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Original Research Article

Dietary fibers, starch fractions and nutritional composition of finger millet varieties cultivated in Sri Lanka

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ABSTRACT

Soluble, insoluble and total dietary fiber contents, rapidly and slowly digestible starch contents, arabinoxylans, β-glucans, fructans, resistant starch, amylose and total sugar contents, minerals and trace elements compositions and proximate compositions of three finger millet varieties, namely Ravi, Rawana and Oshadha, were evaluated using standard protocols. There were no significant differences ($P \geq 0.05$) among the rapidly digestible starch, arabinoxylans, β-glucans, fructans, amylose, total sugar, protein, crude fat and crude fiber contents of Ravi, Rawana and Oshadha varieties. Total dietary fiber contents varied between 13.01% (Ravi) and 13.79% (Oshadha). Slowly digestible starch contents ranged from 43.38% (Ravi) to 49.15% (Oshadha) and resistant starch contents ranged from 3.75% (Ravi) to 4.58% (Oshadha). Ash content of Ravi (3.22%) was significantly higher ($P < 0.05$) than ash contents of other two varieties. Average sodium, magnesium, potassium, calcium, iron, zinc and phosphorous contents of three finger millet varieties were 12.04, 141.78, 407.15, 345.62, 3.49, 1.89 and 331.07 mg/100 g, respectively. Findings of the present study indicated that studied finger millet varieties were good sources of dietary fibers (including resistant starch) as well as minerals and trace elements (especially potassium, calcium, phosphorous and iron) when compared to commonly consumed cereals such as rice and wheat.

1. Introduction

Millets are highly variable small-seeded minor cereals of the grass family, *Poaceae*. They are drought-resistant annual cereals and majority of them are adapted to tropical and arid climates. Millets show resistance to pests and diseases and have a high productivity under drought conditions when compared to commonly cultivated and consumed cereals such as wheat, rice and corn. Hence, millet grains have started receiving a specific attention among other cereal grains (Saleh et al., 2013; Shobana et al., 2013).

Finger millet (*Eleusine coracana* (L.) Gaertn.) is the most important small millet in the tropics and cultivated in more than 25 countries in Africa and Asia, predominantly as a staple food grain of a large segment of the population in those countries (Chandra et al., 2016; Kumar et al., 2016). It is considered to be one of the least allergenic and most digestible grains (Mathanghi and Sudha, 2012; Singh and Raghuvanshi, 2012; Shobana et al., 2013). Finger millet is gluten-free and a good option for people those who are suffering from celiac disease. Hypoglycaemic, hypocholesterolaemic, nephroprotective, anti-cataractogenic, antiulcerative, antioxidant, antimicrobial and wound healing properties of finger millet have been reported in previous studies (Mathanghi and Sudha, 2012; Srivastava and Sharma, 2012; Amadou et al., 2013; Chandra et al., 2016; Sing and Sarita, 2016).

Finger millet is the third important cereal cultivated in Sri Lanka next to rice and corn. It is grown extensively in rain-fed uplands in dry and intermediate climate zones of the country since ancient times (Kumari et al., 2016). However, very limited studies have been conducted on nutritional composition and potential health benefits of the finger millet varieties which are commonly cultivated and consumed in Sri Lanka. Since cereals and cereal based food products are the principal

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components of human diet, knowledge on nutritional composition of a commonly cultivated and consumed cereal is a useful guide in understanding the nutrient intakes and fulfilling the nutrient requirements. Therefore, the present study was focused on evaluating soluble, insoluble and total dietary fiber contents, rapidly and slowly digestible starch contents, arabinoxylans, β-glucans, fructans, resistant starch, amylose and total sugar contents, minerals and trace elements compositions and proximate compositions of finger millet varieties commonly cultivated and consumed in Sri Lanka.

2. Materials and methods

2.1. Sample collection and preparation

Finger millet varieties which are recommended for cultivation by the Department of Agriculture, Sri Lanka namely Ravi, Rawana and Oshadha were collected from Field Crops Research and Development Institute (FCRDI), Mahailuppallama, Sri Lanka in 2013. These varieties were grown in experimental plots (50 m^2 in size) in the Low Country Dry Zone, at FCRDI, Mahailuppallama from April to August (during the *Yala* season) of 2013. Each variety was planted in a plot with seventeen rows placed 30 cm apart. Plants were placed 10 cm apart in the same row. Totally 850 finger millet plants from each variety were planted and finally the average yield was 12.5 kg. The seeds were certified by the Seed Certification Service of Department of Agriculture, Sri Lanka. From each variety 2.5 kg of seeds were collected, dehulled (TM05C, Satake Corporation, Japan) and stored in airtight containers at 4 °C until use for the analysis. Flours from whole grains were obtained by milling (Pulverisette 14, Fritsch, Germany) and passing through a 0.5 mm sieve.

2.2. Enzymes and chemicals

Total dietary fiber assay kit, pancreatin, amyloglucosidase, invertase, glucose oxidase, peroxidase, 4-amino antipyrine, phenol, tween 20, corn starch, D-(+)-glucose, D-(+)-xylose and phloroglucinol were purchased from Sigma Aldrich, MO, USA. Mixed-linkage β-glucan assay kit and Fructan HK assay kit were purchased from Megazyme International, Co. Wicklow, Ireland. All other chemicals and reagents used in the experiments were of ACS, HPLC and analytical grades.

2.3. Determination of soluble, insoluble and total dietary fiber contents

Soluble, insoluble and total dietary fiber contents were determined according to the enzymatic gravimetric procedure (985.29) specified in AOAC (1997) using the Sigma total dietary fiber (TDF) assay kit. After separating the insoluble dietary fiber (IDF) portion by filtering, the filtrate was mixed with 4 volumes of 95% ethanol and filtered to separate the soluble dietary fiber (SDF) portion.

2.4. Determination of arabinoxylans contents

Total arabinoxylans (TAX) and water-extractable arabinoxylans (WEAX) contents were determined according to the methods described by Douglas (1981); Asawaprecha (2004) and Kiszonas et al. (2012). For TAX content determination, flour (10 mg) was measured to a screw cap tube covered with an aluminum foil. It was mixed with 2 ml of distilled water for 30 s. For WEAX content determination, flour (100 mg) was mixed with 10 ml of distilled water and kept for 30 min. The solution was mixed 3 times during the 30-minute extraction time and centrifuged at 3000 × g for 10 min. Supernatant (2 ml) was taken to a screw cap tube covered with an aluminum foil. Freshly prepared phloroglucinol reagent (10 ml) was added to the tubes containing TAX solution and WEAX solution. The tubes were kept at 100 °C for 25 min and cooled rapidly in an ice bath for 5 min. Immediately after cooling, absorbance values were recorded at 558 nm and 505 nm using the UV/VIS spectrophotometer (UV-1601, Shimadzu Corporation, Japan). D-(+)-Xylose was used as the standard. Standard curve was prepared by plotting the difference between absorbance at 558 nm and at 505 nm against D-(+)-xylose concentration. A factor 0.88 was used to convert the D-(+)-xylose concentration to arabinoxylans concentration. Water-unextractable arabinoxylans (WUAX) content was determined by subtracting WEAX content from TAX content.

2.5. Determination of β-glucans content

β-Glucans content was determined according to the method (995.16) specified in AOAC (2005) using the Megazyme mixed-linkage β-glucan assay kit.

2.6. Determination of fructans content

Fructans content was determined according to the method (999.03) specified in AOAC (2003) using the Megazyme Fructan HK assay kit.

2.7. Determination of starch fractions

Rapidly digestible starch (RDS), slowly digestible starch (SDS) and resistant starch (RS) contents were determined according to the method described by Englyst et al. (1992). Enzymatic hydrolysis was carried out using pancreatin, amyloglucosidase and invertase enzymes. After 20th min (G20 portion) and after 120th min (G120 portion) hydrolysates were collected and used to determine RDS and SDS contents, respectively using glucose oxidase-peroxidase (GOPOD) assay. After collecting the G120 portion, total glucose content in the remaining sample was measured using the GOPOD assay in order to determine the total starch content. RS (the starch fraction that remained undigested after 120 min) content was calculated by subtracting RDS and SDS contents from total starch content.

2.8. Determination of amylose content

Starch was isolated according to the method described by Bangoura et al. (2012). Amylose content was determined according to the method described by Williams et al. (1970) with relevant modifications. In brief, starch (10 mg) was mixed with 5 ml of 0.5 M potassium hydroxide and the volume was increased up to 50 ml using distilled water. After that, 10 ml of the solution was mixed with 5 ml of 0.1 M hydrochloric acid and 0.5 ml of iodine reagent and the volume was increased up to 50 ml with distilled water. Absorbance value was measured at 625 nm using a UV/VIS Spectrophotometer (UV 3000, LAB INDIA Analytical, India). Corn starch containing 27% of amylose was used as the standard.

2.9. Determination of proximate composition

Moisture content was determined according to the oven drying method (925.10), protein content was determined according to the Kjeldahl method (2001.11, nitrogen to protein conversion factor was 6.25) and ash content was determined according to the dry ashing method (923.03) as specified in AOAC (2012). Crude fiber content was determined according to the method (978.10) specified in AOAC (2012) using the Fibertec hot extractor (M6 1020, FOSS, Sweden). Crude fat content was determined according to method (2003.05) specified in AOAC (2012) using the Soxhtherm (SOX 416, Gerhardt, Germany) and hot extraction was carried out using petroleum ether (boiling range 40–60 °C) at 150 °C for 30 min. All results were converted to dry weight basis. Total carbohydrate content was determined by subtracting the sum of protein, fat and ash percentages (dry weight basis) of the sample from 100 according to the method described by Sompong et al. (2011).

2.10. Determination of total sugar content

Total Sugar content was determined according to the phenol-sulphuric method described by Dubois et al. (1956). Flour sample (5 g) was refluxed with 250 ml of 80% ethanol for 45 min. Solution was filtered (Whatman No. 1) and the extraction was repeated. After filtering, two solutions were combined and ethanol was evaporated using a rotary evaporator (R-114, BUCHI, Switzerland). Volume of concentrated solution was adjusted to 100 ml with distilled water. Then, 1 ml of the solution was diluted to 250 ml with distilled water. After that, 1 ml of the diluted solution was mixed with 1 ml of 5% phenol solution in a screw cap tube and 5 ml of concentrated sulphuric acid was added to it. It was left for 10 min, mixed well and kept in a water bath at room temperature for 10 min. Absorbance value was measured at 480 nm using the UV/VIS spectrophotometer (UV-1601, Shimadzu Corporation, Japan). D-(+)-Glucose was used as the standard.

2.11. Determination of minerals and trace elements composition

Sodium (Na), magnesium (Mg), potassium (K), calcium (Ca), iron (Fe) and zinc (Zn) contents were determined according to the method (999.11) specified in AOAC (2012) using atomic absorption spectrophotometer (AA240 FS, Varian, Australia). In brief, flour sample (~5 g) was weighed into a cleaned and dried porcelain crucible and ignited in a muffle furnace (SAF 11/1, Lenton Thermal Designs Ltd, England) at 550 °C for 5 h until a light grey color ash was formed. After cooling in a desiccator, ash was dissolved in concentrated nitric acid (5 ml) and the volume was increased up to 25 ml with distilled water. Then, the sample was injected to the atomic absorption spectrophotometer which is calibrated using standard metal solutions. Concentrations of each mineral and trace element were recorded using calibration curves.

Phosphorous (P) content was determined according to the method (965.17) specified in AOAC (1990). Briefly, flour sample (~5 g) was weighed into a cleaned and dried porcelain crucible and ignited in a muffle furnace (SAF 11/1, Lenton Thermal Designs Ltd, England) at 550 °C for 5 h until a light grey color ash was formed. After cooling in a desiccator, ash was dissolved in 100 ml of distilled water. Then 10 ml of concentrated hydrochloric acid and 10 ml of concentrated nitric acid were added to it mixed well, filtered (Whatman No. 1) and the volume was increased up to 250 ml with distilled water. Then 10 ml of the solution was mixed with 25 ml of molybdovanadate reagent and kept in the room temperature for 10 min. Absorbance value was measured at 420 nm using the UV/VIS spectrophotometer (UV-1601, Shimadzu Corporation, Japan).

2.12. Statistical analysis

Data of each experiment were statistically analysed using IBM SPSS Statistics (Version 20) software and results were expressed as mean ± standard error (SE). Statistical significance was set at 95% confidence level. One way analysis of variance (ANOVA) and Tukey's test were used to determine the differences among the varieties.

3. Results and discussion

3.1. Dietary fibers

Soluble, insoluble and total dietary fiber contents of Ravi, Rawana and Oshadha finger millet varieties are presented in Table 1. TDF, SDF and IDF contents varied between 13.01 and 13.79%, 0.52 and 0.59% and 12.49 and 13.20%, respectively on dry weight basis. There were no significant differences ($P \geq 0.05$) among TDF, SDF and IDF contents of Rawana and Oshadha and those were significantly ($P < 0.05$) higher than TDF, SDF and IDF contents of Ravi. According to Singh and Raghuvanshi (2012) TDF content of finger millet was 12% on wet weight basis and according to Shobana et al. (2013) and Kumar et al. (2016) TDF content of finger millet was 11.5% on wet weight basis. Thippeswamy et al. (2016) also have studied dietary fiber contents of finger millet and according to them TDF content of an Indian finger millet variety was 13.44% on dry weight basis. Therefore, TDF contents of Ravi, Rawana and Oshadha were in line with those findings.

Table 1
Total, soluble and insoluble dietary fibers, arabinoxylans, β-glucans and fructans contents of Sri Lankan finger millet varieties.

Parameter	Finger millet variety		
	Ravi	Rawana	Oshadha
Total dietary fiber %	13.01 ± 0.25[b]	13.58 ± 0.20[a]	13.79 ± 0.13[a]
Soluble dietary fiber %	0.52 ± 0.02[b]	0.57 ± 0.03[a]	0.59 ± 0.02[a]
Insoluble dietary fiber %	12.49 ± 0.25[b]	13.04 ± 0.17[a]	13.20 ± 0.11[a]
Total arabinoxylans %[1]	1.88 ± 0.04[a]	1.83 ± 0.03[a]	1.94 ± 0.08[a]
Water-extractable arabinoxylans %[2]	0.17 ± 0.01[a]	0.16 ± 0.02[a]	0.18 ± 0.02[a]
Water-unextractable arabinoxylans %	1.71 ± 0.04[a]	1.67 ± 0.03[a]	1.77 ± 0.08[a]
β-Glucans %[3]	0.12 ± 0.00[a]	0.13 ± 0.02[a]	0.17 ± 0.03[a]
Fructans %[4]	0.32 ± 0.01[a]	0.30 ± 0.01[a]	0.35 ± 0.02[a]

Results are presented as mean ± SE (n = 6) on dry weight basis. Within a row, mean values superscripted with different letters are significantly different at $P < 0.05$ while mean values superscripted with the same letter are not significantly different at $P \geq 0.05$.

[1] LOQ: 0.1%.
[2] LOQ: 0.01%.
[3] LOQ: 0.01%.
[4] LOQ: 0.01%.

According to Yadav et al. (2010) TDF contents of wheat, rice and barley were 8.3, 3.0 and 15.0%, respectively on dry weight basis. In addition, they have reported that SDF contents of wheat, rice and barley were 2.9, 0.9 and 4.3%, respectively on dry weight basis while IDF contents were 5.4, 2.1 and 10.7%, respectively on dry weight basis. As reported by Rakha (2011) TDF contents of rye, whole wheat, corn, dehulled oats and barley were 15.1, 12.2, 7.3, 10.6 and 10.1%, respectively on wet weight basis. According to Dhingra et al. (2012) TDF contents of whole wheat, rice, oats, corn and barley were 12.6, 1.3, 10.3, 13.4 and 17.3%, respectively on wet weight basis. Dhingra et al. (2012) also have reported that SDF contents of whole wheat, rice and oats were 2.3, 0.3 and 3.8%, respectively on dry weight basis while IDF contents were 10.2, 1.0 and 6.5%, respectively on dry weight basis. Shobana et al. (2013) reported that TDF contents of foxtail, little, kodo and barnyard millets were 2.4, 2.5, 2.5 and 1.9%, respectively on wet weight basis. According to Kumar et al. (2016) TDF contents of pearl millet, sorghum, red rice, white rice, whole wheat, corn, oats and barley were 11.3, 6.7, 3.4, 4.1, 12.5, 7.3, 10.6 and 15.6%, respectively on wet weight basis. As reported by Thadhani et al. (2000) TDF contents of raw white rice, raw red rice, refined wheat flour and whole wheat flour were 4.2, 5.5, 3.6 and 11.7%, respectively on dry weight basis. TDF contents of Sri Lankan traditional rice varieties ranged from 4.68 to 5.15% (Abeysekera et al., 2015) and 2.68 and 6.28% (Samaranayake et al., 2017) on dry weight basis. TDF, SDF and IDF contents of Sri Lankan traditional rice varieties varied between 4.2 and 6.9%, 0.8 and 2.1% and 3.1 and 4.8%, respectively on dry weight basis (Abeysekera et al., 2017). When compared with these results, TDF contents of Ravi, Rawana and Oshadha varieties were higher than TDF contents of common cereals including rice, wheat, corn, sorghum, oats, pearl millet, foxtail millet, little millet, kodo millet and barnyard millet. Average TDF content of Ravi, Rawana and Oshadha varieties was approximately 2.9, 1.1 and 1.2 times higher than TDF contents of rice, wheat and corn, respectively.

3.2. Arabinoxylans

Total, water-extractable and water-unextractable arabinoxylans contents of Ravi, Rawana and Oshadha varieties ranged from 1.83 to 1.94%, 0.16 to 0.18% and 1.67 to 1.77%, respectively on dry weight basis with no significant differences ($P \geq 0.05$) among the varieties (Table 1). According to Izydorczyk and Biliaderis (2007) and Izydorczyk (2009) TAX contents of rye and barley ranged from 7.6 to 12.1% and 3.4 to 6.1%, respectively on wet weight basis while TAX contents of wheat, rice, oats and sorghum were 5.77, 2.64, 2.73 and 1.8%, respectively on wet weight basis. In addition, they have reported that WEAX contents of rye and wheat ranged from 2.6 to 4.1% and 0.38 to 0.83%, respectively on wet weight basis while WEAX contents of barley, rice, oats and sorghum are 0.35, 0.06, 0.17 and 0.08%, respectively on wet weight basis. Asawaprecha (2004) stated that refined wheat flour contained 2 to 3% of TAX and 0.5 to 0.8% of WEAX. When compared with these results, TAX contents of Ravi, Rawana and Oshadha finger millet varieties were lower than TAX contents of rye, barley, wheat, rice and oats. Average TAX content of Ravi, Rawana and Oshadha varieties was approximately 5.2, 2.5, 3.1, 1.4 and 1.5 times lower than TAX contents of rye, barley, wheat, rice and oats, respectively.

3.3. β-Glucans

According to the present study, there were no significantly differences ($P \geq 0.05$) among the β-glucans contents of Ravi, Rawana and Oshadha varieties and β-glucans contents ranged between 0.12 and 0.17% on dry weight basis (Table 1). According to Brennan and Cleary (2005) and Guleria et al. (2015) β-glucans contents of wheat, oats, barley and rice ranged from 0.4 to 1.4%, 3 to 7%, 5 to 11% and 0.4 to 0.9%, respectively on wet weight basis. According to Vadnerkar (2004) β-glucans contents of Indian and Canadian wheat varieties ranged from 1.3 to 1.5% on dry weight basis. Therefore, when compared with these results, β-glucans contents of Ravi, Rawana and Oshadha varieties were lower than β-glucans contents of wheat, oats, barley and rice. Average β-glucans content of Ravi, Rawana and Oshadha varieties was approximately 10, 36 and 57 times lower than β-glucans contents of wheat, oats and barley, respectively.

3.4. Fructans

Fructans contents of Ravi, Rawana and Oshadha varieties ranged from 0.30 to 0.35% on dry weight basis with no significant differences ($P \geq 0.05$) among the varieties (Table 1). According to Vadnerkar (2004) fructans contents of Indian and Canadian wheat varieties ranged from 1.3 to 2.3% on dry weight basis. According to Verspreet et al. (2015) fructans contents of rye and wheat ranged from 3.6 to 6.6 and 0.7 to 2.9%, respectively on dry weight basis and fructans contents of barley and oats were 0.4 and 0.1%, respectively on dry weight basis. When compared with these results, fructans contents of Ravi, Rawana and Oshadha varieties were lower than fructans content of wheat. Average fructans content of Ravi, Rawana and Oshadha varieties was approximately 6 times lower than fructans content of wheat.

3.5. Starch fractions and amylose

RDS, SDS and RS contents of Ravi, Rawana and Oshadha finger millet varieties are given in Table 2. RDS contents ranged from 10.90 to 11.97% on dry weight basis with no significant differences ($P \geq 0.05$) among the varieties. SDS and RS contents varied between 43.38 and 49.15% and 3.75 and 4.58%, respectively on dry weight basis. No significant differences ($P \geq 0.05$) were observed in SDS contents of Rawana and Oshadha, which were significantly higher ($P < 0.05$) than SDS content of Ravi. RS content of Oshadha was significantly ($P < 0.05$) higher than that of Ravi and there were no significant differences ($P \geq 0.05$) in RS contents of Rawana and Oshadha. According to the present study, no significant differences ($P \geq 0.05$) were observed in amylose contents of the three finger millet varieties which varied from 11.99 to 13.99% on dry weight basis (Table 2). Amylose and amylopectin percentages of finger millet starch ranged from 16.67 to 18.90% and 81.10 to 83.33%, respectively with no significant differences ($P \geq 0.05$) among the varieties (Table 2).

Table 2
Starch fractions and amylose contents of Sri Lankan finger millet varieties.

Parameter	Finger millet variety		
	Ravi	Rawana	Oshadha
Rapidly digestible starch (RDS) %[1]	10.90 ± 0.18 [a]	11.97 ± 0.50 [a]	11.43 ± 0.19 [a]
Slowly digestible starch (SDS) %[2]	43.38 ± 0.68[b]	48.49 ± 0.35[a]	49.15 ± 0.17[a]
Resistant starch (RS) %[3]	3.75 ± 0.20[b]	4.19 ± 0.22[ab]	4.58 ± 0.04[a]
Amylose %[4]	11.99 ± 0.79[a]	12.68 ± 0.29[a]	13.99 ± 0.41[a]
Amylose % of starch[5]	16.67 ± 1.29[a]	17.17 ± 0.53[a]	18.90 ± 0.49[a]
Amylopectin % of starch	83.33 ± 1.29[a]	82.83 ± 0.53[a]	81.10 ± 0.4[a]

Results are presented as mean ± SE (n = 4). RDS, SDS, RS and amylose contents are presented on dry weight basis. Within a row, mean values superscripted with different letters are significantly different at $P < 0.05$ while mean values superscripted with the same letter are not significantly different at $P \geq 0.05$.
[1] LOQ: 0.05%.
[2] LOQ: 0.05%.
[3] LOQ: 0.1%.
[4] LOQ: 0.05%.
[5] LOQ: 0.1%.

According to Thippeswamy et al. (2016) RS content of an Indian finger millet variety was less than 0.15% on dry weight basis. According to Roopa and Premavalli (2008) RS content of Indian finger millet varieties ranged from 0.9 to 1.0% on wet weight basis. Therefore, RS contents of Ravi, Rawana and Oshadha varieties were approximately more than 3 times higher than the RS contents of aforementioned Indian finger millet varieties. According to Wankhede et al. (1979) amylose and amylopectin contents of Indian finger millet starches ranged from 15.8 to 16.2% and 83.8 to 84.2%, respectively. Singh and Raghuvanshi (2012) reported that about 80 to 85% of the finger millet starch was amylopectin and remaining 15 to 20% was amylose. Therefore, amylose and amylopectin contents of starches of Ravi, Rawana and Oshadha varieties were in good agreement with the findings of previous studies.

Bednar et al. (2001) have studied starch fractions of cereals and according to their findings RDS contents of sorghum, wheat, rice and barley were 63.5, 38.1, 57.7 and 37.7%, respectively on dry weight basis while SDS contents of sorghum, wheat, rice and barley were 24.6, 29.0, 27.6 and 30.6%, respectively on dry weight basis. In addition, they have reported that RS contents of sorghum, wheat, rice and barley were 1.6, 1.7, 1.6 and 1.2%, respectively on dry weight basis. When compared with these results, RDS contents of Ravi, Rawana and Oshadha varieties were lower than RDS contents of sorghum, wheat, rice and barley while SDS and RS contents were higher than those of sorghum, wheat, rice and barley. Average RDS content of Ravi, Rawana and Oshadha varieties was approximately 5, 3, 5 and 3 times lower than RDS contents of sorghum, wheat, rice and barley, respectively while average SDS content was approximately more than 1.5 times higher than SDS contents of sorghum, wheat, rice and barley. In addition, average RS content of Ravi, Rawana and Oshadha varieties was approximately more than 2.5 times higher than RS contents of sorghum, wheat, rice and barley. Pathiraje et al. (2010) have studied the amylose contents of Sri Lankan rice varieties and according to their findings amylose contents of improved and traditional rice varieties ranged from 21.5 to 29.0% and 27.7 to 29.5%, respectively on dry weight basis. As reported by Yadav et al. (2010) amylose percentages of wheat, rice and barley starches were 25.8, 20.7 and 23.8% respectively, on dry weight basis. Therefore, when compared to previously reported data average amylose content of Ravi, Rawana and Oshadha varieties was approximately 2 times lower than amylose contents of wheat and barley while more than 2 times lower than amylose contents of Sri Lankan rice varieties.

The results of the present study implied that the finger millet variety contained the highest amylose content, Oshadha, had the highest RS content as well as the highest SDS content. There was a strong positive correlation between amylose and RS contents of three finger millet varieties ($r = 0.865$, $p < 0.01$). In addition, a positive correlation ($r = 0.77604$, $p < 0.05$) between amylose and SDS contents was observed. Patindol et al. (2010) and Chung et al. (2011) also reported a positive correlation between amylose and RS contents of rice varieties. Besides, Chung et al. (2011) obtained a positive correlation between amylose and SDS contents of rice starches. Thus, results of the present study were comparable to those of rice varieties reported in previous studies. Amylose content is inversely proportional to the starch digestibility due to the positive correlations between amylose and RS contents as well as amylose and SDS contents.

3.6. Proximate composition and total sugars

Moisture, protein, crude fat, ash, total carbohydrate, crude fiber and total sugars contents of Ravi, Rawana and Oshadha varieties are given in Table 3. Protein and crude fat contents ranged from 8.13 to 8.74% and 1.40 to 1.41%, respectively on dry weight basis with no significant differences ($P \geq 0.05$) among the three varieties. Ash contents, which indicated the mineral contents, ranged from 2.95 to 3.22% on dry weight basis and ash content of Ravi was significantly ($P < 0.05$) higher than ash contents of Rawana and Oshadha. Total carbohydrate and crude fiber contents ranged from 86.92 to 87.24% and 3.73 to 3.82%, respectively on dry weight basis with no significant differences ($P \geq 0.05$) among the three varieties. Average total sugars content of the three finger millet varieties was 0.79% on dry weight basis.

Proximate composition of finger millet has been reported in several studies especially in African countries and India (Amadou et al., 2013; Saleh et al., 2013; Katake et al., 2016) and proximate composition of Ravi, Rawana and Oshadha varieties were comparable to the findings of previous studies. As reported by Saleh et al. (2013) protein, crude fat, ash and crude fiber contents of pearl millet were 13.4, 4.8, 2.2 and 2.3%, respectively while protein, crude fat, ash and crude fiber contents of sorghum were 11.8, 3.1, 1.6 and 2.0%, respectively on dry weight basis. In addition, they have reported that protein, crude fat, ash and crude fiber contents of red rice were 8.9, 2.7, 1.3 and 1.0%, respectively, protein, crude fat, ash and crude fiber contents of wheat were 13.18, 2.0, 1.6 and 2.0%, respectively and protein, crude fat, ash and crude fiber contents of corn were 10.45, 4.6, 1.2 and 2.8%, respectively on dry weight basis. When compared with these results, average protein content of Ravi, Rawana and Oshadha varieties was approximately 1.6, 1.4, 1.1, 1.6 and 1.2 times lower than protein contents of pearl millet, sorghum, red rice, wheat and corn, respectively while average crude fat content was approximately 3.4, 2.2, 1.9, 1.4 and 3.3 times lower than crude fat contents of pearl millet, sorghum, red rice, wheat and corn, respectively. However, average ash content of Ravi, Rawana and Oshadha varieties was approximately 1.4, 1.9, 2.3, 1.9 and 2.5 times higher than ash contents of pearl millet, sorghum, red rice, wheat and corn, respectively while average crude fiber content was approximately 1.6, 1.9, 3.8, 1.9 and 1.4 times higher than crude fiber contents of pearl millet, sorghum, red rice, wheat and corn, respectively.

Table 3
Proximate compositions of Sri Lankan finger millet varieties.

Parameter	Finger millet variety		
	Ravi	Rawana	Oshadha
Moisture %	13.16 ± 0.13^a	11.25 ± 0.38^b	10.60 ± 0.34^b
Protein %[1]	8.13 ± 0.05^a	8.74 ± 0.29^a	8.42 ± 0.13^a
Crude fat %	1.41 ± 0.03^a	1.40 ± 0.02^a	1.41 ± 0.02^a
Ash %	3.22 ± 0.03^a	2.95 ± 0.02^b	3.01 ± 0.02^b
Total carbohydrate %	87.24 ± 0.09^a	86.92 ± 0.32^a	87.17 ± 0.10^a
Crude fiber %	3.73 ± 0.07^a	3.79 ± 0.03^a	3.82 ± 0.04^a
Total sugars %[2]	0.79 ± 0.01^a	0.79 ± 0.04^a	0.79 ± 0.01^a

Results are presented as mean ± SE (n = 6). Except moisture contents, all other values are presented on dry weight basis. Within a row, mean values superscripted with different letters are significantly different at $P < 0.05$ while mean values superscripted with the same letter are not significantly different at $P \geq 0.05$.

[1] Nitrogen to protein conversion factor was 6.25.

[2] LOQ: 0.001%.

Table 4
Minerals and trace elements compositions of Sri Lankan finger millet varieties.

Mineral	Finger millet variety		
	Ravi	Rawana	Oshadha
Sodium[1]	10.23 ± 0.05^c	12.46 ± 0.09^b	13.44 ± 0.01^a
Magnesium[2]	139.58 ± 1.20^b	124.45 ± 1.03^c	161.3 ± 0.15^a
Potassium[3]	402.45 ± 3.56^a	407.23 ± 3.19^a	411.77 ± 2.51^a
Calcium[4]	337.53 ± 3.43^b	345.93 ± 2.42^{ab}	353.41 ± 0.59^a
Iron[5]	3.28 ± 0.02^b	3.86 ± 0.03^a	3.33 ± 0.00^{ab}
Zinc[6]	1.96 ± 0.01^a	1.80 ± 0.01^b	1.93 ± 0.00^a
Phosphorus[7]	337.04 ± 0.36^a	341.70 ± 2.12^a	314.46 ± 1.84^b

Results are presented as mean ± SE (n = 3) on dry weight basis as mg/100 g of flour. Within a row, mean values superscripted with different letters are significantly different at $P < 0.05$ while mean values superscripted with the same letter are not significantly different at $P \geq 0.05$.

[1] LOQ: 1 mg/100 g of flour.

[2] LOQ: 0.005 mg/100 g of flour.

[3] LOQ: 0.5 mg/100 g of flour.

[4] LOQ: 0.005 mg/100 g of flour.

[5] LOQ: 0.05 mg/100 g of flour.

[6] LOQ: 0.01 mg/100 g of flour.

[7] LOQ: 0.5 mg/100 g of flour.

3.7. Minerals and trace elements composition

There were significant differences ($P < 0.05$) among the tested minerals and trace elements contents of the three finger millet varieties except for potassium (Table 4). Sodium and magnesium contents of Oshadha were significantly higher ($P < 0.05$) than those of Ravi and Rawana. Calcium content of Oshadha was significantly higher ($P < 0.05$) than that of Ravi. Zinc contents of Ravi and Oshadha were significantly higher ($P < 0.05$) than zinc content of Rawana. Iron content of Rawana was significantly higher ($P < 0.05$) than iron contents of Ravi and Oshadha. Phosphorous contents of Ravi and Rawana were significantly higher ($P < 0.05$) than phosphorous content of Oshadha. Minerals and trace elements contents of Ravi, Rawana and Oshadha varieties were comparable to those of other finger millet varieties reported by Devi et al. (2011); Singh and Raghuvanshi (2012); Shobana et al. (2013); Nazni and Bhuwaneswari (2015); Chandra et al. (2016) and Kumar et al. (2016).

According to Kumar et al. (2016) sodium, magnesium, potassium, calcium, iron, zinc and phosphorous contents of pearl millet were 10.9, 137, 307, 42, 8, 3.1 and 296 mg/100 g, respectively on wet weight basis while sodium, magnesium, potassium, calcium, iron, zinc and phosphorous contents of sorghum were 2, 165, 363, 13, 3.36, 1.7 and 222 mg/100 g, respectively on wet weight basis. In addition, they have reported that sodium, magnesium, potassium, calcium, iron, zinc and phosphorous contents of red rice were 4, 143, 268, 33, 1.7, 2.02 and 264 mg/100 g, respectively, sodium, magnesium, potassium, calcium, iron, zinc and phosphorous contents of wheat were 17.1, 138, 284, 30, 3.5, 2.7 and 298 mg/100 g, respectively and sodium, magnesium, potassium, calcium, iron, zinc and phosphorous contents of corn were 35, 127, 287, 7, 2.7, 2.21 and 210 mg/100 g, respectively on wet weight basis. When compared with these results, potassium, calcium and phosphorous contents of Ravi, Rawana and Oshadha varieties were higher than those of pearl millet, sorghum, red rice, wheat and corn while iron contents were higher than those of red rice and corn. Average calcium content of Ravi, Rawana and Oshadha varieties was approximately 8, 27, 10, 115 and 49 times higher than calcium contents of pearl millet, sorghum, red rice, wheat and corn, respectively. In addition, average potassium, sodium and iron contents of Ravi, Rawana and Oshadha varieties were approximately two times higher than those of red rice and average phosphorous content was approximately two times higher than that of corn.

4. Conclusion

To the best of our knowledge, this is the first study to report arabinoxylans, β-glucans, fructans and nutritionally important starch fractions of Ravi, Rawana and Oshadha finger millet varieties. Findings of the present study indicate that Ravi, Rawana and Oshadha finger millet varieties are good sources of dietary fibers (including resistant starch) as well as minerals and trace elements (especially potassium, calcium, phosphorous and iron) while low in total sugar and crude fat contents when compared to commonly consumed cereals such as rice and wheat. The nutritional information obtained from the present study expands the current knowledge on the nutritional composition of the finger millet varieties commonly cultivated and consumed in Sri Lanka, fulfills the gaps in food composition data bases and acts as a useful guide in selecting foods for daily consumption.

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