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Content and HCl-extractability of minerals as affected by acid treatment of pearl millet

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Abstract

Pearl millet seeds were subjected to acid treatment by soaking the grains in 0.2 N HCl for 6, 12, 18 and 24 h. In order to remove acid residues, the acid-soaked grains were washed thoroughly under running tap water, followed by blanching at 98 °C for 30 s, and then dried in the sun for 2 days. Efficacy of acid treatment of pearl millet on its mineral contents and HCl-extractability was studied. Mineral contents, especially phosphorus, calcium, and iron, were reduced with the increase in period of soaking of pearl millet in acid, but HCl-extractability improved to varying extents. Acid treatment was thus found to be an effective technique for improving the availability of minerals in pearl millet.

Keywords: Acid treatment; Pearl millet; Mineral content; HCl-extractability

1. Introduction

Pearl millet (*Pennisetum glaucum*) is a multipurpose crop which is grown for food, feed and forage. As a coarse grain cereal for human food, pearl millet sustains the lives of many millions of people, particularly these of low income groups in several African and south Asian countries (Kumar & Chauhan, 1993). Pearl millet is a nutritious, healthful and versatile food grain that would be a worthy addition to the diet. It provides cheap staple food with many nutrients. The mineral profile of pearl millet is better than that of cereals (Casey & Lorenz, 1977) and bioavailability of minerals is represented by HCl-extractability of minerals. However, antinutrients, namely phytic acid and polyphenols present in pearl millet, form insoluble complexes with dietary minerals, such as calcium, zinc, iron and magnesium, and make them biologically unavailable to the human organism.

Besides limiting nutrient availability, phenolic pigments also impart a grey colour as well as a bitter taste to pearl millet flour. Presence of pigments in pearl millet is, therefore, a serious problem which makes its products unacceptable for consumption. Due to the presence of certain pigments in the pericarp and endosperm layers of the seed, its coarseness, and the absence of gluten characteristics in its proteins, pearl millet has remained a food for low socio-economic groups. The widespread diversification of pearl millet depends on removal of its pigments in order to enhance its acceptability. Acid-soaking of pearl millet has been reported to be an effective technique for bleaching of pearl millet grains (Naikare, Chavan, & Kadam, 1986). A study was therefore conducted to investigate the efficacy of acid treatment on nutrient composition and shelf life of pearl millet. The present paper is concerned with the effect of acid-soaking of pearl millet on its total mineral content and HCl-extractability.

2. Materials and methods

2.1. Material

Pearl millet seeds, of cultivar HHB-67, were procured from the Department of Plant Breeding, CCSHAU, Hisar. The seeds were cleaned manually from damaged grains and other extraneous materials.

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2.2. Processing

The pearl millet seeds were subjected to acid–soaking in 0.2 N HCl (Seed:HCl ratio 1:2) for 6, 12, 18 and 24 h in glass containers, washed 5–6 times under running tap water, followed by blanching at 98 °C for 30 s in order to remove acid traces and then sun-dried for 2 days. Raw pearl millet was used as a control. All the processed, as well as unprocessed (control), grains were milled to flour in an electric grinder and stored in airtight plastic containers. Phosphorus, calcium, iron, zinc, copper, manganese and zinc content, were determined, as well as their extractabilities.

2.3. Chemical analysis

Total minerals were analysed by extracting the samples in diacid mixture (HNO_3:$HClO_4$ 5:1 v/v) and then dissolving in double-distilled water and filtering through Whatman No. 42 paper. The filtrate was made up to 50 ml with double-distilled water and used for determination of total phosphorus, calcium, iron, zinc, copper and manganese. Phosphorus was determined colorimetrically by employing the method of Chen, Tusibara, and Warner (1956). Calcium, iron, zinc, copper and manganese in the acid-digested samples were determined by atomic absorption spectrophotometry, using a 2380, Perkin-Elmer (USA) atomic absorption spectrophotometer.

HCl-extractabilities of minerals were determined by using the method of Peterson, Skinner, and Strong (1943). Samples were extracted in 0.03 N HCl by incubating the samples in a shaker-cum-water bath for 3 h at 37 °C, to simulate conditions that occur in the human stomach, and then filtered through ashless filter paper (Whatman No. 42). The filtrate was oven-dried, digested in diacid, i.e. nitric and perchloric acid (HNO_3:$HClO_4$ 5:1 v/v) and used for the determination of individual minerals by atomic absorption spectrophotometry.

2.4. Statistical analysis

The data thus obtained were subjected to statistical analysis of variance in a complete randomized design using the standard method (Panse & Sukhatme, 1961).

3. Results and discussion

3.1. Total minerals

Phosphorus content of unprocessed pearl millet was 348±0.85 mg/100 g which decreased to 308±1.16, 281±0.83 and 264±0.63 mg/100 g after 6, 12, and 18 h of acid-soaking. It further decreased to 246±1.32 mg/100 g after 24 h of soaking in acid (Table 1). Therefore, the results indicated that acid treatment significantly reduced the phosphorus content of pearl millet with advancement of the acid-soaking period. The loss of phosphorus during the treatment may be attributed to the leaching out of phosphorus in the discarded water. The results are in close consistence with the results of Pawar and Parlikar (1989) and Archana, Sehgal, and Kawatra (1998) who also reported a significant decline in the total phosphorus content on acid soaking and blanching of pearl millet.

The calcium content of control pearl millet was 39.6±0.83 mg/100 g. Acid treatment presented a range of calcium content varying from 31.0±0.55 mg/100 g in samples acid soaked for 24 h to 35.8±0.37 mg/100 g in sample acid soaked for 6 h (Table 1). A significant ($P<0.05$) decline was observed in the calcium content of pearl millet with increase in time of acid-treatment. The reason for reduction in the calcium content of pearl millet during acid-soaking may again be due to leaching out of calcium in the soaking medium. Similarly, Aggarwal (1992) reported reduction in calcium content of pearl millet on acid steeping of grains. Archana et al. (1998) also observed a reduction of 3% in the calcium content after blanching of pearl millet.

The iron contents of samples given acid treatment for 6, 12, 18 and 24 h were 7.05±0.03, 6.86±0.06, 6.70±0.06 and 6.63±0.02 mg/100 g, respectively. From the initial (control) value of iron content which was 8.16±0.14 mg/100 g, it significantly ($P<0.05$) declined during acid-treatment (Table 1). This may be due to loss of iron in the soaking medium. The results are in good agreement with those of Aggarwal (1992) who observed reduction in iron content of acid soaked pearl millet as compared to raw pearl millet.

Table 1
Effect of acid-treatment on total mineral content of pearl millet (mg/100 g, on dry matter basis)

Acid treatment	Phosphorus	Calcium	Iron	Zinc	Copper	Manganese
Control	348.40±0.85	39.60±0.83	8.16±0.14	2.85±0.02	0.99±0.02	1.20±0.03
6 h	307.90±1.16	35.76±0.37	7.05±0.03	2.72±0.02	0.96±0.01	1.10±0.02
12 h	281.40±0.83	33.80±1.44	6.86±0.06	2.69±0.04	0.95±0.01	1.05±0.02
18 h	264.40±0.63	32.63±0.35	6.70±0.06	2.67±0.01	0.93±0.01	1.00±0.01
24 h	245.70±1.32	31.00±0.55	6.63±0.02	2.67±0.01	0.89±0.02	1.00±0.02
CD ($P<0.05$)	3.12	2.58	0.23	0.07	0.04	0.06

Values are mean SE of three independent determinations.

Data presented in Table 1 indicates that the zinc content of unprocessed sample was 2.85±0.02 mg/100 g and that of acid-treated samples ranged from 2.67±0.01 (24 h) to 2.72±0.02 mg/100 g (6 h). Zinc contents of all the acid-treated samples were significantly lower than the control value but showed non-significant differences among themselves.

Copper content of control pearl millet was 0.99±0.02 mg/100 g and its content in samples acid treated for 6, 12, 18 and 24 h were 0.96±0.01, 0.95±0.01, 0.93±0.01 and 0.89±0.02 mg/100 g, respectively (Table 1). Copper content of pearl millet soaked in acid for 24 h was significantly lower than that of the control. The observed decrease may be ascribed to leaching out of copper into the soaking medium during prolonged acid-soaking of pearl millet grains. Rekha (1997) reported that copper content remained unaltered after blanching of pearl millet.

The control value of manganese was 1.20±0.03 mg/100 g (Table 1). Manganese content of acid-soaked pearl millet ranged from 1.00±0.02 (24 h) to 1.10±0.02 mg/100 g (6 h). Acid-treatment produced significant ($P<0.05$) reduction in the manganese content of pearl millet. The reason may be leaching out of manganese during acid-soaking of pearl millet. Similarly, blanching was also reduced the manganese content of pearl millet, as observed by Rekha (1997).

3.2. HCl-extractable minerals

HCl-extractability of phosphorus in control pearl millet was found to be 124±1.63 mg/100 g (Table 2). Extractable phosphorus contents of acid-soaked pearl millet samples were 135±0.32 (6 h), 149±0.41(12 h), 159±0.49 (18 h) and 162±0.66 mg/100 g (24 h). This clearly indicates that a successive improvement in the phosphorus extractability of pearl millet occurred with the increase in acid-soaking period. Cleavage of phosphorus from phytic acid may explain higher HCl-extractability of phosphorus (Duhan, Khetarpaul, & Bishnoi, 2001).

As visible in Table 2, control value of HCl-extractable calcium was 15.9±0.06 mg/100 g. As the divalent cations, such as Ca and Fe, are generally present in association with phytic acid, this may be responsible for their lower extractabilities (Duhan et al., 2001). Acid-treatment contributed significantly ($P<0.05$) to the increase in calcium extractability and it increased to 17.6±0.06 after 6 h of acid-soaking of pearl millet grains. Improvement in calcium extractability, as a result of blanching, was also noticed by Archana et al. (1998).

As a result of acid-treatment, HCl-extractability of iron increased significantly ($P<0.05$) from the control value of 2.13±0.09 mg/100 g to 2.28±0.02 mg/100 g in 6 h, 2.52±0.04 mg/100 g in 12 h, 2.61±0.01 mg/100 g in 18 h and 2.66±0.03 mg/100 g in 24 h of acid-soaking of pearl millet grains.

HCl-extractability of zinc in raw (control) pearl millet was 0.84 0.02 mg/100 g (Table 2). Acid-treatment did not have any pronounced effect on the zinc extractability of samples soaked in acid for 6, 12, 18 and 24 h and it ranged from 0.85±0.01 (6 h) to 0.88±0.02 mg/100 g (24 h).

HCl-extractable copper content of unprocessed pearl millet (control) was 0.50±0.06 mg/100 g and, in the case of acid treatment, it ranged from 0.50±0.02 in a pearl millet sample acid-soaked for 6 h to 0.52±0.03 mg/100 g in a sample acid-treated for 12 h (Table 2). HCl-extractability of copper remained unaffected as a result of acid treatment of pearl millet grains.

HCl-extractability of manganese in control pearl millet was 0.35±0.04 mg/100 g. Acid treatment presented a range of manganese extractability varying from 0.35±0.02 to 0.36±0.05 mg/100 g (Table 2). Non-significant variation in the extractability of manganese was observed as compared to the control value.

4. Conclusion

Although acid-treatment brought about a decline in total mineral content of pearl millet, but the HCl-extractability of phosphorus, calcium and iron increased significantly as the period of acid-soaking prolonged. The losses in mineral contents of pearl millet may be ascribed to leaching out of these minerals into the soaking medium. Dietary essential minerals, such as

Table 2
Effect of acid-treatment on HCl-extractable mineral content of pearl millet (mg/100 g, on dry matter basis)

Acid treatment	Phosphorus	Calcium	Iron	Zinc	Copper	Manganese
Control	123.67±1.63	15.90±0.06	2.13±0.09	0.84±0.02	0.50±0.06	0.35±0.04
6 h	135.26±0.32	17.60±0.06	2.28±0.02	0.85±0.01	0.50±0.02	0.35±0.02
12 h	149.23±0.41	19.63±0.09	2.52±0.04	0.87±0.03	0.51±0.02	0.36±0.00
18 h	159.33±0.49	20.87±0.24	2.61±0.01	0.88±0.02	0.52±0.01	0.36±0.05
24 h	162.03±0.66	21.53±0.50	2.66±0.03	0.88±0.02	0.52±0.03	0.36±0.01
CD ($P<0.05$)	2.67	0.80	0.13	NS	NS	NS

Values are mean±SE of three independent determinations. NS, non-significant.

phosphorus, calcium and iron, are present in association with antinutrients and this may be the reason for their lower HCl-extractabilities. Improvement in HCl-extractability, which is an index of the bioavailability of minerals, may be explained by the acid-treatment possibly releasing these minerals in free form, thereby increasing their HCl-extractability. Thus, acid-treatment can be considered as a beneficial technique for improving the bioavailability of minerals.

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