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Effect of Processing Followed by Fermentation on HCl Extractability of Ca, P, Fe and Zn of Pearl Millet (*Pennisetum glaucum* L.) Cultivars

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Abstract: Millet grains of cultivars Gazira and Gadarif were processed. The processed grains were fermented for 12 and 24 h. Total and extractable Ca, P, Fe and Zn of processed grains before and after fermentation were investigated. Compared to fine ground grains (control), the data showed that, the effect of processing treatments on minerals content was fluctuated for both cultivars. Fermentation of processed grains for 12 h increased minerals content, thereafter it started to decrease for both cultivars. HCl-extractability (an index of bioavailability) of Ca, P, Fe and Zn was investigated. HCl-extractable Ca, P, Fe and Zn of the processed grains of the cultivars were significantly ($p\leq 0.05$) improved. Fermentation of germinated grains of Gadarif cultivar for 24 h was found to increase Ca extractability to 99.30% compared to other minerals.

Key words: Processing, fermentation, minerals, pearl millet

INTRODUCTION

Pearl millet (*Pennisetum gluucum* L.) is one of the most important drought-tolerant crops of the tropical and subtropical regions of the world; it grows in harsh environments where other crops do not grow well. In Sudan pearl millet grown mainly in western and in some areas in southern regions, where it's considered as a major cereal crop for population. It's consumed as thick porridge (*aseeda*) or a thin porridge (*nasha*) or *kisra* (thin layers) from fermented or unfermented dough (Dirrar, 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 other cereals (Abdelrahman, 2004) and had better bioavailability of minerals, which is represented by HCl extractability. 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. The nutritive value of pearl millet was found less than expected in its nutritional profile. This due to the presence of several antinutrients, mainly phytic acid, polyphenols, alkaloids, lignin and related compounds (Sharma and Kapoor, 1997), these antinutrients had an effective role in reducing the nutritive value of millet grain due to their ability to bind macro nutrients and make them unavailable as well as adverse digestibility of starch and protein (Reed, 1992).

Several methods have been employed to improve the nutritional quality of pearl millet. Pearl millet grain is generally processed before consumption depending upon the cultural and taste preferences. In Sudan, the most common domestic methods of processing pearl millet including soaking for different period of time, dehulling of soaked seeds, germination and fermentation (Dirrar, 1993).

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Processing of millet have been reported to be beneficial for enhancing the nutritive value of the meals as it brings about changes in the level of antinutritional factors (Abdelrahaman *et al*., 2005), which affect the bioavailability of minerals. According to Abdelrahaman *et al*. (2005), extractable minerals in food are those, which are soluble in 0.03 N HCl and were significantly increased after germination and fermentation. Other processes such as sprouting and dehulling have been documented to be effective treatments to reduce the antinutritional factors and enhance nutritive value. The present study was conducted to determine the effect of processing methods followed by fermentation on total and extractable minerals of two pearl millet cultivars.

MATERIALS AND METHODS

Materials

Grain samples of two pearl millet cultivars (Gazira and Gadarif) were obtained from Khartoum North local market, Sudan. Seeds of the two cultivars were carefully cleaned, freed from foreign material as well as broken and shrunken ones. The seeds were divided into six parts and kept for processing. This study was conducted during the season 2005/2006. All chemicals used in this study were of reagent grade.

Processing Treatments

Grinding

The seeds were ground to fine and coarse particles to pass a 0.4 and 1.0 mm screen, respectively.

Soaking

The two cultivars seeds were soaked in water in a conical flask for 18 h. The soaking water was discarded and then the soaked grains were dispersed and dried at 60°C. The dried seeds were ground to pass a 0.4 mm screen.

Debranning

The seeds were soaked in water for 18 h and then hand pounded to separate the bran. The debranned grains were then dried at 60°C and ground to pass a 0.4 mm screen.

Autoclaving

The grain of the two cultivars were ground to pass a 0.4 mm screen and then Placed in a conical flask and autoclaved at 110°C for 15 min.

Germination

The whole grains of both cultivars were immersed in water overnight. The grains were spread on trays lined with cloth and kept wet by frequent spraying of water for 36 h. The germinated grains were sun dried and milled into fine flour to pass a 0.4 mm sieve.

Natural Fermentation

The processed cultivars seeds were ground to pass a 0.4 mm screen and then mixed with distilled water (1:3 w/v). The mixture was incubated at 37°C for 12 and 24 h and then the fermented mixture were dried at 60°C and ground to pass a 0.4 mm screen. The processed and fermented seeds were kept at 4°C for chemical analysis.

Methods

Total Minerals Determination

Minerals content of each sample was extracted according to Perarson method (1981). About 2.0 g of sample were placed in a muffle furnace at 550°C for 4 h. Samples were cooled and 10 mL of

5 N HCl were added, then boiled gently for 10 min using sand bath, diluted to 100 mL with distilled water. Calcium, phosphorous, iron and zinc content were determined by atomic absorption spectrophotometer (Perkin Elmer, 2380, USA).

HCl-Extractability of Minerals

HCl-extractability of minerals was estimated according to the method described by Chauhan and Mahjan (1988) and taken for minerals determination.

Statistical Analysis

Each determination was carried out on three samples and analyzed in triplicate and figures were then averaged. Data was assessed by the analysis of variance ANOVA (Snedecor and Cochran, 1987). Duncan's multiple rang test was used to separate means. Significance was accepted at $p\leq 0.05$.

RESULTS AND DISCUSSION

Effect of Processing Followed by Fermentation on Total and Extractable Calcium

Usually millet grains are ground to fine powder before processing therefore, finely ground grains are considered as controlled samples. Ca content of finely ground grains of Gazira and Gadarif cultivars was found to be 1.42 and 1.51 mg/100 g, respectively (Table 1). The results obtained were lower than those reported by Abdalla *et al.* (1998) but similar to those reported by Badau *et al.* (2005). Germination of the grains significantly ($p\leq 0.05$) increased Ca content of both Gazira (2.62 mg/100 g) and Gadarif (1.84 mg/100 g) cultivars. Soaking of pearl millet grains increased total Ca of the cultivars. Ca content of Gazira cultivar was decreased when the grains were coarse ground, but it was significantly ($p\leq 0.05$) increased after debranning. However, Ca content of Gadarif cultivar was not affected when the grains were coarse ground and debranned. Out of total Ca of finely ground grains about 54.47 and 56.31% were found to be extractable for Gazira and Gadarif cultivars, respectively. Results revealed that all processing treatments were significantly improved Ca extractability except coarse grinding. Soaking of the grains increased Ca extractability of Gazira to 87.16% and Gadarif to 64.51%. Germination, autoclaving and debranning also improved Ca extractability (Table 1). The results obtained agree with those reported by Sripriya *et al.* (1997) who observed an increase in Ca

Table 1: Effect of processing followed by fermentation on total (mg/100 g) and extractable (%) calcium of pearl millet cultivars

	Fermentation time (h)					
	0		12		24	
Treatments	Total	Available	Total	Available	Total	Available
Gazira cultivars						
Finely ground	1.42±0.02^{c}	54.47±0.00^{e}	1.62±0.01^{c}	60.79±0.02^{c}	1.67±0.01^{c}	77.11±0.00^{b}
Coarsely ground	1.32±0.007^{c}	45.27±0.01^{f}	1.62±0.01^{c}	42.33±0.10^{f}	1.81±0.01^{c}	70.96±0.50^{d}
Soaked	1.66±0.01^{b}	87.16±0.14^{a}	1.08±0.03^{e}	63.31±0.01^{b}	2.04±0.002^{b}	67.66±0.02^{e}
Dry heated	1.31±0.01^{c}	77.16±0.08^{c}	3.36±0.06^{a}	60.18±0.00^{d}	1.61±0.01^{cd}	66.95±0.05^{f}
Germinated	2.62±0.02^{a}	57.00±0.19^{d}	2.82±0.01^{b}	64.21±0.00^{a}	3.02±0.002^{a}	74.20±0.07^{c}
Debranned	1.62±0.03^{b}	79.13±0.15^{b}	1.43±0.001^{d}	54.28±0.20^{e}	1.57±0.02^{d}	80.09±0.11^{a}
Gadarif cultivars						
Finely ground	1.51±0.03^{c}	56.31±0.61^{e}	1.06±0.01^{c}	79.73±0.01^{c}	0.68±0.03^{d}	94.77±0.07^{b}
Coarsely ground	1.51±0.00^{c}	47.27±0.55^{f}	0.66±0.005^{e}	73.44±0.00^{d}	0.94±0.01^{c}	76.25±0.00^{e}
Soaked	4.43±0.02^{a}	64.51±0.23^{c}	2.26±0.00^{b}	65.44±0.03^{e}	1.16±0.00^{b}	84.05±0.05^{d}
Dry heated	0.80±0.005^{d}	69.13±0.00^{a}	0.83±0.003^{d}	95.78±0.00^{a}	1.14±0.02^{b}	60.06±0.00^{f}
Germinated	1.84±0.002^{b}	60.6±0.03^{d}	2.18±0.01^{bc}	58.83±0.03^{f}	3.40±0.00^{a}	99.30±0.08^{a}
Debranned	1.51±0.00^{c}	65.35±0.05^{b}	2.44±0.003^{a}	95.17±0.07^{b}	0.97±0.01^{c}	90.06±0.02^{c}

Values are means±SD. Means in a column not sharing a common superscript letter are significantly ($p\leq 0.05$) different as assessed by Duncan's multiple range test extractability of finger millet germinated for 24 h and those obtained by Abdelrahaman *et al.* (2005) for pearl millet cultivars. Fermentation of finely ground grains for 12 h increased both total Ca to 1.62 mg/100 g and its extractability to 60.79% for Gazira cultivar. Further increment in both total and extractable Ca was observed when the grains were fermented for 24 h. However, fermentation of Gadarif cultivar grains significantly decreased total Ca but increased its extractability with time (Table 1). Course grinding, soaking, autoclaving, germination and debranning followed by fermentation for 12 and 24 h were observed to affect total and extractable Ca of both cultivars. For all processing treatments with and without fermentation, the increment in Ca extractability for both cultivars may be attributed to the removal of antinutritional factors (Abdelrahaman *et al*., 2005). The results obtained agree with those reported by Badau *et al.* (2005) who found that germination of pearl millet increased Ca extractability. Khetarpaul and Chauhan (1990) reported that fermentation of pearl millet improved Ca extractability. The increment of Ca extractability after germination and/or fermentation was observed by Abdelrahaman *et al.* (2005).

Effect of Processing Followed by Fermentation on Total and Extractable Phosphorous

The results showed that P content of finely ground grains of Gazira cultivar was found to be 183.43 mg/100 g while that of Gadarif cultivar was 174.45 mg/100 g and out of this amount about 27.67 and 41.32% were found to be extractable for Gazira and Gadarif cultivars, respectively (Table 2). The results obtained were higher than those observed by Badau *et al.* (2005) and lower than those reported by Malleshi and Desikachar (1986). Germination of the seeds significantly increased P content of Gazira (189.41 mg/100 g) and Gadarif (189.74 mg/100 g) cultivars. This probably due to solubilization of phytate P during germination. Soaking, autoclaving and debranning treatments were significantly ($p \leq 0.05$) decreased P content and was found to be ranged from 123.61 to 176.4 mg/100 g. Coarse grinding slightly increased P content to 187.74 mg/100 g for Gazira cultivar and to 175.43 mg/100 g for Gadarif cultivar. The results obtained were higher than those reported by Badau *et al.* (2005) and lower than those reported by Khetarpaul and Chauhan (1989). The processing methods (germination, debranning and autoclaving) were significantly ($p \leq 0.05$) improved the extractable P and was found to be ranged from 30.13 to 83.25% for Gazira cultivar while that of Gadarif cultivar was ranged from 50.31 to 65.31%. However, coarse grinding of the grains significantly

Table 2: Effect of processing followed by fermentation on total (mg/100g) and extractable (%) Phosphorus of pearl millet cultivars

	Fermentation time (h)					
	0		12		24	
Treatments	Total	Available	Total	Available	Total	Available
Gazira cultivars						
Finely ground	183.43±0.00^{c}	27.67±0.99^{d}	205.36±0.00^{c}	65.31±0.00^{d}	159.50±0.00^{d}	76.14±0.00^{d}
Coarsely ground	187.74±0.58^{b}	25.10±0.00^{e}	199.38±0.00^{d}	85.45±0.00^{b}	158.50±0.99^{f}	72.05±1.14^{e}
Soaked	173.45±0.99^{e}	27.17±0.00^{d}	199.38±0.00^{d}	82.69±0.91^{c}	190.31±1.00^{b}	95.23±0.00^{a}
Dry heated	176.4±0.99^{d}	30.13±1.18^{c}	210.34±1.00^{a}	64.77±1.07^{d}	174.45±0.00^{c}	92.39±0.96^{b}
Germinated	189.41±0.00^{a}	83.25±0.00^{a}	208.47±1.02^{b}	95.65±0.87^{a}	198.38±0.00^{a}	85.88±0.00^{c}
Debranned	123.61±0.00^{f}	43.99±0.00^{b}	131.59±0.00^{e}	60.25±0.22^{e}	159.50±0.00^{d}	65.91±0.00^{f}
Gadarif cultivars						
Finely ground	174.45±0.00^{c}	41.32±0.00^{c}	199.97±0.52^{d}	74.32±0.00^{c}	134.58±0.00^{f}	94.27±0.00^{a}
Coarsely ground	175.43±0.99^{b}	37.40±0.00^{d}	204.44±0.99^{b}	78.90±0.00^{b}	196.38±0.99^{a}	62.76±0.00^{e}
Soaked	169.47±0.00^{e}	41.56±0.00^{c}	190.40±0.00^{e}	94.86±0.89^{a}	173.46±0.00^{d}	64.78±0.00^{d}
Dry heated	170.36±1.01^{d}	65.96±0.00^{a}	201.37±0.00^{c}	72.01±0.00^{e}	180.40±0.99^{c}	60.28±0.00^{f}
Germinated	189.74±0.57^{a}	50.31±0.10^{b}	209.01±0.57^{a}	65.91±0.00^{f}	186.08±0.14^{b}	79.10±0.62^{b}
Debranned	123.61±0.00^{f}	60.94±1.00^{b}	159.50±0.00^{f}	72.81±0.46^{d}	181.43±0.00^{c}	74.79±0.45^{c}

Values are (means±SD). Means in a column not sharing a common superscript letter are significantly ($p \leq 0.05$) different as assessed by Duncan's multiple range test

Table 3: Effect of processing followed by fermentation on total (mg/100 g) and extractable (%) Iron of pearl millet cultivars

	Fermentation time (h)					
	0		12		24	
Treatments	Total	Available	Total	Available	Total	Available
Gazira cultivars						
Finely ground	5.84 ± 0.00^b	22.16 ± 0.00^e	8.64 ± 0.00^e	54.72 ± 0.04^e	5.90 ± 0.05^d	60.33 ± 0.00^e
Coarsely ground	5.49 ± 0.05^c	10.02 ± 0.00^f	9.98 ± 0.07^b	16.02 ± 0.08^f	6.54 ± 0.02^c	30.41 ± 0.01^f
Soaked	4.11 ± 0.00^e	42.00 ± 0.11^b	9.20 ± 0.03^d	59.08 ± 0.00^c	5.47 ± 0.00^e	70.11 ± 0.11^d
Dry heated	5.99 ± 0.10^b	39.02 ± 0.02^c	9.47 ± 0.00^c	58.40 ± 0.00^d	6.96 ± 0.01^b	75.11 ± 0.50^c
Germinated	6.54 ± 0.00^a	54.12 ± 0.06^a	8.71 ± 0.04^e	84.50 ± 0.07^a	15.29 ± 0.00^a	85.13 ± 0.13^a
Debranned	5.15 ± 0.06^d	37.12 ± 0.12^d	11.00 ± 0.06^a	60.85 ± 0.04^b	5.78 ± 0.01^d	76.19 ± 0.10^b
Gadarif cultivars						
Finely ground	6.50 ± 0.4^b	25.92 ± 0.02^d	10.26 ± 0.06^a	48.08 ± 0.08^e	5.33 ± 0.03^c	56.00 ± 0.40^e
Coarsely ground	4.03 ± 0.08^d	11.16 ± 0.00^e	4.27 ± 0.02^f	14.04 ± 0.10^f	5.12 ± 0.00^c	39.11 ± 0.00^f
Soaked	4.78 ± 0.05^c	40.72 ± 0.12^b	6.12 ± 0.08^d	75.18 ± 0.18^a	5.22 ± 0.02^c	72.84 ± 0.04^b
Dry heated	6.68 ± 0.09^b	40.20 ± 0.01^c	7.90 ± 0.00^b	50.28 ± 0.07^d	5.35 ± 0.05^c	69.88 ± 0.08^d
Germinated	7.45 ± 0.00^a	40.33 ± 0.02^c	7.90 ± 0.03^b	63.50 ± 0.00^b	18.16 ± 0.06^a	83.95 ± 0.00^a
Debranned	4.10 ± 0.00^d	51.60 ± 0.09^a	7.67 ± 0.14^c	56.04 ± 0.00^c	7.06 ± 0.00^b	70.33 ± 0.00^c

Values are (means±SD). Means in a column not sharing a common superscript letter are significantly ($p\leq0.05$) different as assessed by Duncan's multiple range test

($p\leq0.05$) decreased P extractability. The results obtained in this study were agree with those obtained by Kumar and Chauhan (1993) who reported an increase in P extractability by 50% during sprouting of pearl millet for 24 h at 30°C. Reduction of phytic acid during germination and soaking releases complexes and divalent metal ions and increase P extractability. Fermentation of the processed seeds for 12 h significantly ($p\leq0.05$) increased P content for both cultivars but when the fermentation time increased (24 h) the effect varied between the cultivars and treatments (Table 2). Fermentation of processed millet grains for 12 and 24 h significantly ($p\leq0.05$) improved the extractable P. Fermentation of germinated seeds for 12 h significantly ($p\leq0.05$) increased P extractability and was found to be 85.88% for Gazira cultivar and 79.1% for Gadarif cultivar. Fermentation of soaked and autoclaved grains for 24 h also improved P extractability. The results obtained in this study agreed with those reported by Reddy and Salunkhe (1980) who observed an increase in P content during fermentation. Abdelrahman *et al.* (2005) investigated HCl-extractability in fermented pearl millet and found that fermentation significantly improved minerals extractability.

Effect of Processing Followed by Fermentation on Total and Extractable Iron

Table 3 shows the effect of processing followed by fermentation on total and extractable Fe of the grains of Gazira and Gadarif cultivars. Fe content of finely ground flour was found to be 5.84 and 6.5 mg/100 g for Gazira and Gadarif cultivars, respectively. The results obtained agree with those reported by Klopfenstein *et al.* (1983) but slightly lower than those reported by Abdalla *et al.* (1998). Soaking had significantly ($p\leq0.05$) decreased Fe content of Gazira (4.11 mg/100 g) and Gadarif (4.78 mg/100 g) cultivars. The reduction in Fe during soaking is likely due to leaching out of Fe into soaking water. Debranning of grains also was significantly ($p\leq0.05$) decreased Fe content. Fe content increased slightly during autoclaving. Germination of the grains increased Fe content and was found to be 6.54 and 7.45 mg/100 g for Gazira and Gadarif cultivars, respectively. Fe extractability of finely ground grains of Gazira cultivar was found to be 22.16% while that of Gadarif was found to be 25.92%. The results obtained is comparable to those reported by Badau *et al.* (2005) but slightly higher than those reported by Khetarpaul and Chauhan (1989). Germination significantly ($p\leq0.05$) increased Fe extractability and was found to be 54.12 and 40.33% for Gazira and Gadarif cultivars, respectively. In a similar study Sripriya *et al.* (1997) reported that germination significantly increased Fe extractability of finger millet. Coarse grinding significantly decreased Fe extractability but other

Table 4: Effect of processing followed by fermentation on total mg/100 g and extractable % Zinc of pearl millet cultivars

	Fermentation time (h)					
	0		12		24	
Treatments	Total	Available	Total	Available	Total	Available
Gazira cultivars						
Finely ground	2.92 ± 0.00^{b}	34.88 ± 0.00^{e}	3.38 ± 0.38^{e}	72.35 ± 1.10^{d}	3.07 ± 0.00^{f}	80.62 ± 0.00^{d}
Coarsely ground	3.11 ± 0.01^{a}	30.92 ± 0.00^{f}	5.21 ± 0.08^{a}	74.38 ± 0.10^{c}	3.33 ± 0.00^{cd}	65.44 ± 0.60^{f}
Soaked	2.80 ± 0.00^{c}	64.86 ± 1.05^{c}	3.66 ± 0.00^{c}	70.12 ± 0.00^{e}	3.41 ± 0.06^{c}	96.97 ± 0.00^{b}
Dry heated	2.86 ± 0.00^{bc}	70.88 ± 0.00^{b}	3.92 ± 0.00^{b}	61.94 ± 0.00^{f}	3.55 ± 0.00^{a}	73.53 ± 1.21^{e}
Germinated	3.09 ± 0.02^{a}	62.76 ± 0.00^{d}	3.43 ± 0.00^{d}	76.84 ± 0.00^{b}	3.50 ± 0.05^{ab}	94.78 ± 0.00^{c}
Debranned	2.10 ± 0.09^{d}	90.56 ± 0.13^{a}	2.16 ± 0.05^{f}	80.83 ± 1.43^{a}	3.24 ± 0.00^{e}	97.96 ± 0.98^{a}
Gadarif cultivars						
Finely ground	2.91 ± 0.08^{b}	33.04 ± 0.02^{e}	3.19 ± 0.00^{a}	71.94 ± 0.00^{d}	2.20 ± 0.03^{d}	98.91 ± 0.00^{a}
Coarsely ground	2.63 ± 0.14^{c}	28.24 ± 0.00^{f}	2.78 ± 0.20^{b}	86.50 ± 0.44^{a}	3.07 ± 0.01^{c}	80.61 ± 1.28^{b}
Soaked	$2.54\pm\pm0.00^{d}$	72.98 ± 0.05^{b}	2.71 ± 0.01^{b}	79.90 ± 0.00^{c}	3.07 ± 0.05^{c}	56.00 ± 0.28^{f}
Dry heated	2.70 ± 0.08^{c}	61.72 ± 0.02^{d}	2.05 ± 0.01^{d}	82.80 ± 1.30^{b}	3.20 ± 0.00^{b}	70.46 ± 0.44^{e}
Germinated	3.05 ± 0.00^{a}	65.60 ± 0.00^{c}	3.10 ± 0.00^{a}	71.02 ± 0.00^{e}	3.68 ± 0.00^{a}	72.76 ± 0.00^{d}
Debranned	2.57 ± 0.00^{d}	88.08 ± 1.80^{a}	2.29 ± 0.00^{c}	60.70 ± 1.00^{f}	2.05 ± 0.06^{e}	79.59 ± 0.78^{c}

Values are (means±SD). Means in a column not sharing a common superscript letter are significantly ($p\leq0.05$) different as assessed by Duncan's multiple range test

processing methods (debranning, autoclaving and soaking) significantly improved Fe extractability (Table 3). The results obtained in this study agree with those reported by Mamiro *et al.* (2001) who observed that germination, autoclaving, soaking and fermentation were significantly improved Fe extractability. Fermentation of finely ground grains for 12 h significantly ($p\leq0.05$) improved Fe extractability to 54.72 and 48.08% for Gazira and Gadarif cultivars, respectively. Fermentation of processed grains significantly increased both Fe content and extractability even the coarse ground grains. Fermentation of germinated grains flour for 24 h significantly ($p\leq0.05$) improved Fe extractability to 85.13 and 83.95 for Gazira and Gadarif cultivars, respectively. The results obtained agree with those reported by Abderahaman *et al.* (2005). Improvement of Fe extractability during processing and fermentation may be attributed to decreased level of antinutritional factors, which were observed to affect the availability of minerals.

Effect of Processing Followed by Fermentation on Total and Extractable Zinc

Total Zn of finely ground flour of Gazira and Gadarif cultivars was found to be 2.92 and 2.91 mg/100 g, respectively (Table 4). The results obtained agree with that reported by Badau *et al.* (2005) but lower than those reported by Oshodi *et al.* (1999). Abdelrahman *et al.* (2005) reported values of 1.8 and 1.26 mg/100 g for Zn of pearl millet cultivars. Changes in Zn content during processing were fluctuated and was found to be depend on processing method. Germination significantly ($p\leq0.05$) increased Zn content for Gazira (3.09 mg/100 g) and Gadarif (3.05 mg/100 g) cultivars as reported by Abdelrahaman *et al.* (2005). Soaking and debranning of the grains significantly ($p\leq0.05$) decreased Zn content. Out of total Zn of finely ground grains, the extractable amount obtained for Gazira and Gadarif cultivars was found to be 34.88 and 33.04%, respectively. The results obtained were lower than those reported by Badau *et al.* (2005) and Khetarpaul and Chauhan (1989). The extractability of Zn was significantly ($p\leq0.05$) enhanced during germination and was increased to 54.12% for Gazira cultivar and to 40.33% for Gadarif cultivar. The results obtained agree with those reported by Abderahman *et al.* (2005) and Kumar and Chauhan (1993). Soaking of the grains and autoclaving of the flour were significantly improved Zn extractability as reported by Mamiro *et al.* (2001). Fermentation of processed grains for 12 and 24 h significantly ($p\leq0.05$) increased both total and extractable Zn for Gazira cultivars while that of Gadarif were fluctuated. Fermentation of germinated grains for 12 h improved Zn extractability of Gazira and Gadarif cultivars and was found to be 76.84, 71.02%, respectively. Fermentation of soaked, debranned and autoclaved grains improved Zn extractability. Fermentation of debranned grains of Gazira and Gadarif cultivars significantly improved Zn extractability compared to finely ground samples. Results obtained in this study were comparable to those reported by Khetarpaul and Chauhan (1990) and Abdelrahaman *et al.* (2005).

CONCLUSION

It can be concluded that traditional processing of pearl millet resulted in a significant increased in Ca, P, Fe and Zn extractability. Among processing methods coarse grinding significantly decreased minerals extractability. Processing of the grains followed by fermentation could be regarded as a viable mean for improvement of the nutritional quality of pearl millet.

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