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Original Research Article

Minerals Content in Finger Millet [*Eleusine coracana* (L.) Gaertn]: A Future Grain for Nutritional Security

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Keywords

Finger millet, phytic acid phosphorous, phytic acid and molar ratio

A B S T R A C T

Even though finger millet is nutritionally superior to other staple crops; presence of antinutrients makes the micronutrients to become less bioavailable to the body. Screening of mineral rich food grains with low anti-nutritional factors makes the possible strategy to enhance the nutrient bioavailability. Further, it could become one of the strategies to improve the nutritional security. Hence, the present study was undertaken to find the variation in minerals, phytic acid and molar ratios of phytic acid to minerals in the 20 finger millet (*Eleusine Coracana*) germplasm including RAU-8 variety. Mean values for minerals such as iron, zinc, calcium, magnesium, manganese and phosphorous showed 3.00±0.08, 2.79±0.05, 281.98±3.18, 166.35±2.66, 24.04±0.69 and 228.09±9.90 mg/100 g respectively and with the mean of 654.34 mg/100 g phytic acid. The molar ratio for phytic acid to iron and zinc was in the range of 14-30 and 18-32 respectively and statistically, significant correlation was observed between phytic acid to iron and zinc.

Introduction

Mineral deficiencies are most prevalent among human population which is not only due to insufficient availability offood but also due to the poor nutritional quality of food available for consumption. Poor nutritional quality is due to low nutrient content or due to the presence of anti-nutritional factors which makes the low nutrient bio availability. Phytic acid in cereals, millets, legumes, nuts and oil seeds acts as an anti-nutritional factor that forms complexes with minerals such as calcium, magnesium, zinc and iron reduces their bioavailability. Finger millet (*Eleusine coracana* L) is one of the minor cereals, which is nutritionally significant in terms of high calcium, phosphorous, iron and zinc. Ten per cent of the world's 30 million tonnes of millet produced is finger millet (Dida *et al.,* 2008). In India, finger millet occupies the largest area under cultivation among the small millets (Chandra *et al.,* 2016). Even though it is rich in neutraceutical property, presence of antinutritional factor makes the decreased availability of minerals. Phytic acid is one of the antinutrients, found relatively high amounts in plant foods, particularly in

cereals and legumes (Schlemmer *et al.*, 2009). Phytate in cereals, millets, legumes, nuts and oil seeds accounts about 60-90 per cent of total phosphorus content (Lott *et al.*, 2000). Although studies revealed that phytate may have beneficial roles as an antioxidant and anticarcinogen (Jeanb and Thompsonm, 2002), owing to its ability to chelate and precipitate minerals, phytate can decrease the bioavailability of nutritionally important nutrients such as zinc, iron, calcium (Weaver and Kannan, 2002) and magnesium (Pallauf *et al.*, 1998). Daily intake of phytic acid varies largely according to diet from 0.2–4.6 g globally and vegetarian diets generally contain higher amounts of phytic acid compared to mixed diets (Schlemmer *et al.*, 2009). One of the methods being used in the determination of the bioavailability of minerals in the human body is to measure the molar ratio of phyate to minerals in the food. Ma *et al.*, 2007 reported that phytate to minerals molar ratios are used to predict the inhibitory effect of phytate on the bioavailability of mineral.

Both iron and zinc absorption have been shown to be inhibited when the phytic acid: mineral ratio increases above 10:1 (Gharib *et al.*, 2006). Hence, the greater understanding of phytic acid to mineral molar ratio in finger millet would form a powerful basis for further improvement in increasing the bioavailability of minerals which further helps in achieving the nutritional security.

Materials and Methods

Procurement of sample and pretreatment for analysis

Finger millet germplasm along with national check variety RAU-8 were procured from All India Co-ordinated Research Project on Small Millets (AICRPSM), Gandhi Krishi Vignana Kendra, Bengaluru. Seeds were thoroughly cleaned to remove extraneous matter, deglumed and dried in oven at 45±5˚ C and were ground in a coffee bean grinder to obtain fine powder and passed through a 60 mesh sieve, further subjected for phytic acid and minerals estimation.

Minerals composition

Minerals such as iron, zinc, calcium, phosphorous and magnesium were estimated by inductively coupled plasma-optical emission spectrometry (ICP-OES). Ground powder of 0.5 g of each sample was weighed in clean acid washed 100 ml conical falsks and then 10 ml of nitric acid was added and kept overnight for cold digestion.

Next day 10 ml of Nitric acid and perchloric acid mixture was added (10:4) and kept on hot plate at 120^0C for digestion. The digested solution was diluted to 50 ml with double distilled water and filtered using membrane filters (0.1 - 5.0 µm pore). These extracts were used for the measurement of minerals using ICP-OES (Thermo scientific, USA). Results were expressed in dry weight (mg/100g).

Phytic acid content

Phytic acid phosphorous (PA-P) was estimated by Wade reagent method. Phytic acid was obtained by multiplying the phytic acid phosphorous with the conversion factor 3.55 (Gao *et al.*, 2007). Standard curve for phytic acid estimation was developed by using sodium salt of phyticacid with the concentration 1.12 to 11.2 µg/L. of phytic acid phosphorous and was considered based on the phosphorous (18.38 mg/100 g) content of standard sodium salt of phytic acid.

Molar ratio of phytic acid with minerals

The molar ratios between phytic acid and minerals were calculated by dividing the mole of phytate with mole of mineral content using the following formula.

$$\text{PA: Mineral} = \frac{\text{PA}/\text{MW(PA)}}{\text{Min}/\text{MW(Min)}}$$

Where, PA = Phytic acid analysed; $MW_{(PA)}$ = Phytic acid molecular weight (660.06 Da); Min= Mineral content (Zn/Fe/Ca/Mg/Mn/P); $MW_{(min)}$ = Mineral molecular weight (Fe = 55.845 Da; Zn = 65.38 Da; Ca=40.07 Da; Mg =24.31Da; Mn= 54.93Da and P=30.97Da)

Statistical analysis

The data was subjected to analysis of variance (ANOVA) for testing the significance of variation in germplasm for minerals and phytic acid traits using MSTAT. Mean values were calculated and compared at 5% level of significance. Hierarachial clustering was done using the IBM-SPSS.

Results and Discussion

The results indicated the significant variability among germplasm (Table 1) for mineral nutrient and anti-nutrient content. The iron and zinc content of the finger millet germplasm in present study ranged from 1.90-4.65 and 1.95-4.27 with the mean of 3.00 and 2.79 mg/100 g respectively. GE-1033 (1.95 mg/100 g) germplasm had the lowest zinc and highest was found in GE-778 (4.27 mg/100 g) followed by GE-91 (3.71 mg/100 g) (Table 1). Three of the finger millet germplasm *viz.,* GE 778, GE 902 and GE 91 had higher iron content of 4.65, 4.53 and 4.22 mg/100 g respectively. In contrast, GE-2940 (1.95 mg/100 g) had the lowest iron content. Previous studies carried out on a large number of finger millet varieties screened for iron (Fe) and zinc (Zn) contents reported similar ranges (Shashi *et al.,* 2007) suggesting the existence of larger genetic variation in finger millet germplasm. Solmon *et al.,* (2014) also found the wide variation for iron and zinc content in six finger millet genotypes with an average of 9.8 and 1.69 mg/100 g.

Singh and Raghuvanshi (2012) reported that the finger millet has the highest calcium content among all cereals (344 mg/100g). The calcium content in finger millet germplasm under study varied from 207.65 to 368.00 mg/100 g with the mean of 281.98 mg/100g (Table 1). The germplasm GE 5140 had the highest calcium content (368.00 mg/100 g) followed by GE 778 (323.49 mg/100 g) and lowest was found in GE 125 (207.65 mg/100 g). the results for calcium was on par with the result of wide variability for calcium content was also reported by Bachar *et al.,* 2013 in finger millet and was varied from 189.93 to 1272.36 mg/100g. Magnesium content of finger millet germplasm in the present study ranged from143.24-192.94 mg/100 g (Table 1) with little variation. The result obtained was in line with the findings reported by Bachar *et al.,* (2013) where the range reported to be 84.71 to 567.45 mg/100g.

Present findings for magnesium are slightly lower than that of result revealed by Prasanna *et al.,* (2015) for finger millet with the range of 0.28 to 0.31 per cent. Present findings of phosphorous results are in tune with the result of Singh and Srivastava (2006), ranging from 130 to 295 mg/100 g with a mean value of 180.43 mg/100 g (Table 1) and similar findings were also reported by Shashi *et al.,* (2007) which ranged from 234 to 292 mg/100 g in eight varieties of finger millets.

Table.1 Minerals and phytic acid composition of finger millet germplasm (n=20)

Germplasm	Fe (mg/100 g)	Zn (mg/100 g)	Ca (mg/100 g)	Mg (mg/100 g)	Mn (mg/100 g)	P (mg/100 g)	PA (mg/100 g)
GE 70	2.50^{h}	2.46^{gh}	306.38^{d}	188.83^{ab}	17.74^{h}	230.72^{d}	554.66^{h}
GE 91	4.22^{b}	3.71^{b}	277.04^{f}	169.69^{c}	32.35^{e}	305.48^{a}	847.22^{a}
GE 106	2.16^{ij}	2.57^{g}	271.92^{f}	163.74^{cd}	12.12^{i}	189.20^{f}	560.99^{h}
GE 125	2.59^{h}	2.54^{g}	207.65^{i}	149.98^{ef}	38.13^{c}	254.63^{c}	680.10^{de}
GE 595	2.18^{ij}	2.77^{f}	271.99^{f}	157.56^{de}	23.39^{f}	215.43^{e}	604.84^{g}
GE 608	2.97^{efg}	2.92^{de}	318.11^{c}	156.28^{de}	35.14^{d}	213.84^{e}	570.27^{h}
GE 778	4.65^{a}	4.27^{a}	323.49^{bc}	192.94^{a}	13.40^{i}	283.41^{b}	780.12^{b}
GE 902	4.53^{a}	3.58^{b}	228.85^{h}	157.51^{de}	16.94^{h}	298.74^{a}	752.80^{b}
GE 1033	3.20d^{e}	1.95^{k}	272.00^{f}	143.20^{f}	18.55^{h}	152.52^{g}	523.14^{i}
GE 1557	2.08^{jk}	2.72^{f}	250.12^{g}	157.09^{de}	12.45^{i}	184.92^{f}	580.50^{gh}
GE 2940	1.90^{k}	2.12^{j}	327.81^{b}	169.17^{c}	45.65^{b}	211.19^{e}	673.07^{def}
GE 3353	3.62^{c}	2.97^{d}	287.67^{e}	163.21^{cd}	23.39^{f}	260.50^{c}	686.38^{d}
GE 3628	3.30^{d}	3.11^{c}	275.27^{f}	183.37^{b}	21.11^{g}	278.13^{b}	751.67^{c}
GE 5146	2.96^{efg}	2.76^{f}	304.00^{d}	180.79^{b}	23.62^{f}	237.00^{d}	655.35^{ef}
GE 6370	3.39^{cd}	2.78^{f}	226.00^{h}	143.43^{f}	21.05^{g}	215.42^{e}	648.92^{f}
GE 3219	2.39^{hi}	2.50^{g}	288.33^{e}	157.33^{de}	51.00^{a}	231.33^{d}	665.63^{def}
GE 1640	3.19^{def}	2.82^{ef}	270.67^{f}	183.37^{b}	21.11^{g}	153.33^{g}	559.81^{h}
GE 4983	2.94^{fg}	2.35^{hi}	266.67^{f}	183.37^{b}	23.62^{f}	218.33^{e}	677.73^{de}
GE 5140	2.40^{hi}	2.55^{g}	368.00^{a}	170.89^{c}	18.20^{h}	240.34^{d}	732.33^{c}
RAU 8	2.90^{g}	2.30^{i}	297.67^{d}	155.22^{de}	11.82^{i}	187.33^{f}	581.25^{gh}
Mean	3.00	2.79	281.98	166.35	24.04	228.09	654.34
C.D.(0.05)	0.24	0.14	9.64	8.08	2.08	9.90	26.55
SEm±	0.08	0.05	3.18	2.66	0.69	3.27	8.76
CV%	4.65	2.95	1.95	2.67	4.95	2.48	2.32

Note: PA-Phytic acid

Table.2 Molar ratio of phytic acid with minerals in finger millet germplasm (n=20)

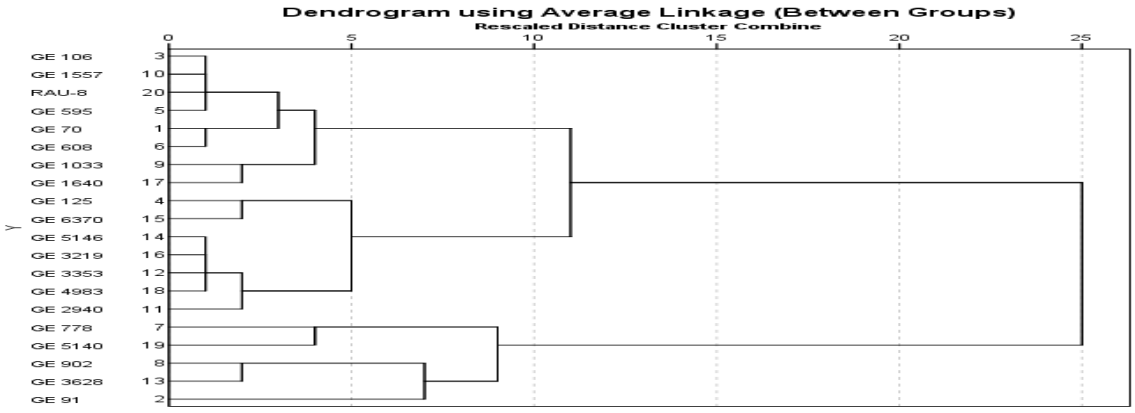
	PA:Fe	PA:Zn	PA: Ca	PA:Mg	PA:Mn	PA:P
Average	19.31	23.69	0.14	0.15	2.65	0.14
Range	14-30	18-32	0.11-0.20	0.11-0.18	1.09-4.85	0.12-0.17
Correlation coefficient ('r' value)	0.575**	0.674**	0.060^{NS}	0.294^{NS}	0.189^{NS}	0.889**

**. Correlation is significant at the 0.01 level (2-tailed).

Table.3 Molar ratio of phytic acid with iron and zinc

Germplasm	PA:Fe	PA:Zn
GE 70	18.75	22.38
GE 91	16.99	22.65
GE 106	21.98	21.63
GE 125	22.18	26.55
GE 595	23.51	21.61
GE 608	16.27	19.32
GE 778	14.20	18.11
GE 902	14.06	20.81
GE 1033	13.82	26.52
GE 1557	23.65	21.15
GE 1640	14.84	19.68
GE 2940	29.90	31.52
GE 3219	23.59	26.32
GE 3628	19.24	23.95
GE 3353	16.04	22.90
GE 4983	19.52	28.62
GE 5140	25.78	28.48
GE 5146	18.75	23.53
GE 6370	16.20	23.13
RAU-8 (NC)	17.23	25.43
Mean	**19.31**	**23.69**
Range	**14-30**	**18-32**

Fig.1 Hierarchical clustering of the 20 finger millet germplasm based on nutrient and anti-nutrient content



In the present study the phosphorous content was significantly associated with phytic acid (r =0.889) content. This result is in close are slightly lower than that of result revealed by Prasanna *et al.,* (2015) for finger millet with the range of 0.28 to 0.31 per cent. Present findings of phosphorous results are in tune with the result of Singh and Srivastava

(2006), ranging from 130 to 295 mg/100 g with a mean value of 180.43 mg/100 g (Table 1) and similar findings were also reported by Shashi *et al.,* (2007) which ranged from 234 to 292 mg/100 g in eight varieties of finger millets. In the present study the phosphorous content was significantly associated with phytic acid (r = 0.889) content. This result is in close agreement with those results obtained by Govindaraj *et al.,* (2009) in 61 genotypes of pearl Millet (r = 0.8366). Significant correlation was also reported by Arulselvi *et al.,* (2007) in pearl millet hybrids (r = 0.908**). Lott *et al.,* (2000) also reported that phytic acid accumulates during seed development until the seeds reach maturity and that accounts for 60-90 per cent of total phosphorus content in cereals, legumes, nuts and oil seeds. The phytic acid content of finger millet germplasm was ranged from 523.14-847.22 mg per 100g with an average of 654.34 mg/100 g and it was found that there is a large variation in phytic acid content. Lowest phytic acid was recorded in GE-1033 and highest phytic acid in GE-91 (Table 1). Such genetic variation for phytic acid phosphorus in finger millet genotypes were also reported by Katake *et al.,* (2016) which ranged from 0.22 to 0.35 per cent. Such varietal difference was also studied by Lorenz *et al.,* (1983) in 24 proso millet (0.17 to 0.47%) varieties. The results of phytic acid are on par with the reported values of Gunashree *et al.,* (2014) (685 mg/100 g) in finger millet but slightly lower than that reported by Makhoka *et al.,* (2001) in which phytic acid content of finger millet ranged from 852-1419 mg/100 g.

Molar ratio between phytic acid to calcium, magnesium and phosphorous were comparatively lower (Table 2). The hierarchial clustering of the finger millet germplasm showed the formation of three clusters of unique types (Fig 1) which helps in identification of optimized line with higher mineral content with lower phytic acid. There was a significantly higher molar ratio was observed between phytic acid to iron and zinc. The obtained results of phytic acid to zinc molar ratio in finger millet was in accordance with the reported result of Hemalatha *et al.,* (2007) with the ratio of 23.90. Present findings showed the molar ratio 14 to 30 with the mean of 19.31 for iron and for zinc it is ranged from 18 to 32 with an average of 23.69 (Table 2 and Table 3). Results reported by Queiroz *et al.,* (2010) also showed the higher variability for Phy/Zn and Phy/Fe molar ratios ranged from 18.0 to 43.5 and from 16.3 to 45.5 respectively.

Obtained results for molar ratio of phytic acid to iron and zinc are indicating the low absorption of iron and zinc where Gharib *et al.,* (2006) reported that iron and zinc absorption have been shown to be inhibited when the phytic acid to mineral ratio increases above 10:1. About 35 per cent of zinc content of foods is expected to be absorbed if PA/Zn ratio of foods is 5-15 (WHO, 1996). Inspite of having higher phytate content in GE 778, GE 902 and GE 1033 showed comparatively lower molar ratio with iron and zinc.

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