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ORIGINAL ARTICLE

Anti-diabetic and anti-cancer related health food properties of selected Sri Lankan traditional rice based porridges

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Abstract Four Sri Lankan porridges including madathawalu (MWP), kaluheenati (KHP), mixed rice of sudu heenati, goda heenati, masuran, and dikwee (MXP) and special traditional porridge (STP) were screened for in vitro glycemic indices (GI), α-amylase inhibition and anti-glycation activities. All four porridges had the medium GI values, those were in the range of 40.5 ± 4 to 63.9 ± 2. The highest antiglycation activity was reported for MWP demonstrating IC_{50} of 228.20 ± 4.20 µg/mL. In relation to the α-amylase inhibition activity, the porridge extracts of MWP and STP low IC_{50} values (117.54 ± 1.92 µg/mL and 128.75 ± 5.91 µg/mL) showed their high capability to inhibit α-amylase enzyme. Due to the medium to low GI values and high antiglycation and α-amylase inhibition activities, traditional rice based porridges can be considered as effective for the prevention of diabetic conditions as well as from various complications in diabetic patients. Anticancer activity against human lung and HeLa cell lines revealed that KHP and MXP exhibited anticancer activity (IC_{50} of 274.6 µg/mL and 940.2 µg/mL respectively) against HeLa- human cervical cancer cells. In conclusion, porridge composites prepared using Sri Lankan traditional rice helped to eliminate or notably reduce nutrient deficiencies, and it provided numerous health benefits and economical gains.

Keywords Sri Lankan traditional rice · Porridges · In vitro glycemic index · Antiglycation · Amylase inhibition · Anticancer

Abbreviations

MWP	Madathawalu porridge
KHP	Kaluheenati porridge
MXP	Mixed rice porridge
STP	Special traditional porridge
GI	Glycemic index
HI	Hydrolysis index

Introduction

In recent times, the increasing prevalence of diabetes and related chronic diseases has prompted intense research attention (Sapra and Bhandari 2019). Type 1 and type 2 diabetes mellitus are fast growing chronic metabolic diseases in epidemic proportions in the world including Sri Lanka (Association 2014). In fact, prevalence of diabetes in Sri Lanka is more than 10% and that of pre-diabetes is 11.5% (Katulanda et al. 2012). Further, dramatic changes in the prevalence or incidence of type 2 diabetes have been observed in communities where there have been major changes in the type of diet consumed, from a traditional indigenous diet to a modern food patterns. Food and Agriculture Organization (FAO) of the United Nations and the World Health Organization (WHO) recommend the

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consumption of low glycemic index (GI) cereal foods for good health (Woodruff 2001). Hence, consumption of low or medium glycemic food plays a vital role in prevention and management of diabetes as well as its complications.

Cancers cause more deaths than all coronary heart diseases or all strokes according to the WHO estimates for 2011 (Rebecca et al. 2012). In ancient time plants and the natural products were used in the treatments of cancer after discovery and development of vinca alkaloids in 1950 (Horner et al. 2009). It has been reported that some traditional rice varieties and their derivatives have been recognized as a source of therapeutic agents for many diseases including cancer (Abeysekera et al. 2013). Therefore, it is useful to discover the anticancer related properties of plant and food products. Mainly, bioactive components of rice bran have been reported to have antioxidant, anti-inflammatory, anti-diabetic, and anti-cancer activities (Sohail et al. 2017). According to the research findings, biologically active phytochemicals in rice exhibit their potential beneficial health effects in human such as anticancer properties and antidiabetic properties (Verma and Srivastav 2020). Not only the individual rice varieties, their porridges also are known to have various health benefits and have been used by medical practitioners since early days (Graidist et al. 2019).

These rice porridges are common Sri Lankan dietary remedies as breakfast practice and they can be easily prepared. In fact, rice based herbal porridges are a good source of minerals, vitamins and phytonutrients (Thushara et al. 2019). Some novel rice varieties have exhibited high nutrient content compared to the hybrid rice cultivars (Thushara et al. 2020). Rice grain with its bran in herbal porridges contains significant quantities of all the major nutrients, including predominant macronutrient, carbohydrate, protein, fat and fibre (Schenker 2012). Sri Lankan traditional rice varieties are used to prepare porridges to improve their medicinal values. Among them, Kalu heenati, Pokkali, Masuran, Dik Wee, Goda Heenati, and Sudu Heenati rice varieties have been proven their high nutritional value compared to the improved varieties (Kariyawasam et al. 2016). Current literature pays certain attention to bioactive properties of rice. The physical parameters such as pH, firmness, cohesiveness, consistency, index of viscosity and color of sub-Saharan African thin porridges have been evaluated (Onyango and Wanjala 2018). Prospective studies have demonstrated that low-GI diets reduce the fasting and post-prandial insulin, glucose, triacylglycerol and non- esterified fatty acid concentrations, while improving in vivo and in vitro insulin mediated glucose uptake. Among the bioactivity studies, Premakumara et al. (2013) proved the in vitro glycation reversing and anti-glycation activity of rice brans of 23 traditional and 12 improved (both red and white) rice varieties in Sri Lanka for the first time. Significantly high anti amylase and anti-glycation activities were detected for bran extracts of traditional red rice varieties, Masuran, Sudu Heeneti, Dik Wee and Goda Heeneti, compared to improved red rice varieties. These bran extracts of four Sri Lankan traditional rice varieties can be further developed as potential pharmaceuticals for diabetes and related complications (Abeysekera et al. 2013). According to the recent literature, white kidney bean extracts of different porridges have shown considerably high α-amylase inhibitory properties (Ma et al. 2018). Improved in vivo glycemic response as well as the increased antioxidant activities were detected in parboiled finger millet porridge grains (Kumari et al. 2020). According to the research findings of randomised, crossover trial in healthy humans, pearl millet porridge can act as an alternative breakfast food with similar beneficial effects to those of oats due to the similar glycemic responses (Alyami et al. 2019).

One of the most important research findings has shown the acute anticancer activity of Sri Lankan traditional rice varieties. The rice bran extracts, fractions and gastrointestinal-resistant protein hydrolysates of selected four rice varieties (Masuran, Dik wee, Goda heenati, Sudu heenati) have shown great growth inhibition and cytotoxicity against both lung and cervical cancers. Moreover, above rice bran extracts have been reported the high Glutathione-S transferese inhibition activity. These selected rice brans may be useful in the management of lung and cervical cancers (Abeysekera et al. 2015a, b).

Although individual rice brans have tested for anti-diabetic and anticancer related food properties, their porridges have not been scientifically tested yet. By preparing rice-based porridges bioactivities of these porridges can be studied. In this project, we have focused our attention on study the in vitro glycemic index, anti-amylase activity, antiglycation capacity and anticancer activity of herbal porridges based on selected Sri Lankan traditional rice varieties.

Methodology

Preparation of rice based porridges

Four Sri Lankan traditional rice based porridges were analyzed for their bioactivities. Madathawalu rice porridge (MWP), Kalu Heenati rice porridge (KHP), Mixed rice porridge with Sudu Heenati, Goda Heenati, masuran, Dik Wee (1:1:1:1) (MXP) and Special traditional porridge (STP) were prepared. The Madathawalu rice porridge was prepared using Madathawalu rice while Kalu Heenati rice porridge was prepared using Kalu Heenati rice. Exactly 25 g of Sudu Heenati, 25 g of Goda Heenati, 25 g of

Masuran and 25 g of Dik Wee rice were used to prepare mixed rice porridge. For the general procedure of preparing porridges, an amount of 100 g of rice was weighed (KERN PCB electronic scale, Germany), washed five times and soaked in water for 10 h. The wet rice was poured in to a 2.5 L pot (Sri Lanka). Then 1.5 L of water, 10 g of chopped garlic and 5 g of salt were added to the pot. Porridges were cooked about 1 h at medium high heat with stirring using a wooden spoon to avoid formation of lumps until the final volume was approximately 400 mL.

When preparing STP, Madathawalu rice (100 g) was weighed (KERN PCB electronic scale, Germany), washed five times and soaked in water for 12 h. The wet rice was poured in to a 2.5 L aluminium pot (ALCOA, Sri Lanka). 1.5 L of water and 10 g of chopped garlic and 5 g of salt were added to the aluminium pot. Then the spices of coriander, cloves, cardamom, cinnamon, fenugreek, ginger (1 teaspoon of each) were placed in a separate cloth pocket and that pocket was kept in the pot. After that onion, pepper, tamarind, pandan, lemongrass (1 teaspoon of each) were added to it. Then porridge was cooked 1 h until the final volume was approximately 300–400 ml. Porridges were then blended using a blender (MAXMO, GTM8318, China).

In vitro *glycemic index of rice porridges*

The samples were digested ant tested according to a known method (Abeysekera et al. 2015a, b). Two grams of available carbohydrate portions of each of the freshly prepared porridge samples (crushed grains) were placed in dialysis bags (12,000 molecular weight cutoff), 10 mL of human saliva was added. Then the sample was stirred for 10 s followed by adjusting the volume to 35 mL with distilled water. Then samples were dialyzed against 800 mL of distilled water at 37 °C for 2 h (n = 3). White bread was used as the reference food material. Digestion and the dialysis (n = 4) were carried out in the same manner. For 2 h (15 min intervals), 1 mL dialysate samples were taken and analyzed for total sugars by 3,5-dinitrosalicylic acid (DNS) method (Thompson et al., 1987). The absorbance was recorded at a wavelength of 540 nm using SPECTRONIC® GENESYS TM5 Spectrophotometer. Glucose concentration vs time graph was plotted for each rice sample and the incremental area under the curve (IAUC) was calculated by using the trapezoidal method.

According to the Goñi et al. (1997) there is a high correlation between the rate of starch digestion and the glycemic response by various in vitro digestion methods. The hydrolysis index (HI) exhibits the starch digestion rate whereas the estimated GI shows the digestibility of sample against white bread. The HI of each test food was calculated using the following formula:

$$\text{Hydrolysis index} = \frac{\text{AUC of the test food}}{\text{AUC of the standard}}$$

$$\text{AUC} = \text{Area under the curve}$$

The in vitro glycemic index of a particular food is calculated by using the following equation (Goñi et al. 1997).

$$\textit{Invitro}\text{Glycemic Index} = 39.71 + 0.549\ \text{HI}$$

Preparation of the porridge extracts for bio assays

Prepared four porridges were lyophilized in a freeze drier (Christ-Alpha 1–4 Freeze dryer, Biotech International, Germany) until free of moisture. After the porridge freeze dried, they were stored at −20 °C until analysis for less than 1 month. Lyophilized porridge composites were ground and passed through a 500 µm sieve to obtain a consistent fine residue.

Ten grams of lyophilized porridge powder of each of the porridges were extracted with 10 times the sample weight of 70% methanol/water (v/v) for 24 h at room temperature (28 ± 2 °C). Then extracts were filtered through Whatman 52 filter paper to obtain filtrate. Filtered extracts were evaporated under reduced pressure in a rotary evaporator (Buchi, RE111, Switzerland) to remove methanol. Remaining water was removed by freeze drying (Christ-Alpha 1–4 Freeze dryer, Biotech International, Germany). The extracts were then used to prepare known concentrations of porridge extracts and the solutions were passed through 0.2 µm millipore filters. Filtered extracts were used for the bioassays.

Anti-glycation activity of porridges

The anti-glycation activity was performed according to the method described by Matsuura et al. (2002) with some modifications. The fluorescence intensity was measured at an excitation wavelength of 370 nm and emission wavelength of 440 nm using spectrofluorometer. All rice extracts were initially screened at 200 µg/mL (for initial screening, n = 3) and dose response (200, 100, 50, 25 µg/mL) studies (n = 3) were performed. Rutin was used as the standard (positive control). Anti- glycation activity (in terms of inhibition %) of rice extracts and Rutin was calculated.

$$\text{Inhibition}\ (\%) = \frac{[(\text{Fc} - \text{Fb}) - (\text{Fs} - \text{Fsb})] \times 100}{(\text{Fc} - \text{Fb})}$$

Fc: florescence of incubated BSA, glucose and DMSO (control); Fb: florescence of incubated BSA alone (blank); Fs: florescence of incubated BSA, glucose and rice extracts (sample); Fsb: florescence of incubated BSA with rice extracts (sample blank).

The α-amylase inhibition activity of porridge extracts

The anti-amylase assay was performed using α-amylase enzyme according to a known procedure (Balasubramaniam et al. 2013) with modifications. Absorbance was taken at 540 nm using a 96-well micro plate reader (SpectraMax Plus384, Molecular Devices, USA). Control experiments were conducted in an identical way, replacing porridge extracts with 30 µL of distilled water. Same procedure followed using acetate buffer instead of the enzyme solution as the sample blank. Anti-amylase activity (inhibition %) of each porridge extract was calculated using the given standard equation.

$$\text{Inhibition } (\%) = \frac{\text{Ac} - (\text{As} - \text{Ab}) \times 100}{\text{Ac}}$$

Ac: Absorbance of the control; Ab: Absorbance of sample blank; As: Absorbance in the presence of porridge extracts.

Anticancer activity of porridges

Human lung mucoepidermoid carcinoma cells NCI-H292 (ATCC® CRL-1848™) and human cervical cells-HeLa (ATCC® CCL-2™) were plated on 96 well plates (5000 cells/well) with 200 µl of growth medium separately. Eagle's minimum essential medium (EMEM) with 10% fetal bovine serum (FBS) were used as the growth medium for HeLa whereas Dulbecco's modified eagle medium (DMEM) with 10% fetal bovine serum (FBS) were used as the medium for NCI cell lines. Cells were exposed to test compounds (concentrations ranging from 25 to 400 µg/mL) for 24, 48 and 72 h at 37 °C under 5% CO2 and cell viability was assessed using Sulforhodamine B assay (Orellana and Kasinski 2016). Paclitaxel was used as the positive control.

Upon incubation for 24, 48, and 72 h, the cell supernatant was completely removed and washed with PBS. Subsequently, the cell monolayers were fixed with 10% trichloroacetic acid or TCA (25 µl 50% TCA l mixed with 200 µl FBS free fresh medium), and was incubated at 4 °C for one hour prior to the SRB assay. The plate was then washed with five washing cycles using tap water and dried completely. Each well was stained for 15 min using 100 µL SRB (0.4%) dye dissolved in 1% TCA. The plate was again washed with five washing cycles to remove unbound dye using 1% (v/v) acetic acid. The protein-bound dye was solubilized with tris base (10 mM, pH 7.5, 200 µL), after air drying and the plates were shaken for 60 min to homogenize the dye solution. The absorbance was then measured at 540 nm using a Synergy HTBioT microplate reader. The percentage viability (IC_{50}) was calculated as given below. Each experiment was triplicated. Percentage viable cells were determined using the equation:

Viability (%) = (absorbance of treated cells / absorbance of the control) × 100.

Statistical Analysis

All experiments had three replications of each measurement. Tests 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.

Results and discussion

In vitro *glycemic index of rice porridges*

The dietary fiber content, available carbohydrate content and hydrolysis indices of porridge composites are illustrated in the Table 1. The in vitro GI values of porridge composites were calculated by obtaining the hydrolysis index (HI index). The hydrolysis indices of porridge composites were in the range of 40.4 ± 0.5 to 63.9 ± 0.5. The lowest hydrolysis index was reported for MWP whereas the highest hydrolysis index was exhibited the KHP. Our study indicated that one portion of porridge (around 250 mL) can provide around 40%–45% of the suggested dietary fiber intake while one portion of MXP can easily provide more dietary fiber intake, since it exhibited the highest dietary fiber content among the tested, four porridge composites. Food and drug administration suggest that dietary fiber intake should be 25–30 g per day https://www.accessdata.fda.gov/scripts/interactivenutritionfactslabel/.

Several researches showed a high correlation between the rate of starch digestion and the glycemic response by various in vitro digestion methods that imitate the in vivo methods (Goñi et al. 1997). Glycemic response has been employed as a criterion to guide the selection of foods in balanced dietary schemes or in the formulation of new products (Bellmann et al. 2018). The HI is the ratio of the area under the hydrolysis curve of the sample to the area under the hydrolysis curve of white bread as reference sample.

Rice, being one of the primary dietary sources of carbohydrates worldwide, is of particular interest when assessing variability in starch digestibility. The in vitro GI of rice is known to be relatively high compared to other starchy foods. Literature have greatly shown that glycemic index of 96 for brown rice and 83 for white rice (Jenkins et al. 1984). According to the research conducted by

Table 1 Dietary fiber content, available carbohydrates, hydrolysis index and the in vitro GI indices of porridge composites

Porridge	Dietary fiber (%)	Available carbohydrate (%)	HI (%)	in vitro GI
MWP	5.1 ± 0.3[a]	78.9 ± 0.3[a]	40.4 ± 0.5[a]	39.9 ± 0.5[a]
KHP	4.6 ± 0.3[b]	80.1 ± 0.4[b]	63.9 ± 0.5[b]	40.2 ± 0.5[a]
MXP	5.3 ± 0.3[a]	79.7 ± 0.3[a]	56.5 ± 0.5[c]	40.1 ± 0.5[a]
STP	4.5 ± 0.3[b]	80.9 ± 0.4[b]	45.5 ± 0.2[a]	40.0 ± 0.2[a]

*Mean (± SD) followed by the same superscript within a column (a, b and c) is not significantly different ($P > 0.05$) as measured by ANOVA

MWP: Madathawalu Porridge; *KHP*: Kaluheenati Porridge; *MXP*: Mixed rice Porridge; *STP*: Special traditional Porridge

Anuruddhika Subhashinie Senadheera and Ekanayake (2013) the in vitro GI obtained for tested porridge composites were in the range of 39.9 ± 0.5 to 40.2 ± 0.5 (Senadheera et al. 2013). The MWP had the lowest in vitro GI, while KHP had the highest in vitro GI value. Rice porridge made out of 272 6B rice variety has been reported the GI of 46 (Senadheera et al. 2013) which is a higher value than the above obtained values. Moreover, the glycemic indices of Thailand Jasmine rice porridges are higher (68–90) (Srikaeo and Sopade 2010) than the in vitro GI of tested MWP, KHP, MXP and STP. Hettiarachchi and coworkers further reported that the GI of seven improved rice varieties were in the range of 55–73 (Hettiarachchi et al. 2014), which are higher than the results of the present study of porridge composites. Pirasath et al. reported a higher GI value of 66 in a Samba variety (Pirasath et al. 2010) which is a commonly consumed rice type in Sri Lanka. Some parboiled improved rice varieties of Bg 352, Bg 358, Bg 356 and Bg 406 possess higher GI values of 60, 62, 64 and 71 than traditional rice varieties (Pathiraje et al. 2010). Therefore, it is clear that the Sri Lankan traditional rice varieties and traditional rice based porridges have medium in vitro GI values and these values are lower than that of improved rice and hybrid rice types in Sri Lanka.

Blood glucose response is generally estimated by determining the GI, which relates the response of a test food to that of a reference food, usually fresh white bread. The GI is usually obtained dividing the blood glucose production due to the corresponding food after ingestion by that of an equal carbohydrate portion of the reference food (Jenkins et al. 1983). Hence, a known protocol (Thompson et al. 1987) was followed and GI was calculated by considering the action of the salivary amylase. A low glycemic response is considered beneficial from a nutritional point of view, especially for individuals suffering from impaired glucose tolerance. Glycemic index (GI) is a parameter of blood glucose response in the body. Blood glucose response relates to the response of a test food to that of a reference food. A low glycemic response is considered beneficial from a nutritional point of view, especially for individuals suffering from impaired glucose tolerance.

According to the results, consumption of the traditional rice based porridges is considered effective for the prevention of diabetic conditions as well as from various complications in diabetic patients.

Antiglycation activities of rice based porridges

The graph of percentage glycation inhibition against concentration illustrated in the Fig. 1. In vitro anti-glycation IC_{50} (µg/mL) values and α-amylase inhibition activity IC_{50} (µg/mL) values depicted in Table 2. Investigation of the anti-glycation activity is important in the prevention of complications associated with diabetic patients.

Percentage inhibitions of MWP, KHP, MXP and STP were 79.89%, 66.83%, 63.19% and 59.04% respectively at 500 µg/mL concentration. These obtained values were less than the percentage inhibitions of rice bran extracts. According to the recent studies, brans of 23 traditional and 12 improved (both red and white) rice varieties in Sri Lanka have been screened for anti-glycation activities. Among them, rice brans of traditional red rice varieties of Masuran, Sudu Heeneti, Dik Wee and Goda Heeneti (% inhibitions of 91.28 ± 0.06, 90.87 ± 0.25, 91.30 ± 0.71

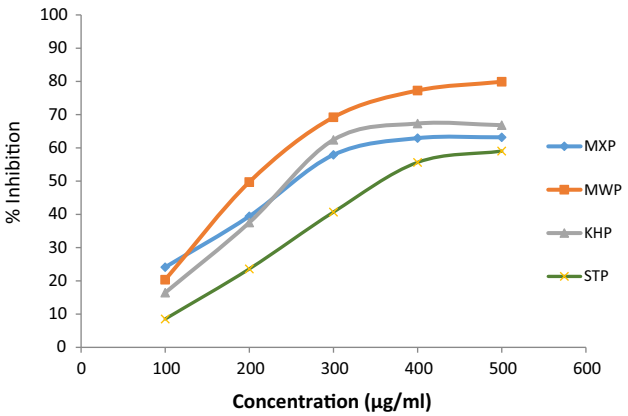

Fig. 1 Percentage glycation inhibition against the concentration of porridge composites, MWP: Madathawalu Porridge; KHP: Kaluheenati Porridge; MXP: Mixed rice Porridge; STP: Special traditional Porridge

Table 2 Anti-glycation and α-amylase inhibition activities of porridge extracts

Porridge/compound	Antiglycation activity IC_{50} (μg/mL)	α-amylase inhibition activity IC_{50} value (μg/mL)
MWP	228.20 ± 4.20[a]	117.54 ± 1.92[a]
KHP	272.84 ± 5.99[b]	439.90 ± 6.65[b]
MXP	278.92 ± 6.01[b]	188.08 ± 1.85[c]
STP	362.84 ± 4.46[c]	128.75 ± 5.91[d]
Rutin	100.85 ± 2.31	NA
Acarbose	NA	247.86 ± 1.25

*Mean (± SD) followed by the same superscript within a column (a, b, c and d) is not significantly different ($P > 0.05$) as measured by ANOVA

MWP: Madathawalu Porridge; *KHP*: Kaluheenati Porridge; *MXP*: Mixed rice Porridge; *STP*: Special traditional Porridge; Results are expressed as mean ± SD; n = 3. *NA*: not applicable

and 90.36 ± 0.66 respectively) have been exhibited significant and dose dependent antiglycation activity. This study was done by Premakumara and co-workers and the authors demonstrated a positive correlation of anti-glycation activity with TPC of the rice bran (r = 0.67) which is relatively not strong (Abeysekera et al. 2015a, b). This suggests that the anti-glycation activity of the rice extracts cannot always be attributed to their phenolic content or antioxidant activity, because there may be compounds which interfere with the fluorescent measurements and give out false results. Among the studies porridge composites, high antiglycation activities of MWP may attribute to its higher antioxidant activity. Madathawalu porridge is recommended in traditional ayurvedic medicine in order to reduce the blood glucose level as it possess high antiglycation activity. KHP and MXP exhibited slightly similar IC_{50} values (272.84 ± 5.99 μg/mL and 278.92 ± 6.01 μg/mL respectively). The findings of Séro et al. (2013) and Grzegorczyk-Karolak et al. (2016) have reported the presence of anti-glycation activity in phenols and other compounds having antioxidant properties. Higher antiglycation activity may associate with the scavenging of free radicals derived from glycation and thereby provides a protective effect against hyperglycemia mediated damage.

The α-amylase inhibition activity of rice based porridge extracts

The Table 2 depicts the IC_{50} values of porridge extracts with respect to the α-amylase inhibition assay. Starch digestion in our body initiates with salivary amylase, and then by pancreatic amylase in the small intestine. The α-amylase enzyme is responsible for hydrolyzing maltose, which breaks down into glucose prior to absorption. Partial digestion by the salivary amylase by catalyzing the hydrolysis of alpha-1,4-glycosidic linkages of starch, glycogen and various oligosaccharides is resulted in the degradation of polymeric substrates into shorter oligomers (Hara and Honda 1990). Inhibition of α-amylase leads to decrease in post prandial hyperglycemia in diabetic condition. The inhibition of the activity of α-amylase in the digestive tract is considered as an effective way to control diabetes (Taslimi et al. 2018). Furthermore, this leads to diminish absorption of monosaccharaides (Hara and Honda 1990). Many drugs, compounds and natural products have been investigated with respect to suppression of glucose production from the carbohydrates in the gut or glucose absorption from the intestine. Effective and nontoxic inhibitors of α-amylase enzyme have long been sought.

In this study, four porridge extracts were evaluated for their α-amylase inhibitory activity. Acarbose was used as the positive control. The half maximal inhibitory concentration (IC_{50}) is a measure of the effectiveness of a substance in inhibiting a specific biological or biochemical activity. The major outcome of this study revealed that all four porridge extracts have exhibited potent inhibition of α-amylase enzyme activity. In addition, MWP, MXP and STP extracts had low IC_{50} values (117.54 ± 1.92 μg/mL, 188.08 ± 1.85 μg/mL, 128.75 ± 5.91 μg/mL) showing their high capability to inhibit α-amylase enzyme. However, only KHP showed slight alpha-amylase inhibition activity with regard to its high IC_{50} value (439.90 ± 6.65 μg/ml). Similar study has been carried out to investigate the in vitro anti-amylase activity of brans of 23 traditional and 12 improved (both red and white) rice varieties in Sri Lanka (Abeysekera et al. 2013). Significantly high anti amylase activity can be seen in bran extracts of red varieties compared to white varieties at screening. Significant and dose dependent anti-amylase activity was exhibited by traditional red rice varieties of Masuran, Sudu Heeneti, Dik Wee and Goda Heeneti (IC_{50} values of 58.28 ± 3.17 μg/mL, 58.63 ± 5.33 μg/mL, 76.93 ± 1.80 μg/mL and 102.65 ± 7.01 μg/mL respectively). On the other hand, people consume porridge and cooked rice, not the bran only. Rice brans consist of higher amount of active compounds than the whole grain. Hence,

these porridges exhibited lower α-amylase inhibition ability than that of rice bran. Even though the α-amylase inhibition activity of porridge extracts are lower than that of brans of Sri Lankan traditional red rice varieties, these porridge extracts exhibited considerably high amount of α-amylase inhibition ability. Therefore, these porridges may act as potential food supplements for diabetes.

In vitro *Anti-cancer activity of porridges*

The SRB assay was conducted using four porridge extracts (70% methanol/water). NCI human lung cancer cell lines and HeLa human cervical cancer cell lines were exposed to extracts in a concentration gradient and cytotoxicity was measured.

The SBR assay can be used to determine which of these take place for lung cancer cells and cervical cancer cells from the effect due to porridge extracts have resulted in a reduction of proliferation of cells at the end of the specified time compared to the control wells that is there on microplate in which the SBR assay is carried out where no cytotoxic substance has been added. Paclitaxel was used as the positive control to obtain IC_{50} values. Comparing to IC_{50} values obtained for extracts, only KHP and MXP porridge extracts have shown the anti-cancer activity against human cervical cancer cell lines, according to the Table 3. After 72 h, IC_{50} value of KHP was 274.6 µg/mL while that of MXP was 940.2 µg/mL showing slight anti-cancer activity. Other two porridge extracts have not shown a considerable anti-cancer activity against human cervical cancer cell lines. The positive control, paclitaxel demonstrated very high anti-cancer activity to human cervical cancer cells even within first 24 h. Previous studies on Sri Lankan traditional rice bran extracts have shown acute anti-cancer activity against HeLa- human cervical cancer cells (Abeysekera et al. 2015a, b). Individual rice bran extracts of Sudu Heenati, Masuran, Dik Wee and Goda Heenati possess high growth inhibition (GI) and cytotoxicity against human lung cancer (NCI-H460) cells showing IC_{50} values of 240.12 ± 9.23 µg/mL, 323.75 ± 0.71 µg/mL, 437.20 ± 3.44 µg/mL and 476.22 ± 0.05 µg/mL respectively. More apparently, they have not shown any cytotoxicity to normal cells from these rice bran extracts (Abeysekera et al. 2015a, b). According to the obtained results, MXP has high anti-cancer activity compared to rice bran extracts of Masuran, Dik Wee and Goda Heenati. However, significant anti-cancer activity was not evident by 70% methanolic porridge extracts of MWP and STP against cervical cancer cell lines.

The anti-cancer activity of porridge extracts against NCI-human lung cancer cell lines was also evaluated. According to the Table 3, none of the 70% methanolic porridge extracts have exhibited significant anti-cancer activity against lung cancer cells.

The positive control; paclitaxel possessed very high, acute anti-cancer activity throughout the tested time periods. In relation to the cytotoxicity against NCI- H460 human lung cancer cells, Sudu Heenati, Masuran, Dik Wee and Goda Heenati have high growth inhibition and anti-cancer activity (IC_{50} values of 255.36 ± 1.81 µg/mL, 344.00 ± 8.33 µg/mL, 340.21 ± 10.97 µg/mL, 412.07 ± 17.73 µg/mL respectively) (Abeysekera et al. 2015a, b). According to the IC_{50} values of examined porridge extracts, KHP has slight anti-cancer activity showing IC_{50} value of 1.31 mg/mL at 72 h. Among four porridge extracts, 70% methanolic extracts of MWP, MXP and STP have not shown effective anti-cancer activity against NCI-human lung cancer cell lines. There might be several reasons which attribute to the high IC_{50} values. The concentrations which may be very thick solutions, so there may be changes in osmotic pressure. And 70% methanol/water solution which generally carry lots of macro molecules thereby make small active molecules dilute. The crude extracts of porridges were subjected to anticancer assay and active compounds were not isolated. Therefore, the considerably high IC_{50} values of porridge extracts were obtained may be due to that reason.

Table 3 IC_{50} values (ppm) reported for porridge extracts against HeLa- human cervical cancer cells and NCI- human lung cancer cells

Porridge extract/compound	IC_{50} value (µg/mL)					
	24 h		48 h		72 h	
	HeLa	NCI	HeLa	NCI	HeLa	NCI
MWP	6818	11,398	8836	8975	> 100,000	4551
KHP	2284	> 100,000	24,019	67,569	**274.6**	1311
MXP	74,313	7922	2319	334,124	**940.2**	11,004
STP	69,707	98,764	15,077	95,380	17,972	17,012
Positive control	0.326	2.314	< 0.0001	0.2096	< 0.0001	0.1688

MWP: Madathawalu Porridge; *KHP*: Kaluheenati Porridge; *MXP*: Mixed rice Porridge; *STP*: Special traditional Porridge

Conclusion

In conclusion, this study reveals that studied four herbal porridges: MWP, KHP, MXP, STP possess anti-diabetic activity. Among the four porridges, MWP has the lowest GI and GL as well as the highest antiglycation and α-amylase inhibition activity. According to the glycemic indices obtained for tested porridge composites, GI values were medium compared to the other non-traditional rice porridges. The MWP had the lowest GI, while KHP had the comparatively high GI value. Since all four porridge composites showed marked antiglycation and α-amylase inhibition properties, consumption of these rice based porridges may play an important role in reducing the risk of oxidative stress associated chronic diseases. Moreover, MWP, KHP, MXP and STP are recommended for diabetic patients by traditional ayurvedic practitioners since early days. This study provides the scientific basis and proves their bioactivities. Notably, MWP and MXP can be recommended for diabetic patients, due to their low GI values.

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Data availability The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Code availability Not applicable.

Declarations

Conflict of interest The authors have declared no conflict of interest for this article.

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