}	8.05^{a}	1.59^{a}	76.00^{a}	2.37^{a}	73.63^{a}	74.02^{a}
TC	13.31^{a}	1.00^{b}	7.99^{a}	1.57^{ab}	76.13^{a}	3.15^{a}	72.98^{a}	64.55^{a}

Means bearing the same letters in a column under pericarp color or under type of variety are not significantly different at P<0.05. MC: Moisture content, TAC: total ash content, PC: protein content, FC: fat content, TCHO: total carbohydrate content, TDF: total dietary fiber content, ACHO: available carbohydrate content (g/100g raw rice), DR: starch digestibility rate, NIV: new improved varieties, OIV: old improved varieties, TC: traditional cultivars.

Pigmented rice exhibited significantly higher (*P*<0.05) MC, TAC, FC and TDF than non–pigmented rice (Table 2). Non–pigmented rice exhibited significantly higher (*P*<0.05) ACHO compared to pigmented rice but, CPC, TCHO and DR were similar in both groups. Previous researches on health benefits of traditional rice in Sri Lanka reported brans of pigmented rice contained higher antioxidant, anti–diabetic, anti–inflammatory and cytotoxic effects on human cancer cell lines compared to brans of non–pigmented rice (Abeysekera *et al*., 2017b).

Comparison between traditional and new improved rice did not exhibit difference in any of the variables but old improved variety H4 exhibited higher TAC and FC compared to new improved varieties (*P*<0.05). In contrast to that Gunaratne *et al*. (2013) reported higher protein content in traditional rice than improved rice.

Present study highlighted some traditional cultivars such as *Madathawalu, Kalu Heenati* and *Pokkali* with high TAC, FC and moderate CPC, TDF with acceptable AC and GT even with 70% polishing rate. Despite the low grain yields, such traditional cultivars can be utilized for improving nutrition and grain quality of existing or newly developing rice lines through breeding (Singh *et al*., 2005, Rohman *et al*., 2014). Furthermore the old improved variety H4 and new improved varieties Bw272–6B, At 311, At 373 were identified to have high CPC, high–moderate TAC, FC, TDF with intermediate–low GT but high AC.

Conclusions

Results reveals that there are several improved and traditional varieties with high protein, ash, fat and dietary fiber contents with favorable physicochemical properties and low starch digestion. Pigmented rice showed higher total ash content, fat content and total dietary fiber content compared to non–pigmented rice. No significant difference was observed in proximate composition between improved and traditional varieties. *Madathawalu, Kalu Heenati, Pokkali*, H4, Bw 272–6B, At 311 and At 373 contained higher quantity of total ash, crude protein, fat and total dietary fiber with moderate *in-vitro* starch digestibility and accepted amylose content and gelatinization temperature.

Acknowledgements

Authors wish to express their appreciation to industrial technology institute and the division of grain quality, RRDI for facilitating the sample analysis.

References

Abeysekera, W. K. S. M., Arachchige, S. P. G., Ratnasooriya, W. D., Chandrasekharan, N. V., & Bentota, A. P. (2017a). Physicochemical and nutritional properties of twenty three traditional rice (*Oryza sativa* L.) varieties of Sri Lanka. *Journal of Coastal Life Medicine, 5*(8), 343-349.

Abeysekera, W. K. S. M., UKDSS, G., Arachchige, S. P. G., & WPKM, A. (2017b). Antioxidant potential of brans of twenty-nine red and white rice (*Oryza sativa* L.) varieties of Sri Lanka. *Journal of Coastal Life Medicine, 5*(11), 480-485.

AgStat, (2018). Agriculture Statistics. Volume XV, Socio Economics and Planning Centre, Department of Agriculture.

Ahmed, R., Segal, I., & Hassan, H. (2000). Fermentation of dietary starch in humans. *The American journal of gastroenterology, 95*(4), 1017-1020.

AOAC (2000) Official Methods of Analysis. 17th Edition, The Association of Official Analytical Chemists, Gaithersburg, MD, USA. Methods 925.10, 65.17, 974.24, 992.16.

Babu, P.D., Subhasree, R.S., Bhakyaraj, R. and Vidhydakshmi, R. (2009). Brown rice-beyond the colour reviving a lost health food- a review. *American-Eurasia Journal of Agronomy, 2*(2), 67-72.

Barros, F., Awika, J. M., & Rooney, L. W. (2012). Interaction of tannins and other sorghum phenolic compounds with starch and effects on *in vitro* starch digestibility. *Journal of agricultural and food chemistry, 60*(46), 11609-11617.

Cruz, N. D. and Khush, G.S. (2000). Rice grain quality evaluation procedures. In Sing, R.K., Sing, U.S. and Khush, G.S. (Eds.), *Aromatic rices* (pp. 15-28). Oxford and IBH Publishing Co. Pvt. Ltd. New Delli, India.

Englyst, K. N., Englyst, H. N., Hudson, G. J., Cole, T. J., & Cummings, J. H. (1999). Rapidly available glucose in foods: an *in vitro* measurement that reflects the glycemic response. *The American journal of clinical nutrition, 69*(3), 448-454.

Frei, M., Siddhuraju, P., & Becker, K. (2003). Studies on the *in vitro* starch digestibility and the glycemic index of six different indigenous rice cultivars from the Philippines. *Food chemistry, 83*(3), 395-402.

Gunaratne, A., Wu, K., Kong, X., Gan, R-Y., Sui, Z., Kumara, K., Ratnayake, U.K., Senarathne, K., Kasapis, S. and Corke, H. (2020). Physicochemical properties, digestibility and expected glycaemic index of high amylose rice differing in length-width ratio in Sri Lanka. *International Journal of Food Science & Technology*, 55(1), 74-81.

Gunaratne, A., Wu, K., Li, D., Bentota, A., Corke, H., & Cai, Y. Z. (2013). Antioxidant activity and nutritional quality of traditional red-grained rice varieties containing proanthocyanidins. *Food chemistry,* 138(2-3), 1153-1161.

Hafeel, R.F., Bulugahapitiya, V.P., de Zoysa, G.E.D. and Bentota, A.P. (2020). Variation in Physicochemical Properties and Proximate Composition of Improved and Traditional Varieties of Rice in Sri Lanka. *Journal of Food and Agriculture*, 13(1), 19–32.

Herath, H.M.A.J., Chandrasekara, G.A.P., Pulenthiraj, U., Chandrasekara, C.M.N.R. and Wijesinghe, D.G.N.G. (2019). Mineral contents of Sri Lankan rice varieties as affected by inorganic fertilization. *Tropical Agricultural Research, 30*(3), 89–96.

Juliano, B. (1971). A simplified assay for milled-rice amylose. *Cereal Science Today*, 16, 334-340.

Kennedy, G., & Burlingame, B. (2003). Analysis of food composition data on rice from a plant genetic resources perspective. *Food Chemistry, 80*(4), 589-596.

Leeman, A. M., Karlsson, M. E., Eliasson, A. C., & Björck, I. M. (2006). Resistant starch formation in temperature treated potato starches varying in amylose/amylopectin ratio. *Carbohydrate Polymers,* 65(3), 306-313.

Liyanaarachchi, G. V. V., Mahanama, K. R. R., Somasiri, H. P. P. S., Punyasiri, P. A. N., Wijesena, K. A. K., & Kottawa-Arachchi, J. D. (2021). Profiling of amino acids in traditional and improved rice (*Oryza sativa* L.) varieties of Sri Lanka and their health promoting aspects. *Cereal Research Communications*, 1-8.

Panlasigui, L. N., Thompson, L. U., Juliano, B. O., Perez, C. M., Yiu, S. H., & Greenberg, G. R. (1991). Rice varieties with similar amylose content differ in starch digestibility and glycemic response in humans. *The American journal of clinical nutrition, 54*(5), 871-877.

Prasantha, B. D. R. (2018). Glycemic index of four traditional red pigmented rice. *Integrative Food, Nutrition and Metabolism, 5,* 1-3.

Rajapakse, D., Benthota, A. P., Wijesundara, S. M., Premakumara, G. A. S., & Herath, T. (2011). Properties of some traditional rice varieties of Sri Lanka. *Industrial Technology Institute and Department of Agriculture, Sri Lanka, 61*.

Rohman, A., Helmiyati, S., Hapsari, M. and Setyaningrum, D.L. (2014). Rice in health and nutrition. *International Food Research Journal*. 21, 13-24.

Sagum, R., & Arcot, J. (2000). Effect of domestic processing methods on the starch, non-starch polysaccharides and *in vitro* starch and protein digestibility of three varieties of rice with varying levels of amylose. *Food Chemistry, 70*(1), 107-111.

Samaranayake, M. D. W., Yathursan, S., Abeysekera, W. K. S. M., & Herath, H. M. T. (2017). Nutritional and antioxidant properties of selected traditional rice (*Oryza sativa* L.) varieties of Sri Lanka. *Sri Lankan Journal of Biology*, 2(2).

Sandhu, R. S., Singh, N., Kaler, R. S. S., Kaur, A., & Shevkani, K. (2018). Effect of degree of milling on physicochemical, structural, pasting and cooking properties of short and long grain Indica rice cultivars. *Food Chemistry,* 260, 231-238.

Singh, N., Kaur, L., Sodhi, N.S. and Sekhon, K.S. (2005). Physicochemical, cooking and textural properties of milled rice from different Indian rice cultivars. *Food Chemistry.* 89, 253-259.

Somaratne, G. M., Prasantha, B. D. R., Dunuwila, G. R., Chandrasekara, A., Wijesinghe, D. G. N. G., & Gunasekara, D. C. S. (2017). Effect of polishing on glycemic index and antioxidant properties of red and white basmati rice. *Food Chemistry, 237*, 716-723.

Sompong, R., Siebenhandl-Ehn, S., Linsberger-Martin, G., & Berghofer, E. (2011). Physicochemical and antioxidative properties of red and black rice varieties from Thailand, China and Sri Lanka. *Food chemistry, 124*(1), 132-140.

Wickramasinghe, H. A. M., & Noda, T. (2008). Physicochemical properties of starches from Sri Lankan rice varieties. *Food science and technology research, 14*(1), 49-54.

Wolever, T. M., & Mehling, C. (2002). High-carbohydrate–low-glycaemic index dietary advice improves glucose disposition index in subjects with impaired glucose tolerance. *British Journal of Nutrition, 87*(5), 477-487.

Xu, Z., Hua, N., & Godber, J. S. (2001). Antioxidant activity of tocopherols, tocotrienols, and γ-oryzanol components from rice bran against cholesterol oxidation accelerated by 2, 2 ‘-azobis (2-methylpropionamidine) dihydrochloride. *Journal of agricultural and food chemistry, 49*(4), 2077-2081.

Young, I. S., & Woodside, J. V. (2001). Antioxidants in health and disease. *Journal of clinical pathology, 54*(3), 176-186.