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Influence of Traditional Processing on Minerals HCl–Extractability of Pearl Millet (*Pennisetum glaucum*)

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Abstract: Two cultivars of pearl millet, Ugandi and Dembi yellow, were subjected to three traditional processing methods: fermentation, sprouting and *damirga* preparation. The HCl-extractability of minerals from the two cultivars ranged from 16.70 to55.20%. Fermentation, *damirga* preparation and sprouting significantly ($P \leq 0.05$) improved the HCl-extractability to 32.5–92.5, 48.9-96.4 and 44.6-89%, respectively.

Key words: Pearl millet, minerals HCl-extractability, traditional processing, fermentation, sprouting and *damirga* flour.

INTRODUCTION

Pearl Millet (*Pennisetum glaucum*) is one of the most important drought–tolerant crops of the tropical and subtropical regions of the world; it grows in harsh environment where other crops do not grow well[11]. As a cereal for human food, pearl millet sustains the lives of poorest people in Africa and Asia, and often considered highly palatable and good sources of protein and energy. Also, pearl millet is a good source of minerals, however owing to the presence of certain anti-nutritional factors including phytic acid and polyphenols, the availability of the minerals from pearl millet may be low. Traditional processing of pearl millet (natural fermentation as well as sprouting) was reported to improve the HCl-extractability of minerals along with reduction in the level of phytic acid[12, 15]
The objective of the present investigation was to examine the influence of fermentation as well as *damirga* preparation and sprouting on minerals HCl-extractability of pearl millet.

MATERIALS AND METHODS

Two pearl millet cultivars, Ugandi and Dembi yellow, were procured from Elobied Agricultural Research Station, Sudan. The seeds of each cultivar were cleaned from damaged grains, foreign materials and broken seeds then processed to three products, fermented dough, *damirga* flour and sprouted pearl millet flour.

2.1 Dough Preparation: Fermented dough was prepared according to the method used in Sudanese homes[7] as described by El Tinay *et al*. (1979). Whole millet flour was mixed with water (1:2 ratio) in a plastic laboratory beaker, a starter from previously fermented dough (Khumar) was then added to the mixture of flour and water (The starter of each dough was of the same cultivar of millet and was about 10% of the dough volume). The mixture was then incubated for 14 hours at 37 °C; the fermented samples were then dried in an air oven at 70 °C.

2.2 *Damirga* Preparation: *Damirga* flour was prepared traditionally as described by Abdalla *et al*.[1]. The grains were first moistened with water (approximately 20% of their weight) and then hand-pounded by wooden mortar and pestle until the required degree of dehulling was reached (about 30 min). The grains were then winnowed in the winnowing basket to remove the hulls. The bran–free kernels were soaked in water (1:2 ratio) and fermented for 72 h at ambient temperature (30±2°C). Water was then decanted and the fermented dehulled grains were sun dried and finely ground (1 mm mesh) in Grain Mills type 120 No. 69444, RPM 2800.

2.3 Sprouted Pearl Millet Flour: The sprouting of pearl millet was carried out according to the method of Bhise *et al*.[3] with some modifications. Pearl millet grains were steeped in distilled water for 24 h. The water was then decanted and seeds incubated in

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wooden trays covered with gane at ambient temperature (30±2°C) and germinated for 3 days. Water was sprinkled on the grains every day to avoid drying. The germinated grains were then sun dried. The root portions were manually removed.

The grains were milled into fine flour, passing a 1mm mesh using Grain Mills type 120 NO.69444, RPM 2800.The samples were then kept in a polyethylene sacks in a refrigerator.

2.4 Minerals Determination: Total Minerals were determined by atomic absorption spectrophotometry[9] using SP 3110 Perkin Elmer spectrophotometer.

2.5 Hcl-extractability of Minerals: For determining HCl-extractable minerals, the samples were extracted with 0.03 N HCl (the acid found in human stomach) by shaking at 37 °C for 3 h. The clear extract obtained after filtration with Whatman No. 42 filter paper was oven–dried at 100 °C[15]. Dried extracts were ashed in muffle furnace for 3 h at 550 °C. Ash was then dissolved in HCl/HNO_3[2] by addition of 5 ml of 33% HNO3 together with 10 ml 50% HCl then boiling for 1 h, followed by addition of another 10 ml 50% HCl. The boiling was continued for additional 20 minutes. Solution was filtered through Whatman No. 42 and the volume was completed to 100 ml using distilled water. The solution was used for determination of minerals by atomic absorption spectrophotometry[9] using SP 3110 Perkin Elmer spectrophotometer.

The extractability was calculated as follow:

Extractability% = Minerals extractable in HCl / Total minerals.

2.6 Statistical Analysis: Data were subjected to analysis of variance (ANOVA)[18] using CRD with three replicates, treatments means were compared using Duncan's multiple – range test with probability $P \leq 0.05$[6].

RESULTS AND DISCUSSION

Tables 1 and 2 show minerals HCl-extractability of fermented sprouted and *damirga* flours for Ugandi and Dembi yellow pearl millet cultivars, respectively. The same tables also show the total mineral contents which were utilized for calculation of mineral extractability.

The HCl-extractability of sodium of the raw flour of Ugandi was 35.6 %, which increased significantly ($P \leq 0.05$) to 61.5% following fermentation for 14 h at room temperature. Sripriya *et al*.[19] stated that fermentation appears to be very effective in increasing bioavailability of minerals. The extractability was further improved to 83.1% by sprouting. The extent of improvement was 94.2% due to *damirga* preparation. Sodium extractability of Dembi yellow was significantly ($P \leq 0.05$) elevated from 39.1% to 63.4, 86.5 and 89.1% due to fermentation, *damirga* preparation and sprouting, respectively.

The potassium extractability of Ugandi cultivar was significantly ($P \leq 0.05$) enhanced from 27.8% to 44.1 and 50.9% due to traditional fermentation and sprouting, respectively, whereas, that of Dembi yellow was slightly increased from 43.00% to 45.80 and 46.1% due to the same treatments, respectively. Data showed no significant difference ($P \leq 0.05$) in K extractability between the fermented and malted products of Dembi yellow cultivar. However, previous study[15] mentioned that germination significantly increased the extractability of mineral of pearl millet. Maximum improvement in potassium extractability (76.10% for Ugandi and 67.80% for Dembi yellow) was obtained as a result of *damirga* preparation.

HCl-extractability of calcium of untreated pearl millet flours was found to be 18.40% and 16.70% for Ugandi and Dembi yellow cultivars, respectively. Results of the present investigation were lower than those of 35% - 32% earlier reported[12,15]. The extractability of Ca of Dembi yellow cultivar was almost doubled following fermentation, while that of Ugandi was elevated to 32.50%. According to Khetarpaul and Chauhan[14] pure sequential culture fermentation of pearl millet flour by *S. diastaticus* + *L. brevis* increased the extractability of Ca from 36 to 72%. Sprouting significantly ($P \leq 0.05$) improved Ca extractability from 18.40 to 53.40% for Ugandi and from 16.70 to 60.10%for Dembi yellow. Germination of finger millet for 24 h increased Ca extractability from 47.60 to 53.50%[19]. *Damirga* preparation appeared to be more effective in improving Ca extractability (to 59.50% and 65.80% for Ugandi and Dembi yellow, respectively) when compared with sprouting and fermentation.

Both fermentation and damirga preparation significantly ($P \leq 0.05$) raised the extractability of Magnesium of Ugandi cultivar to the same level from 46.10% to 84.60, 84.90, respectively. Extractability of 82.50% was brought about by germination for 72 h at room temperature. Concerning Dembi yellow a significant ($P \leq 0.05$) enhancement of magnesium extractability from 42.50 % to 89.40, 92.50 and 96.30% was noticed as a result of sprouting, fermentation and *Damirga* preparation, respectively. Fermentation has been reported to increase the extractability of minerals in corn and soybean[4].

Copper extractability was 45.40 for Ugandi and 49.90 for Dembi yellow, which were slightly higher than those given by Khetarpaul and Chauhan[14], who found that copper extractability of pearl millet flour was 35%. Sprouting and *damirga* preparation

Table 1: Effect of traditional processing on HCl-extractability of minerals from Ugandi pearl millet cultivar.

	Na	K	Ca	Mg	Cu	Fe	Mn	Zn	P
Total minerals (mg/100g)	208±(0.10)	3848±(1.78)	16.08±(0.01)	121.97±(1.48)	0.389±(0.09)	18.657±(1.05)	2.098±(1.39)	7.290±(0.36)	1110.0±(10.60)
Extractability (%)									
Untreated	(35.6)^{d}±0.00	(27.8)^{d}±0.78	(18.4)^{d}±1.68	(46.1)^{c}±1.50	(45.4)^{c}±1.84	(50.6)^{d}±0.31	(44.9)^{d}±1.47	(21.9)^{d}±0.72	(30.6)^{d}±1.05
Dough	(61.5)^{c} ±2.88	(41.1)^{c}±0.60	)32.9(^{c}±0.00	(84.6)^{a}±0.83	(64.4)^{b}±0.2	(56.7)^{b}±0.22	(58.6)^{b}±0.98	(68.9)^{b}±0.34	(50.5)^{b}±1.12
Damirga	(94.2)^{a}±0.00	(76.1)^{a}±1.23	(59.5)^{a}±3.30	(84.9)^{a}±0.89	(66.9)^{a}±0.32	(58.6)^{a}±1.11	(48.9)^{c}±1.02	(58.2)^{c}±2.13	(60.5)^{a}±1.06
Sprouted	(83.1)^{b}±0.00	(50.9)^{b}±1.50	(53.4)^{b}±3.30	(82.5)^{b}±0.17	(65.7)^{a}±1.93	(55.6)^{c}±0.96	(60.2)^{a}±0.73	(73.3)^{a}±1.17	(45.8)^{c}±1.03

Each value is an average of three experimental samples expressed on dry matter basis.
Values are means ± standard deviation.
Means not sharing a common superscript letter in a column are significantly different at P≤ 0.05 as assessed by DMRT.

Table 2: Effect of traditional processing on HCl-extractability of minerals from Dembi pearl millet cultivar.

	Na	K	Ca	Mg	Cu	Fe	Mn	Zn	P
Total minerals (mg/100g)	193±(0.10)	3164±(0.01)	16.09±(0.06)	104.38±(0.59)	0.320±(0.08)	17.88±(0.32)	2.148±(0.64)	6.733±(0.03)	1110.2±(10.55)
Extractability (%)									
Untreated	(39.1)^{d}±0.88	(43.0)^{c}±0.02	(16.7)^{d}±0.01	(42.5)^{d}±1.28	(49.9)^{c}±1.66	(55.2)^{d}±0.32	(47.0)^{d}±0.56	(25.8)^{d}±1.26	(33.7)^{d}±1.10
Dough	(63.4)^{c}±1.42	(45.8)^{b}±0.60(	(32.5)^{c}±0.05	(92.5)^{b}±1.97	(68.4)^{b}±1.50	(61.1)^{b}±0.33	(57.1)^{c}±0.85	(73.2)^{c}±0.83	(49.8)^{b}±1.05
Damirga	(86.5)^{b}±1.40	(67.8)^{a}±3.82	(65.8)^{a}±0.02	(96.3)^{a}±0.45	(77.7)^{a}±1.40	(70.4)^{a}±0.38	(57.9)^{b}±0.56	(81.2)^{a}±1.01	(62.7)^{a}±1.11
Sprouted	(89.1)^{a}±3.68	(46.1)^{b}±1.25	(60.1^{b})±3.71	(89.4)^{c}±2.07	(78.3)^{a}±1.36	(58.8)^{c}±0.20	(58.6)^{a}±0.85	(74.8)^{b}±0.96	(44.6)^{c}±1.06

Each value is an average of three experimental samples expressed on dry matter basis.
Values are means ± standard deviation.
Means not sharing a common superscript letter in a column are significantly different at P≤ 0.05 as assessed by DMRT

significantly (P≤0.05) improved copper extractability to 65.70% and 66.90%, respectively for Ugandi, and that for Dembi yellow to 78.30% and 77.70%, respectively. Results showed no significant difference in extractability of Cu between the malted and *damirga* products. Fermentation was relatively less effective in enhancing Cu extractability; values were 64.40% and 68.40% for Ugandi and Dembi yellow, respectively. Previously, copper extractability during 72 h natural fermentation at 20, 25 and 30 ºC was found to be more than doubled[14].

The iron extractability was 50.60% for Ugandi and 55.20% for Dembi yellow. These findings were higher than those formerly reported[17]. The Fe extractability of Ugandi cultivar was significantly (P≤0.05) rose to 55.60% and 56.70% as a result of sprouting and fermentation, respectively. The highest percent increase (58.60%) was achieved in *damirga* product. Dembi yellow cultivar followed the same trend; its Fe extractability significantly (P≤0.05) improved in the sequence of 58.80, 61.10 and 70.40% for sprouted, fermented and damirga products, respectively. Fairweather-Tait and Hurrel[8] stated that some traditional food processes such as fermentation, germination and soaking can activate native phytase in cereal grains, degrading phytic acid and therefore improving Fe absorption.

Manganese extractability of Ugandi was significantly (P≤0.05) elevated from 44.90% to 48.90% in the *damirga* flour. The extractability was further improved to 58.60% following fermentation; that of Dembi yellow was significantly (P≤0.05) increased from 47.00% to 57.10% following fermentation, further improved to 57.90% was obtained as a result of *damirga* preparation. A significant increase in Mn extractability was noticed during fermentation of pearl millet flour at 20, 25 and30 ºC[13]. Manganese extractability of pearl millet was reported to increase from 43% to 65 and 64% after 24 h fermentation at 30 and 40 ºC, respectively[17]. For the two cultivars investigated, the maximum improvement (60.20% for Ugandi and 58.60% for Dembi yellow) was brought about by sprouting. Malting for 24 h at 30ºC significantly increased the Mn extractability of finger millet from 19% to 31%[19].

Zinc extractability of Ugandi and Dembi yellow were 21.90% and 25.80%, respectively. These results were lower than the values of 42% - 46% earlier reported[14, 15]. For Ugandi cultivar, data showed that the extractability of Zn was highest (73.3%) in the malted product, followed by the fermented dough (68.90%), while the lowest extractability (58.20%) was attained in *damirga* flour. The extractability of Zn of Dembi yellow was significantly (P≤0.05) higher in *damirga* flour (81.20%), followed by the malted flour (74.80%) and then the fermented dough (73.20%). However, germination was well known in improving Zn extractability[15, 19]. During rabadi (Indian fermented food) fermentation for 9 h at 35ºC the extractability of Zn significantly (P≤0.05) was observed to increase from 46 to 72%[5].

Concerning phosphorus extractability, *damirga* preparation, fermentation and sprouting showed significant (P≤0.05) enhancement in P extractability of Ugandi cultivar from 30.60% to 60.50, 50.50, and 45.80%; and from 33.70% to 62.70, 49.80 and 44.60% for Dembi yellow, respectively. The three traditional treatments were found to vary in their capability in improving P extractability, with *damirga* preparation being the most effective followed by fermentation and then sprouting. Lactic acid fermentation of pearl millet for 24 h at 30 and 40ºC was reported to elevate

extractability of P from 40.40% to 72 and 71%, respectively[16]. Also, natural fermentation of autoclaved pearl millet for 72 h at 20, 24 and 30ºC resulted in a considerable increase in HCl–extractable P. Phosphorus extractability was more pronounced at incubation temperature of 30 followed by those at 20 and 25 ºC[13]. Relevant to sprouting, Kumar and Chauhan[15] stated that germination at 30ºC for 24 h seems to be more beneficial in improving P extractability in pearl millet. Sprouting of finger millet for 24 h at 30 ºC, similarly, increased phosphorus extractability from 17.80 to 20%[19]. The cleavage of P from phytic acid by phytase enzyme might explain the resultant higher extractability of phosphorus after sprouting and fermentation.

Conclusions: Improvement in extractability of minerals through *damirga* preparation is perhaps, due to the decrease in the level of phytic acid in *damirga* flour. Hydrolytic diminishing of phytic acid during germination may account for enhanced extractability of divalent cations in pearl millet sprouts. The higher extractability of minerals from the fermented dough could be partially ascribed to the reduced content of phytic acid by fermentation possibly through hydrolysis of the phytate –mineral complexes by phytase of pearl millet grain or elaborated by the fermenting microflora, which may release the divalent cations in free form and therefore account for their elevated extractability in the fermented product. In conclusion traditional processing proved to be a potential method for improving extractability of pearl millet minerals under simulated gastric conditions, an indicator of their bioavailability to human digestive system. Increased mineral extractability is particularly important from a nutritional viewpoint as consumption of such products may be helpful in preventing mineral deficiency diseases and lead to a better nutritional status of rural people in developing countries where pearl millet is widely grown and commonly consumed.

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