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Effect of fermentation and dehulling on starch, total polyphenols, phytic acid content and in vitro protein digestibility of pearl millet

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Abstract

Two pearl millet cultivars: Standard and Ugandi, obtained from El Obeid Research Station, were used in this study. Investigation showed that the Ugandi variety had significantly ($P \leqslant 0.05$) higher polyphenols and phytic acid contents than the standard and significantly lower in vitro protein digestibility (IVPD), (72.7 and 70.4% for the Standard and Ugandi, respectively), indicating lower nutritional quality. The two cultivars were fermented for 14 h at room temperature ($30 \pm 2^{\circ}$ C) and starch, polyphenols, phytic acid and IVPD were determined at 2-h intervals. Dehulling was found to cause a significant reduction in protein, polyphenols and phytic acid contents for the two cultivars. Fermentation and dehulling caused a significant increase in the IVPD for the two cultivars: 82 and 84% for the fermented ones and 79.1 and 78.6% for the dehulled samples.

Keywords: Dehulling; Fermentation; In vitro protein digestibility; Pearl millet; Phytic acid; Starch; Total polyphenols

1. Introduction

Bulrush millet (*Pennisetum typhoideum*), also known as pearl millet, is of the same order and height as maize and sorghum; it is the most drought-resistant millet. Pearl millet is sown on about 15 million ha in Africa and 12 million in Asia (Riley, Gupta, Seetharama, & Mushonga, 1993). Among millets, pearl millet is known to have a higher protein content and better amino acid balance than sorghum. The higher ratio of germ to endosperm is responsible for the higher protein content (Dendy, 1995).

Fermented cereal products are widely consumed in India and many countries of Central and Southern Africa. Fermentation usually involves malting and souring by mixed cultures of yeast and lactobacilli. Fermentation causes degradation of grain components, especially starch and soluble sugars, by both grain and fermented media enzymes (Chavan & Kadam, 1989a, 1989b).

Generally, in Africa and Asia, sorghum and millets are consumed after decortication; the grains are wetted and decorticated traditionally using a wooden mortar and pestle. Decortication is found to decrease anti-nutrients of pearl millet, decreasing the total polyphenols and phytic acid (Monawar, 1983), increasing starch content (Almeida-Dominguez, Serna-Saldivar, Gomezma, & Rooney, 1993) and increasing the IVPD (Dhankher & Chauhan, 1987).

2. Materials and methods

2.1. Materials

Two pearl millet cultivars, Standard and Ugandi, obtained from El Obeid Research Station, were cleaned and ground to pass a 0.4-mm screen. Another portion was dehulled mechanically and the milled part was used to prepare the fermented dough.

2.2. Preparation of dough

Fermented dough was prepared in the traditional domestic way. Pearl millet flour (600 g) was mixed with 600 ml water; previously fermented dough (150 g) was then added to the mixture of flour and water to act as a starter. After thorough mixing, samples were taken at 2 h intervals until the end of fermentation, which was terminated after 14 h at ambient temperature ($30 \pm 2\,^{\circ}$C). Samples were dried in an air oven at 70° C and were finely ground.

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2.3. Moisture, protein, starch, total polyphenols, phytic acid and IVPD

Moisture and protein (N×6.25) were determined according to the AOAC (1984). Starch was determined by the method of dispersal in $CaCl_2$, followed by iodine spectrophotometery (Kerr, 1950). Total polyphenols were determined according to the Folin-Denis method (Swain & Hillis, 1959). Phytic acid content was determined according to Wheeler and Ferrel (1971). The IVPD was determined according to the method of Maliwal (1983), as modified by Manjula and John (1991).

2.4. Statistical analysis

Each determination was carried out in three separate samples, which were analyzed and the figures were then averaged. Data was assessed by analysis of variance (ANOVA; Snedecor & Cochran, 1987) and by Duncan's multiple range test with a probability $P \leqslant 0.05$ (Duncan, 1955).

Table 1
Starch content of fermented pearl millet[a]

Fermentation period (h)	Standard cultivar		Ugandi cultivar	
	pH	Starch (%)	PH	Starch (%)
Raw whole	–	66.9 (0.05)a	–	68.5 (0.03)a
0	6.6	66.7 (0.30)a	6.7	68.2 (0.20)a
2	6.4	66.0 (0.41)b	6.4	66.5 (0.28)b
4	6.0	64.0 (0.15)c	6.1	66.1 (0.15)c
6	5.3	63.1 (0.30)d	5.6	65.1 (0.50)d
8	5.0	62.0 (0.30)e	5.2	65.0 (0.61)e
10	4.6	60.5 (0.45)f	4.8	64.2 (0.72)f
12	4.1	59.4 (0.20)g	4.2	63.6 (0.26)g
14	3.8	59.0 (0.24)h	3.9	63.3 (0.43)h

[a] Values are means±(S.D.).Means not sharing a common letter in a column are significantly different at $P \leqslant 0.05$, as assessed by Duncan's multiple range test.

3. Results and discussion

3.1. Effect of dehulling on protein content of pearl millet

The dehulling treatment significantly ($P \leqslant 0.05$) decreased the protein content for both cultivars. However, the Standard cultivar contained more protein than the Ugandi cultivar (Table 4). The protein content of Standard whole was significantly ($P \leqslant 0.05$) higher than the Ugandi whole, while the protein content of Standard dehulled was insignificantly different from the Ugandi dehulled (Table 5).

3.2. Effect of fermentation and dehulling on starch content of pearl millet

Table 1 shows starch content during pearl millet fermentation. A significant ($P \leqslant 0.05$) decrease was first observed after 4 h fermentation and further significant ($P \leqslant 0.05$) reductions at 6, 8, 10, 12 and 14 h for the two cultivars. The decrease was from 67 to 59% for Standard variety and from 69 to 63% for Ugandi variety. The decrease in starch content caused by fermentation could be attributed to yeast growth, breaking down sugars to ethanol and carbon dioxide (Pederson, 1971). On the other hand, Tables 4 and 5 show that the dehulling significantly ($P \leqslant 0.05$) increased starch content. The Ugandi cultivar is of higher starch content than the Standard cultivar. However, their interaction was insignificant.

3.3. Effect of fermentation and dehulling on total polyphenols of pearl millet

Total polyphenols of the two pearl millet cultivars are shown in Table 2. A significant ($P \leqslant 0.05$) decrease in polyphenols was first observed after 2 h fermentation and further significant ($P \leqslant 0.05$) reductions at 4, 6, 8, 10, 12 and 14 h for the Standard cultivar. For the

Table 2
Total polyphenols and phytic acid content of fermented pearl millet[a]

Fermentation time (h)	Standard cultivar		Ugandi cultivar	
	Total polyphenols (mg/100 g)	Phytic acid (mg/100 g)	Total polyphenols (mg/100 g)	Phytic acid (mg/100 g)
Raw whole	304 (0.01)a	943 (0.04)a	444 (0.05)a	1076 (0.16)a
0	278 (0.01)b	943 (0.04)a	427 (0.01)a	1076 (0.16)a
2	251 (0.02)c	840 (0.03)b	410 (0.03)a	988 (0.14)b
4	233 (0.03)d	762 (0.62)c	401 (0.01)a	920 (0.26)c
6	214 (0.05)e	667 (0.14)d	391 (0.05)b	841 (0.18)d
8	192 (02.0)f	598 (0.36)e	376 (0.02)c	773 (0.32)e
10	175 (0.01)g	462 (0.48)f	354 (0.02)d	704 (0.24)f
12	152 (0.03)h	416 (0.09)g	327 (0.01)e	680 (0.08)g
14	122 (0.01)i	380 (0.17)h	306 (0.02)f	580 (0.06)h

[a] Values are means±(S.D.). Means not sharing a common letter in a column are significantly different at $P \leqslant 0.05$, as assessed by Duncan's multiple range test.

Ugandi cultivar, a significant ($P \leqslant 0.05$) decrease was first observed after 8 h fermentation and further significant ($P \leqslant 0.05$) reductions at 10, 12 and 14 h. The decrease was from 304 to 122 mg/100 g after 14 h of fermentation for Standard variety and from 444 to 306 mg/100 g for Ugandi variety after 14 h of fermentation. This decrease in total polyphenol content could be due to microbial activity during the fermentation process. Table 4 shows that dehulling significantly ($P \leqslant 0.05$) decreased total polyphenol content; this decrease is due to removal of outer layers. The Ugandi cultivar had more total polyphenols than the Standard cultivar. Table 5 shows that total polyphenol content of Ugandi, whole, was significantly ($P \leqslant 0.05$) higher than Standard, whole, while the total polyphenols content of Ugandi, dehulled, is significantly ($P \leqslant 0.05$) higher than Standard, dehulled (Table 5).

3.4. Effect of fermentation and dehulling on phytic acid content of pearl millet

Table 2 shows the decrease in phytic acid content of pearl millet due to fermentation for 14 h. A significant ($P \leqslant 0.05$) decrease was first observed at 4 h fermentation and further significant reductions at 6, 8, 10, 12 and 14 h in phytic acid for both cultivars. The reduction was from 943 to 380 mg /100 g (59.5% reduction) for Standard cultivar and from 1076 to 580 mg/100 g (46.1% reduction) for Ugandi cultivar. Generally, fermentation is known to cause a greater reduction in phytic acid than other anti-nutrients and this could be due to the low pH of fermented dough, which is considered to be optimum for phytase activity. Tables 4 and 5 show that the dehulling significantly ($P \leqslant 0.05$) decreased phytic acid content; this is due to removal of outer layers, where phytic acid is thought to be abundant. The Ugandi cultivar showed higher levels of phytic acid than the Standard cultivar. The phytic acid content of Ugandi, whole, was significantly ($P \leqslant 0.05$) higher than the Standard, whole, while the phytic acid content of Ugandi, dehulled, was significantly ($P \leqslant 0.05$) lower than Standard, dehulled.

3.5. Effect of fermentation and dehulling on the IVPD of pearl millet

The effect of fermentation on IVPD is shown in Table 3. A significant increase ($P \leqslant 0.05$) was first observed at 2 h fermentation and further significant increases at 4, 6, 8, 10, 12 and 14 h in the IVPD of the two millet cultivars. The increase was from 72.7 to 83.6% for Standard cultivar and from 70.4 to 81.6% for Ugandi cultivar. This improved IVPD caused by fermentation could be attributed to the partial degradation

Table 3
In vitro protein digestibility of fermented pearl millet cultivars[a]

Fermentation time (h)	Standard cultivar			Ugandi cultivar		
	pH	IVPD	% increase	pH	IVPD %	% increase
Raw whole	–	72.7 (0.15)i	–	–	70.4 (0.20)i	–
0	6.6	74.4 (0.15)h	2.3	6.7	72.3 (0.20) h	2.9
2	6.4	75.8 (0.10)g	4.2	6.4	74.4 (0.21)g	5.6
4	6.0	76.6 (0.15)f	5.4	6.1	75.0 (0.12)f	6.5
6	5.3	78.1 (0.21)e	7.4	5.6	75.8 (0.05)e	7.7
8	5.0	78.7 (0.01)d	8.3	5.2	77.1 (0.15)d	8.9
10	4.6	79.9 (0.15)c	9.9	4.8	77.8 (0.12)	10.5
12	4.1	81.6 (0.15)b	12.2	4.2	79.0 (0.31)b	12.2
14	3.8	83.6 (0.10)a	15.0	3.9	81.6 (0.10)a	15.9

[a] Values are means±(S.D.). Means not sharing a common letter in a column are significantly different at $P \leqslant 0.05$, as assessed by Duncan's multiple range test.

Table 4
Effect of dehulling on protein, starch, polyphenols, phytic acid and IVPD of pearl millet—main treatment

Treatment	Moisture	Protein	Starch	Total polyphenols	Phytic acid	IVPD
Whole	7.9	16.9	67.7	374	1010	71.6
Dehulled	9.1	15.2	72.5	339	473	78.9
$LSD_{dehulling}$	0.23	0.25	0.25	0.023	0.24	0.3
Whole	9.0	16.4	69.3	269	708	75.9
Dehulled	8.1	15.7	71.0	385	776	74.5
$LSD_{cultivar}$	0.23	0.25	0.25	0.023	0.24	0.3

Table 5
Effect of dehulling on protein, starch, polyphenols, phytic acid and IVPD of pearl millet[a]—interaction

Analysis	Standard whole	Standard dehulled	(%) Change	Ugandi whole	Ugandi dehulled	(%) Change
Moisture (%)	8.2 (0.21)b	9.7 (0.25)a	18.3 +ve	7.6 (0.21)c	8.5 (0.02)b	11.8 +ve
Protein (%)	17.5 (0.17)a	15.3 (0.25)c	12.6 −ve	16.3 (0.17)b	15.1 (0.15)c	7.7 −ve
Starch (%)	66.9 (0.17)a	71.6 (0.05)a	7.0 +ve	68.5 (0.15)a	73.4 (0.30)a	7.2 +ve
Total polyphenols (mg/100)	303.7 (0.01)c	235 (0.02)d	22.4 −ve	444 (0.02)a	326 (0.02)b	26.4 −ve
Phytic acid (mg/100)	943 (0.01)b	473 (0.13)c	49.8 −ve	1076 (0.16)a	473 (0.30)d	43.9 −ve
IVPD (%)	72.7 (0.15)c	79.1 (0.30)a	8.8 +ve	70.4 (0.25)d	78.6 (0.15)b	11.6 +ve

[a] Values are means ± (S.D.). Means not sharing a common letter in a row are significantly different at $P \leqslant 0.05$, as assessed by Duncan's multiple range test.

of complex storage proteins to more simple and soluble products (Chavan, Chavan, & Kadam, 1988); it could also be attributed to the degradation of tannins, polyphenols and phytic acid by microbial enzymes. Tables 4 and 5 show that dehulling treatment positively affected the IVPD. The IVPD of Standard cultivar was higher than the IVPD of Ugandi cultivar. The IVPD of Standard dehulled was significantly ($P \leqslant 0.05$) higher than Ugandi dehulled; also the Standard, whole, was significantly ($P \leqslant 0.05$) higher than the Ugandi, whole. Dehulling decreases the anti-nutrients that interfere with the IVPD. High molecular weight polyphenols are known to precipitate proteins, reduce protein digestibility and produce off-coloured products (Hulse, Liang, & Pearson, 1980).

4. Conclusion

Fermentation of pearl millet caused significant reduction in total polyphenols and phytic acid for both cultivars studied. This was accompanied by significant increase in the in vitro protein digestibility. Although dehulling significantly reduced protein content it resulted in significant reductions in polyphenols and phytic acid for both cultivars. This was accompanied by significant improvement in the in vitro protein digestibility. Fermentation and dehulling could be regarded as viable means for improvement of the nutritional quality of pearl millet.

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