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Nutritional Values and Bioactive Properties of Breakfast Porridges Based on Selected Sri Lankan Traditional Rice Varieties

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Abstract— *Uncovering the nutritional values, bioactivities and health benefits of traditional rice based porridges has become crucial in order to prevent the non-communicable diseases as well as to build a healthy generation. This study was conducted to determine the range of nutrients and bioactive properties of porridges of madathawalu (MWP), kaluheenati (KHP), mixed rice of sudu heenati, goda heenati, masuran, and dikwee (MXP) and special traditional porridge (STP). The water, nitrogen, crude fat and ash contents of porridges ranged from 93.3±0.2% - 96.9±0.2%, 1.6±0.1% - 1.9±0.2%, 1.9±0.2% - 2.8±0.2% and 1.6±0.2% - 2.0±0.1% respectively. STP possessed the highest amount of Mg, K, Ca, Mn, and Fe contents. The prominent fatty acids in the porridges were oleic, palmitic, and linoleic acids. The polyphenolic contents of porridges were 8.24±0.2 - 13.24±0.3 mg gallic acid equivalents/g. The order of antioxidant capacity of porridges was MWP > KHP > MXP > STP. Consumption of Sri Lankan traditional rice-based porridges may play a vital role in providing a balanced, nutrient rich healthy diet.*

***Keywords*— Antioxidants, fatty acid, phenols, porridges, proximate composition, Sri Lankan traditional rice.**

I. INTRODUCTION

Rapid increment of non-communicable diseases and the outcomes of scientific investigations conducted on the medicinal values of food such as traditional rice and porridges, have positively contributed to the re-emergence of the consumption of traditional rice varieties by upcoming generations in Sri Lanka. It is important to encourage farmers, policy makers and the relevant government authorities in order to improve the traditional rice cultivation under organic farming. According to the research, non-communicable diseases resulted from life style changes and accompanying urbanization due to the busy schedules (Howden et al., 1993).

Herbal porridges are popular breakfast cereal meal to consume herbal extracts in both rural and urban areas of Sri Lanka. To make these porridges with aqueous herbal extracts more palatable, these are supplemented with rice, coconut milk, salt, and spices such as pepper, garlic, and ginger. Previously, it has been shown that these porridges elicit various health benefits and important in preventing non-communicable diseases (Thushara et al., 2019). Herbal porridges are a good source of minerals, vitamins, amino acids, antioxidants, and phytonutrients (Anuruddhika Subhashinie Senadheera and Ekanayake, 2013). Recent findings have revealed the importance and health benefits of green leafy porridges (GLP) prepared using Ranawara (*Cassia auriculata*), Heen Bovitiya (*Osbeckia octandra*) and Curry Leaves (*Murraya koenigi*), which are high in fiber and phytonutrients. Consumption of GLPs is beneficial against different ailments, depending on their phytochemical constituents. However, most of the green leaves are known to reduce digestive problems (Anuruddhika Subhashinie Senadheera and Ekanayake, 2013).

Herbal porridges prepared with rice grain with its bran consist of significant quantities of major nutrients including predominant macronutrient, carbohydrate, protein, fat, and fiber than polished rice grain (Schenker, 2012). Sri Lankan traditional rice such as kalu heenati, pokkali, masuran, dikwee, goda heenati, sudu heenati are known for their high nutritional values including high mineral contents such as iron and zinc compared to polished, hybrid rice varieties (Kariyawasam et al., 2016b, Kariyawasam et al., 2016a). A study conducted on gastrointestinal-resistant protein hydrolysates using extracts from selected four rice barn varieties (masuran, dikwee, goda heenati, sudu heenati), and their fractions have reported a high cell growth inhibition and cytotoxicity against lung and cervical cancers. Moreover, the above rice bran extracts have also been reported to exhibit high Glutathione-S transferase inhibition activity.(Abeysekera et al., 2015)

Traditional medical practitioners recommend consuming rice porridges as dietary therapies due to ease of preparation, low cost, and their medicinal properties. Though the evaluation of chemical parameters of most of the traditional rice varieties has been documented, the bioactivities of traditional rice based porridges are yet to be proven. Further, revealing the nutritional values of these traditional rice-based porridges is an important task and timely need as some school children were encouraged to have them as their breakfast meal to avoid consuming junk food. Further, some rice porridges are prescribed to eliminate obesity, diabetic, cholesterol and skin diseases, thus they are yet to be proven. Hence, the present work is a comparative study of the nutritional composition and bioactivity of selected Sri Lankan traditional rice based porridges including madathawalu (MWP), kaluheenati (KHP), and mixed rice of sudu heenati, goda heenati, masuran, and dik wee (MXP), and special traditional porridge (STP) with spices.

II. MATERIALS AND METHODS

Selection of rice varieties to prepare rice porridges

Four Sri Lankan traditional rice-based porridges including madathawalu rice porridge (MWP), kaluheenati rice porridge (KHP), mixed rice porridges containing suduheenati, goda-heenati, masuran, dikwee with 1:1:1:1 ratio (MXP), and special traditional porridge (STP) prepared according to an ayurvedic recipe were included in this study. To prepare the porridges, de-hulled traditional rice varieties were obtained from an organic paddy farm using organic fertilizers (cow dung, animal bones, hay, plant material, compost) and employ biological pest control methods from February – December 2018 from Homagama (coordinates: 8433°N, 80.0032°E), Sri Lanka. Rice samples were stored at 4 °C for a maximum of one week until the preparation of porridges. Additional materials including garlic and iodinated salt were purchased from the local market.

Preparation of rice porridges

The preparation of rice porridge samples were done according to a traditional ayurvedic recipe with different proportions of garlic, salt, and rice (Senarathne, 2019). For general porridge processing, 100 g of each rice variety was weighed (KERN PCB electronic scale, Germany) and soaked in tap water for 1 h. The soaked rice was poured into a clay pot and supplemented with 1.5 L of water, 10 g of chopped garlic, and 5 g of iodized table salt. Further, a cloth packet containing spices such as coriander, cloves, cardamom, cinnamon, fenugreek, ginger (0.5 g each) were prepared and placed inside the clay pot. Subsequently, onion, pepper, tamarin, pandanus leaves, and lemongrass (1g each) were added to prepare the special traditional porridge. All porridge samples were cooked for about 1 hour and 30 min at medium-high heat with constant stirring using a wooden spoon to avoid the formation of lumps until the final volume was approximately 400 ml. The final porridges were then blended using a domestic blender (MAXMO, GTM8318, China) and lyophilized in a freeze-dried (Christ-Alpha 1-4 Freeze dryer, Biotech International, Germany). The freeze-dried four porridges were stored at -20°C until further analysis until 1 month. To carry out the bioactivity assays, dehydrated rice porridge powder samples were extracted using 70% methanol. The extracts were filtered using Whatman no: 52 filter paper and evaporated under reduced pressure in a rotary evaporator (Buchi, RE111, Switzerland).

Proximate analysis and energy value

The water content of porridge samples was determined by the gravimetric method using a laboratory oven (OBERSAL HD 230, Spain) at 105 °C until a constant weight is obtained. Crude fat, crude protein, crude fiber, and ash contents of the porridges were determined according to the association of official analytical chemists procedures (AOAC, 2016). The AOAC 991 2.0 was followed to determine the nitrogen content (Kjeldahl method: N x 6.25). Crude fat content was determined using Soxhlet apparatus with petroleum ether following AOAC 989.05, while the ash content was determined following AOAC 989.42. The total carbohydrate content in each porridge was determined using the equation: total carbohydrates (g/100g) = 100g – g (fat + protein + ash + fiber), while the total energy content (kcal/100g) was calculated using the equation: 4 x (protein + carbohydrate) + 9 x fat.

Analysis of minerals

Minerals including Na, Mg, K, Ca, Mn, Fe, and Zn of the rice porridge sample were determined from ashes using the inductively coupled plasma atomic emission spectrometry (ICP-AES, Varian 720-EZ) according to the method described by (Teem et al., 1980).

Oil content and fatty acid profile

The oils present in the porridge samples were extracted with petroleum ether using soxhlet apparatus and a heating mantle (Type ERS, E.E.C.). The results oil samples were filtered through Whatman no; 52 to remove impurities and moisture and subsequently, saponification value (SV), iodine value (IV), peroxide value (PV), and acid value (AV) were determined for prepared four porridge oil samples according to the A. O. C. S. Official Method Cd 3-25, 1999, Cd 1-25, 1999, Cd 8b, 1999 and Cd 3a-63, 1999 respectively.

Fatty acid in the porridge samples was determined using GC-MS in accordance to the previously described procedure (Dias et al., 2015). The results were expressed as the relative percentage of each fatty acid.

Total polyphenolic content (TPC)

The total polyphenolic content of porridge extracts was performed as described previously by the (Singleton et al., 1999) with slight modifications using 96-well microplates following the Folin-Ciocalteu method.. The absorbance was read at 765 nm in a microplate reader (Biobase- EL10A ELISA reader). Gallic acid was used as the standard antioxidant and the TPC content was expressed as mg gallic acid equivalents per 1 gram of porridge on a dry weight basis. Each porridge extract was measured in triplicate (n=3).

Antioxidant activity

Ferric reducing ability of plasma (FRAP) measurements - Ferric reducing antioxidant power was determined according to the method described by (Benzie and Szeto, 1999) with slight modifications. Briefly, the FRAP reagent was prepared, a 50 µL of sample extracts (n = 3) was diluted in 150 µL FRAP reagent and was incubated for 8 min at room temperature. After incubation, a plate reading was made at 593 nm. Trolox was used as the standard and the results were expressed as mg Trolox equivalent per 1 g dry weight of extract or fraction. Trolox was used as the standard antioxidant and different concentrations of Trolox (25, 50, 75, 100, and 125 µg/mL) were used to construct the standard curve.

2,2-diphenyl-1-picrylhydrazyl(DPPH) radical scavenging activity - The DPPH radical scavenging assay was performed as described previously (Blois, 1958) with modifications using 96-well microplates (n=3). Exactly, 100 µL of DPPH and different concentrations of porridge extracts (100 µL) were added to microplates and were incubated at 25°C for 15 min. Upon incubation, plate readings were recorded at 517 nm. Trolox was used as the standard antioxidant and different concentrations of Trolox (25, 50, 75, 100, and 125 µg/mL) were used to construct the standard curve. Results were expressed as mg of Trolox per 100 g of porridge on a dry weight basis.

2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) radical scavenging activity - The ABTS radical scavenging activity was determined according to the method described by Re et al. (1999) in 96-well microplates (n=3). ABTS radical generation was performed by diluting ABTS solution 7 times with 50 mM Phosphate Buffer Saline (PBS; pH 7.4). Then 100 µL of PBS, 50 µL porridge extract, and 50 µL of ABTS solution were added to microplates and were incubated at room temperature for 10 minutes. The absorbance was read at 734 nm. Trolox was used as the standard antioxidant and different concentrations of Trolox (25, 50, 75, 100, and 125 µg/mL) were used to construct the standard curve. Each porridge extract was measured in triplicate (n=3).

Statistical Analysis

All experiments had three replications of each measurement. Tests were carried out to determine significant differences between means by one-way analysis of variance (ANOVA) at the significance level of 95% and the analyses were performed using SPSS version 16. Differences in means at $p < 0.05$ were considered significant. Pearson's correlation coefficient was used for the correlation analysis. $p < 0.05$ was regarded as significant.

III. RESULTS AND DISCUSSION

Proximate composition of rice porridges

The results of the proximate analysis on the porridge samples are shown in Table 1. The water content of the porridge samples ranged from 93.3±0.2 to 96.9±0.2% with an average value of 95.1±1.5%. A similar trend was also observed in the porridge prepared with 272 6B rice variety (92.2%) (Anuruddhika Subhashinie Senadheera and Ekanayake, 2013). Water is the main ingredient in porridge samples and thus results in high values of water. Dry matter content of prepared porridges was in the range of 3.1% to 6.7%. The highest dry matter content was reported for MWP whereas the least dry matter content was reported for STP.

Table 1. Proximate compositions of porridge samples

Nutritional value	Percentage			
	MWP	KHP	MXP	STP
Water Content (wb)	93.3±0.2^{a}	95.7±0.1^{b}	94.6±0.2^{c}	96.9±0.2^{d}
Dry matter % (db)	6.7±0.2a	4.3±0.1b	5.9±0.2c	5.4±0.2d
Nitrogen Content	1.9±0.2^{a}	1.8±0.1^{a}	1.7±0.2^{a}	1.6±0.1^{a}
Crude Protein (db)	11.9±0.2^{a}	11.5±0.1^{a}	10.9±0.1^{b}	9.9±0.1^{c}
Crude Fat (db)	2.1±0.1^{a}	1.9±0.2^{a}	2.5±0.2^{a}	2.8±0.2^{b}
Crude Fiber (db)	1.2±0.2 ^{a}	1.0±0.2 ^{a}	1.4±0.2 ^{a}	1.0±0.2 ^{a}
Ash (db)	2.0±0.1^{a}	1.9±0.1^{a}	1.6±0.2^{a}	1.9±0.2^{a}
Total carbohydrate (db)	82.8±0.2^{a}	83.7±0.4^{a}	83.6±0.7^{a}	84.4±0.7^{a}
Total energy (kcal/100 g)	397.7±1.5^{a}	397.9±0.2^{a}	400.5±0.6^{b}	402.4±0.6^{b}

MWP: Madathawalu porridge; KHP: Kaluheenati porridge; MXP: Mixed rice porridge; STP: Special traditional porridge; wb : wet basis; db : dry basis. Results are expressed as mean ± SD; n=3.

The protein content in the porridge samples was estimated in terms of nitrogen. Crude protein was the second most abundant component in dry samples, followed by carbohydrates. The results showed that the crude protein content in all the porridge samples ranged between 9.9±0.1% - 11.9±0.2%. Madathawalu porridge sample (11.9±0.2%) had the highest crude protein content while the STP (9.9±0.1%) had the least protein content. These values are noticeably higher than the reported crude protein content of 4.8±0.5% in the rice porridge prepared from 272 6B rice variety (Anuruddhika Subhashinie Senadheera and Ekanayake, 2013). The protein content obtained in the present study is about 2 times higher than the, reported protein contents (6.84 -11.18%: improved rice varieties of Bg 352, Bg 300, Bg 403, Bg 94-1, Ld 356, At 306, and At 405) (Fari et al., 2011). Furthermore, the protein content obtained for KHP (11.5±0.1%) is higher than the reported value for individual kaluheenati rice variety (10.1%) (Gunaratne et al., 2013). Studies conducted on protein analysis have found that there are major differences between the plant (especially rice) and animal protein sources (Young et al., 1975). It is known that plant proteins are responsible for lowering the blood pressure levels (Elliott et al., 2006) and risks of type 2 diabetes (Sluijs et al., 2010). Therefore, these porridge samples with high protein content can be a good source of plant proteins to manage blood pressure and type 2 diabetes.

The fat content of four porridge samples ranged from 1.9±0.2% to 2.8±0.2%, while STP had the highest crude fat content and KHP had the least. The crude fat content of the rice porridge sample made with 272 6B rice variety was found to be 2.5±0.9% (Anuruddhika Subhashinie Senadheera and Ekanayake, 2013). Furthermore, these values are in agreement with the reported values (1.9% - 2.4%) for kaluheenati, suduheenati, madathawalu, wedaheenati and other four traditional rice varieties (Gunaratne et al., 2013). A similar trend was detected in the crude fat content found in other traditional rice varieties of pokkali, kahawanu, sudumurunga, and unakolasamba; which were 2.3±0.0%, 2.8±0.0%, 2.7±0.0%, and 2.9±0.1% respectively (Kariyawasam et al., 2016b). It was previously recorded that the crude fat content found in the improved rice varieties including BG250 (2.1%), BG300 (2.3%), and BG359 (1.9%) was more or less equal to the crude fat contents found in the porridge samples used in the current study. The crude fiber content of the porridge composites varied between 1.0±0.2% - 1.4±0.2%. The fiber contents were significantly high than the previously reported values (0.9–1.1%) for selected traditional rice varieties (Kariyawasam et al., 2016b). Further, the fiber contents of BG250, BG300, and BG359 improved rice varieties were 0.5%, 0.3%, and 0.5% respectively (Gunaratne et al., 2013). The present study revealed that four tested porridge composites possess higher fiber content compared to the reported improved rice varieties (Gunaratne et al., 2013). The high fiber content in the diet can lead to several health benefits including reducing gastrointestinal disorders such as gastroesophageal reflux disease, duodenal ulcers, diverticulitis, constipation, and hemorrhoids (Anderson et al., 2009). Ash content of the porridge composites represents the inorganic matter found in corresponding porridge. And the values ranged from 1.6 ± 0.2% - 2.0 ± 0.1%. These values are lower compared to the ash content (6.6±1.2%) reported with 272 6B rice porridge (Anuruddhika Subhashinie Senadheera and

Ekanayake, 2013). The ash content of KHP (1.9±0.2%) is slightly similar to its rice or kaluheenati alone (1.8±0.2%) (Kariyawasam et al., 2016b). However, the ash content of tested four rice porridge samples is more or less similar to the reported individual Sri Lankan traditional rice varieties (1.2±0.0% - 1.9±0.1%) (Kariyawasam et al., 2016b). According to the results, carbohydrate content was the most abundant component in the prepared porridge samples on a dry weight basis. Equal quantities of rice added contributed to the increased carbohydrate content in the mixed porridge sample. The carbohydrate contents of MWP, KHP, MXP, and STP were 82.8±0.1%, 83.7±0.4%, 83.6±0.7%, and 84.4±0.7%, respectively. The obtained values for the carbohydrate content of porridge samples were higher than the previously reported data for rice porridge made with 272 6B rice variety (Anuruddhika Subhashinie Senadheera and Ekanayake, 2013). Amongst the tested four porridge varieties, the highest carbohydrate content was reported with STP (84.4±0.7%), followed by KHP (83.7±0.4%), while the lowest value was reported with MWP (82.8±0.1%). The reported carbohydrate content of kaluheenati individual rice variety was 76.3±0.1% (Kariyawasam et al., 2016b). These high values of carbohydrate contents of the porridge samples can be explained in terms of other ingredients such as coconut milk used for preparation. Dietary energy supply is essential for life and is required to fuel many different body processes. It measures the chemical energy inherent in the bonds of the organic compounds found in protein, carbohydrate, and as well as in minor constituents such as organic acids. The total energy was estimated using conversion factors of 17 kJ/100g (4.0 kcal/100g), 37 kJ/100g (9.0 kcal/100g), and 17 kJ/100g (4.0 kcal/100g). All the porridge samples exhibited high energy values, and the highest was found in STP. The calorific value of MWP, KHP, MXP, and STP were 397.7, 397.9, 400.5, and 402.4 kcal/100 g, respectively. These values are higher than the energy values recorded for selected Sri Lankan traditional rice varieties (352.3 - 372.8 kcal/100 g) (Kariyawasam et al., 2016b). Hence, this study provides insight on selected Sri Lankan rice based breakfast cereal, which exhibited high percentages of carbohydrates, proteins, fat, fiber, and ash contents. The consumption of such nutrient-rich porridge varieties plays a vital role in decreasing malnutrition and boosting immunity.

Mineral composition of rice porridges

Table 2 illustrates the mineral content in porridge composites. It was identified that MXP rice porridge samples contained the highest sodium content of 21.13±0.02 mg/mL, followed by MWP (20.38±0.01 mg/L) compared to KHP and STP, where STP had the lowest sodium content (1.71±0.00 mg/L). In contrast, STP possessed the highest magnesium amount (15.58±0.01 mg/L), whereas MWP had the lowest amount (7.22±0.01 mg/L). STP contained exceptionally high potassium content of 20.25±0.00 mg/L while the rest of the porridge composites contained significantly low amounts of potassium content. The calcium content of four rice porridge samples ranged from 2.35±0.01 - 5.19±0.01 mg/L. The manganese content of STP showed the highest content (0.34±0.00 mg/L) compared to the other three porridge samples. The iron content of porridge composites is lower than 1.00 mg/L and the highest iron content was reported with STP (0.70±0.00 mg/L). The zinc content of porridges varied from 0.38±0.00 mg/L to 1.92±0.00 mg/L. Overall, STP possessed the highest mineral content, and iron content compared to other porridge composites. Therefore, STP can be considered a good source of minerals to maintain daily intake. Minerals compared with vitamins are more resistant to industrial production processes. However, these components cannot tolerate alterations after exposure to light, moisture, heat, or oxygen during the processing and storage of food materials. Also, Cu, Fe, and Zn may be lost by reacting with a large variety of interactive food constituents (Hazell, 1985). Therefore, the preparation process of porridge samples may result in the loss of minerals. Minerals are the nutrients essential to maintain the proper composition of body fluids, the formation of blood and bone, the maintenance of healthy nerve function, and regulation of muscle tone, including the cardiovascular system (Somer, 1995).

Table 2. The mineral content of rice porridge samples

	MWP	KHP	MXP	STP
Na (mg/L)	20.38±0.01^{a}	18.91±0.01^{a}	21.13±0.02^{a}	1.71±0.00^{a}
Mg (mg/L)	7.22±0.01^{b}	12.67±0.01^{b}	11.50±0.01^{b}	15.58±0.01^{b}
K (mg/L)	0.96±0.00^{c}	0.22±0.00^{c}	0.12±0.00^{c}	20.25±0.00^{c}
Ca (mg/L)	2.35±0.01^{d}	3.60±0.01^{d}	4.62±0.01^{d}	5.19±0.01^{d}
Mn (mg/L)	0.14±0.00^{e}	0.16±0.00^{e}	0.18±0.00^{e}	0.34±0.00^{e}
Fe (mg/L)	0.30±0.00^{f}	0.27±0.00^{f}	0.41±0.00^{f}	0.70±0.00^{f}
Zn (mg/L)	1.12±0.00^{g}	0.46±0.00^{g}	1.92±0.00^{g}	0.38±0.00^{g}

MWP: Madathawalu porridge; KHP: Kaluheenati porridge; MXP: Mixed rice porridge; STP: Special traditional porridge; Wb : wet basis; db : dry basis. Results are expressed as mean ± SD. The results are expressed as mean ± SD.

3.3 Oil content and fatty acid profile of rice porridges

The structure and quality indices are the two main analytical indices associated with fats and oils. Common structure indices of fats and oils are the iodine value, the saponification value, and the hydroxyl value. Recommended quality indices are the peroxide value, anisidine value, and other similar values (Knothe, 2002). Among them, the parameters of acid value, iodine value, peroxide value, and saponification value were estimated in the current study. The results of different chemical parameters of rice porridge oil are given in Table 3. The oil extracted from the porridges appeared in liquid form at room temperature. The MWP oil is brownish yellow in color while KHP oil is a dark yellow color. Both MXP and STP oils were light yellow color. AVs of the prepared porridge composites ranged between 11.1 ±0.3 - 18.9 ±0.3 mg KOH/g. Rice oils of kaluheenati, pokkali, sudumurunga, and kahawanu have been reported to have AVs of 18.2±0.2 - 29.2±0.6 mg KOH/g. Hence, the low levels of AVs in the porridge composites indicate the fresh nature of oils in porridges.

Table S3. Different chemical parameters of oils in rice porridges

Chemical parameter	MWP	KHP	MXP	STP
Acid value (mg KOH/g)	12.9±0.3 [a]	11.1±0.3[b]	18.9±0.3[c]	14.2±0.4[d]
Iodine value (g I_2/100g)	55.6±0.3 [a]	74.2±0.3 [b]	63.4±0.4 [c]	68.6±0.4[d]
Peroxide value (meq O_2/kg)	9.5±0.3 [a]	8.7±0.3 [a]	7.3±0.3 [b]	9.1±0.3 [a]
Saponification value (mg KOH/g)	173.4±0.3 [a]	177.2±0.2 [b]	174.6±0.3 [c]	176.6±0.2 [a]

MWP: Madathawalu porridge; KHP: Kaluheenati porridge; MXP: Mixed rice porridge; STP: Special traditional porridge. Results are expressed as mean ± SD. Results are expressed as mean ± SD

Acid value (AV) is a relative measure of rancidity in terms of free fatty acids, which are normally formed during the decomposition of oil glycerides (Akubugwo and Ugbogu, 2007). It is used as an indicator of the edibility and suitability of oil for industrial usage (Amoo et al., 2004). It has been shown that foods having high AVs are not suitable for consumption (Amoo et al., 2004).. The iodine value (IV) is an estimation of the relative degree of unsaturation oil composition in the crude oil. The melting point and oxidative stability of an oil sample are related to the degree of unsaturation. A greater iodine value indicates high unsaturation and the higher susceptibility to oxidation (Caballero et al., 2003). Iodine value index also indicates the ability of an oil to undergo rancidity. IVs of porridge composites were ranged between 55.6±0.3 - 74.2±0.3 g I_2/100g. Oils in rice bran extract from Madathawalu rice variety had an IV of 94.47±1.22 g I_2/100g (Bulathsinghala, 2008). Peroxide value (PV) is used as an indicator of deterioration of oil (Amoo et al., 2004). The recommended peroxide value should be lower than 10 meq O_2/kg for fresh oils and 40 meq O_2/kg for crude oil (Akubugwo and Ugbogu, 2007). PVs of the porridge mixtures were in the range of 7.3±0.3 to 9.5±0.3 meqO_2/kg. Amongst them, MWP demonstrated the highest PV while MXP exhibited the lowest PV. The presence of low PVs in the porridge composites can be further explained in terms of their high antioxidant properties. The saponification values (SVs) of the porridge samples were found to be in the range of 173.4 ±0.3 – 177.2 ±0.2 mg KOH/g of oil. The longer the carbon chain, the less acid is liberated per gram of hydrolyzed fat. Hence it is considered as a measure of the average chain length of the fatty acids present in a food sample (Amoo et al., 2004).

The fatty acid profile of the porridge composites is presented in Table 4. The most prominent fatty acids in the porridge composites are oleic (18:1 n-1), palmitic (16:0) and linoleic acids (18:2 n-9,12). Key features of these oleic, linoleic, and linolenic fatty acids are that they are essential fatty acids required for growth and development and must be obtained from diet. High amounts of monounsaturated fatty acids including oleic acid enhance the stability of oil during cooking (Goffman et al., 2003). Linolenic acid is an omega-6 fatty acid and was the only fatty acid present in MXP. The most abundant fatty acids in STP are oleic, linoleic, and cis-vaccenic acids. The total unsaturated fatty acid (USFA) percentage in the porridge composites ranged from 69.89 – 91.06 %. Therefore, more than half of the total fatty acids were made up of USFAs, which are considered important for good health. In this context, these porridge mixtures can be recommended to consume, due to their abundant health benefits.

The variation in the fatty acid composition can be observed among the selected porridge mixtures. It might be due to the differences in genotype, seed maturity, climatic condition, growth, and interaction of used Sri Lankan traditional rice varieties (Andersen and Gorbet, 2002).

Table 4. Fatty acid profile of rice porridges

Lipid number	**Fatty acid**	**Fatty acid content (%)**			
		MWP	**KHP**	**MXP**	**STP**
12:0	Lauric acid	0.58	0.08	nd	nd
16:0	Palmitic acid	0.38	23.49	21.22	19.94
16:1 (n-7)	Palmitoleic acid	0.73	nd	nd	nd
18:0	Stearic acid	3.27	3.62	3.08	nd
18:1 (n-3)	3-Octadecylenic acid	nd	68.69	nd	nd
18:1 (n-6)	Petroselinic acid	27.10	nd	nd	nd
18:1 (n-9)	Oleic acid	60.05	nd	47.04	38.58
18:1 (n-11)	Cis-vaccenic acid	nd	nd	nd	21.08
18:2 (n-9,12)	Linoleic acid	nd	nd	26.57	19.75
20:0	Arachidic acid	2.86	1.65	1.44	0.65
20:1 (n-7)	Paullinic acid	3.16	1.26	0.65	nd
22:0	Behenic acid	0.83	0.59	nd	nd
24:0	Lignoceric acid	1.04	0.62	nd	nd
Total USFA %		91.06	69.89	74.26	79.41
Total SFA%		8.94	30.11	25.74	20.59
USFA/SFA		10.19	2.32	2.88	3.86

MWP: Madathawalu Porridge; KHP: Kaluheenati Porridge; MXP: Mixed rice Porridge; STP: Special traditional Porridge. Results are expressed as mean ± SD. nd; not detected.

Total polyphenolic content of rice porridges

According to the obtained results (Table 5), the total polyphenolic content (TPC) varied from 8.24±0.2 to 13.24±0.3 mg GAE /g and the values differ significantly. The highest phenolic content was observed in the MWP, while the lowest content was observed in the STP. The total phenolic content increased in the order of STP < MXP < KHP < MWP. According to the previously reported data, the phenolic contents of rice bran extracts of Masuran, Dik Wee, Godaheenati, and Suduheenati varied between 11.74 ± 0.18 - 29.75 ± 0.97 mg GAE/g respectively (Abeysekera et al., 2011). Among the tested porridges which were made by traditional rice varieties, the MWP, exhibited the highest phenolic content of 13.31 mg GAE/g and was higher than the reported value (9 mg GAE/g) of 272 6B red raw rice porridge (Senadheera et al., 2014a).

Table 5. Total polyphenolic content (TPC) and antioxidant capacity (FRAP, DPPH, ABTS) of four rice porridges.

Porridge	TPC (mg GAE/g)	FRAP	DPPH	ABTS
		Activity equivalent to standard (mg TE/100 g)		
MWP	13.24±0.3 ^{d}	39.71±0.3 ^{a}	42.46±0.2 ^{a}	64.46±0.3 ^{a}
KHP	12.11±0.2 ^{c}	35.60±0.2 ^{b}	39.04±0.3 ^{b}	30.31±0.2 ^{b}
MXP	11.25±0.2 ^{b}	10.10±0.1 ^{d}	28.04±0.2 ^{c}	40.05±0.2 ^{c}
STP	8.24±0.2 ^{a}	7.82±0.1 ^{c}	16.74±0.2 ^{d}	12.01±0.2 ^{d}

MWP: Madathawalu Porridge; KHP: Kaluheenati Porridge; MXP: Mixed rice Porridge; STP: Special traditional Porridge. Results are expressed as mean ± SD. Results are presented on a dry weight basis. GAE: Gallic acid equivalents; TE: Trolex equivalents. *Mean (±SD) followed by the same superscript within a row is not significantly different (P> 0.05) as measured by ANOVA.

Similarly, the phenolic content in the Kaluheenai (KH) rice variety alone was reported to be 3.09 mg GAE/g (Gunaratne et al., 2013), while the porridge prepared from KH exhibited phenolic content of 12.11 mg GAE/g. Studies have also found that the phenolic content in the black rice and its cooked porridge decreased significantly from 29.48 µg to 2.03 µg (PRANIL, 2017). Furthermore, the phenolic content obtained in the present study was higher than the values reported for Marama-sorghum composite flours and porridges in Southern Africa (0.5 - 4.8 mg GAE/ mg sample) (Kayitesi et al., 2012).

3.5 Antioxidant activity of rice porridges

The results obtained for the FRAP assay are presented in equivalents Table 5. The ferric reducing capacity of the porridge composite varied between 7.82±0.1 to 39.71±0.2 mg TE/100 g. Among the tested four porridge varieties, the highest ferric reducing capacity was obtained for the MWP while the lowest was obtained for the STP. The order of mean FRAP antioxidant capacity of porridges was increased in the order of MWP > KHP > MXP > STP. Ferric reducing capacity for reported four rice bran extracts of Sudu Heeneti , Masuran, Goda Heeneti, and Dik Wee were ranged between 8.30 - 11.02 mmol FeSO4/100 g (Premakumara et al., 2013).

The DPPH free radical capacities of the porridge composites were determined in terms of TE and results are presented in Table S5. They tested four porridge varieties exhibited significantly high (16.74±0.2 – 42.46±0.2 mg TE/100 g) free radical capacities. The MWP was found to possess the highest antioxidant capacity. The order of mean DPPH radical scavenging capacity of the porridge composites decreased in the order of MWP > KHP > MXP > STP. The DPPH free radical ability of the black rice products including raw and cooked porridge (BRP 15) was found to be 63.79% (PRANIL, 2017). Researchers have attempted to emphasize the fact that porridge mixtures with garlic possess a higher level of antioxidant capacity. The extract of kochujang supplemented with garlic porridge (GPK) exhibited greater (66.38%) DPPH radical scavenging capacity (Song et al., 2008). DPPH radical scavenging capacities of reported four rice bran extracts of SuduHeeneti, Masuran, GodaHeeneti and Dik Wee were higher than our results and were in the range of 1286.5 – 1694.5 mg trolox equivalents /100g bran (Abeysekera et al., 2011). According to previous studies, antioxidant activities were obtained for extracts from the aleurone layer of four *Oryza sativa cv.* rice varieties (in Korea) ranged between 58.8 to 85.6% (Chung and Shin, 2007). In another study, Iqbal et al. (2005) found that the antioxidant activity of five Pakistan indigenous rice bran varieties possesses 20% - 30% of DPPH scavenging capacity. The authors also suggest that the consumption of tested Pakistan rice varieties could be considered as a possible treatment for cardiovascular diseases, cholesterol-lowering, and other lipid peroxidation processes (Iqbal et al., 2005). Thai pigmented rice is a natural antioxidant source with an antioxidant capacity of IC_{50} 0.10 - 1.12 mg/ml for DPPH (Vichit and Saewan, 2015). However, literature has emphasized that regardless of the different antioxidant assay, pigmented rice varieties possess high antioxidant activities compared to non-pigmented rice varieties. Nevertheless, *Japonica* rice varieties were known to be richer in antioxidant compounds than *Indica* rice varieties (Goufo and Trindade, 2014).

The preformed ABTS• radical mono-cation which is formed by oxidation of ABTS with potassium persulfate is reduced in the presence of antioxidants (Re et al., 1999). The antioxidant capacities in terms of ABTS radical scavenging activity decreased in the order of MWP > MXP > KHP > STP. The mean antioxidant capacities of the porridge composites obtained for ABTS assay ranged between 12.01±0.2 to 64.46±0.3 mg TE/100 g. The highest antioxidant capacity was found in the MWP (64.46 mg TE/100 g) whereas the lowest antioxidant capacity was found in the STP (12.01±0.2 mg TE/100 g). The ABTS radical scavenging capacity of porridge mixtures were high compared to the reported value for 272 6B red raw rice porridge (5 µg TE/100 g) (Senadheera et al., 2014a). Furthermore, the Pakistan indigenous rice bran extracts have shown even low values than our values (7.51 – 12.51 mg trolox equivivalents/g bran) for ABTS scavenging activity (Iqbal et al., 2005). In contrast, Marama-sorghum composite porridges have shown lower ABTS antioxidant activities (0.575 – 3.42 mg trolox equivalents/100 mg) in southern Africa (Kayitesi et al., 2012).

Table 6. Pearson's correlation coefficients among antioxidant activity and total phenolic content.

	Antioxidant capacity (mg TE/100 g)		
	FRAP	DPPH	ABTS
TPC (mg GAE/g)	0.839	0.972	0.884

According to the table 6, there are strong positive correlations among antioxidant activity and the phenolic contents of the porridges. This signifies that these compounds may be responsible for the DPPH and ABTS radical scavenging activities and FRAP activity. In general, strong antioxidant potential indicates the lead to increased scavenging of reactive oxygen species, reduction of adipocyte differentiation, and blood glucose differentiation (Heendeniya et al., 2020).

IV. CONCLUSION

The study concluded that the nutritional values of a cereal meal made of selected traditional rice varieties are high compared to that of reported hybrid rice varieties in Sri Lanka. The overall nutritional value of the rice porridges was high in terms of crude protein contents and crude fiber contents. STP possessed the highest quantity of minerals compared to other tested porridge samples. Furthermore, the fatty acid profile, revealed that the total fatty acids were made up of USFA, which is considered to be good fatty acid for human health. KHP and MXP porridge composites have significant anticancer activity against HeLa- human cervical cancer cell lines. The porridges made of traditional rice provide a nutritionally completely healthy, cereal breakfast meal that is rich in good, unsaturated fatty acids, proteins, dietary fibers, minerals and antioxidants.

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DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article and any additional material will be available on request.

CONFLICTS OF INTEREST

The authors have declared no conflict of interest in this article.

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