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Effect of decortication methods on the chemical composition, antinutrients, Ca, P and Fe contents of two pearl millet cultivars during storage

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Abstract

Purpose – The purpose of this paper is to evaluate the impact of modern and traditional decortication methods on the chemical composition, antinutrients, Ca, P and Fe contents during storage of two pearl millet cultivars (white and green) grown in Sudan.

Design/methodology/approach – The grains of each cultivar were either decorticated traditionally using traditional stone dehuller or by using modern dehuller. The chemical composition, antinutrients and Ca, P and Fe contents of the cultivars were evaluated during storage for six months.

Findings – The results showed that both methods of decortication (modern and traditional) employed significantly decreased ash, protein, oil and crude fiber contents but increased moisture and nitrogen free extract contents of the grains for both cultivars. Storage resulted in a slight and gradual decrease in the chemical composition of the treated and untreated grains of the cultivars. Modern decortication of the grains significantly ($P = 0.05$) reduced tannin content in both cultivars compared to untreated and traditionally decorticated grains. Phytic acid content of the white cultivar was not affected by the method of decortication used but modern decortication reduced that of green cultivar. Decrease in tannin and phytic acid was observed as the storage continued in both treated and untreated cultivars. Decortication significantly ($P = 0.05$) reduced the Ca, P and Fe contents in both cultivars grains. Lower P and Fe contents were found in modern decorticated grains compared to traditional decorticated ones. Storage of the cultivars resulted in gradual decrease in Ca, P and Fe contents.

Research limitations/implications – Processing methods such as decortication affect the quality attributes of pearl millet cultivars. The application of modern decortication method on pearl millet cultivars has better quality attributes than those treated with traditional decortication.

Originality/value – The study uses decortication methods (traditional and modern) to improve the quality attributes of pearl millet cultivars. Antinutrients such as tannin and phytic acid were observed to reduce the bioavailability of minerals like Fe. Decortication of the grains significantly reduced the level of such antinutrients and improved bioavailability of minerals.

Keywords Antinutrients, Pearl millet, Chemical composition, Decortications, Mineral contents

Paper type Research paper

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Introduction

For majority of people in developing countries, cereal grains serve as their staple food due to high cost of animal foods and limited income (Fageer and El Tinay, 2004). Millet is regarded as the sixth cereal crop in terms of world agricultural production and can thrive under drought condition. Pearl millet is a millet widely cultivated in the semi-arid tropics of Asia and Africa. The grain serves as a main source of nutrients like protein, vitamins and minerals as well as energy for majority of poorest people in these regions (Abdalla, 1996; Ahmed, 1999). Pearl millet, grown majorly in western region of Sudan, has serve as multipurpose crop providing food, feed, construction materials and fuel (Abdalla, 1996). Nutritionally, pearl millet is better than most other cereals by being rich in lipids, quality proteins and minerals like calcium, iron and zinc (Klopfenstein and Hoseney, 1995). However, like other cereals, the presence of antinutritional factors lowered nutritional quality of the grains thereby resulting in poor digestibility of the nutrients. Low availability of minerals like iron and zinc in cereal-based foods cause a great problem for infants and young children in developing countries. Phytates, certain phenolic compounds and fibers are the major anti-nutritional factors that affect bioavailability of iron and zinc (Cámara and Amaro, 2003).

The preparation of millet grains for food involve traditional processing techniques such as fermentation (Nour *et al.*, 2016), malting (AbdelRahaman *et al.*, 2005), grinding and cooking (Nour *et al.*, 2015) in order to improve their nutritional and sensory properties. In addition, these processing techniques also decreased the proportion of antinutrients in the grain depending on the antinutrient location in cereal grain (Kheterpaul and Chauhan, 1991; Akingbala, 1991; Sharma and Kapoor, 1996), thereby modifying the content and bioavailability of minerals in the grain.

Traditional decortication of millet involves the use of wooden mortar and pestle to remove the outer layer of the grain. These outer layers or waste parts of the decorticated grain such as pericarp, seed coat and aleurone layer are high in antinutrients like phytates (Awika *et al.*, 2005). Studies have shown that traditional decortication of millet had no effect on protein and fat content of the millet. However, the technique reduced crude and dietary fiber, minerals and total phenolic content of millet thereby reducing the use of the grain as functional foods. Furthermore, dehulling of pearl millet grains has been reported to lower phytic acid, polyphenols and tannin and other quality attributes of the grain (ElShazali *et al.*, 2011; Chandrasekara *et al.*, 2012; Krishnan *et al.*, 2012).

The lowering of some nutrients (minerals, fibers and antioxidant) and antinutrients (phytates and tannin) could be due to the removal of peripheral parts of the grain, which contains most of these components, during the decortication process (Hama *et al.*, 2011). In addition, depending on the cultivar and growing location, the proportion of nutrients and antinutritional factors in cereal grains varied (Adom *et al.*, 2003; Bonoli *et al.*, 2004; Zieliński and Kozłowska, 2000). A need arises for the development of innovative decortication method that can be applied to pearl millet grain to lower antinutritional factors and also minimize nutrients loss. Therefore, the aim of the study is to evaluate the influence of the modern decortication technique on the nutritional attributes and antinutritional factors of two pearl millet cultivars during storage.

Materials and methods

Materials

Two pearl millet cultivars (white and green) were obtained from Department of Agronomy, Faculty of Agriculture, University of Khartoum. The grains of each cultivar were cleaned from damaged grains, foreign materials and broken seeds. The grains of each cultivar were either decorticated traditionally using traditional stone dehuller (6NS-33, India) with speed rate of 800–1,200 rpm and size of the grinder wheel of 300 × 205 mm or by using modern dehuller (Tangential Abbrasive Dehuller Device, TADD) (4E-220, Saska Twon, Sask, Canada).

Analysis

Chemical composition of processed pearl millet cultivars. The moisture, crude protein, fat, fiber, ash and nitrogen free extract (NFE) content were determined according to AOAC (1995) methods. The total energy was calculated using Atwater factors.

$$\text{Energy value} = \text{Protein}(\%) \times 4 + \text{Carbohydrate}(\%) \times 4 + \text{Fat}(\%) \times 9.$$

Phytic acid. The method of Wheeler and Ferrel (1971) was employed in the determination of phytic acid using 2.0-g dried sample. A standard curve was prepared expressing the results as $Fe(NO_3)_3$ equivalent. Phytate phosphorous was calculated from the standard curve assuming a 4:6 iron to phosphorous molar ratio.

Tannins content. Tannins were determined by the modified procedure of Maxon and Rooney, as described by Price *et al.* (1978). A 200-mg sample was extracted with 10 ml 1 percent (v/v) conc. HCl in methanol for 20 min in capped rotating test tubes. Vanillin reagent (0.5 percent, 5 ml) was added to the extract (1 ml) and the absorbance of the color developed after 20 min at 30 °C was read at 500 nm. A standard curve was prepared expressing the results as catechin equivalents, i.e. amount of catechin (mg ml−1) which gives a color intensity equivalent to that given by tannins after correcting for blank.

Determination of Ca, P and Fe. Minerals were extracted from the samples by the dry ashing method that described by Chapman and Pratt (1982). About 2.0 g of sample was acid digested with diacid mixture (HNO3:HClO4, 5:1, v/v) in a digestion chamber. The digested samples were dissolved in double-distilled water and filtered (Whatman No. 42). The filtrate was made to 50 ml with double-distilled water and was used for determination of total minerals. Calcium was determined by a titration method. Phosphorus was determined spectrophotometerically by using molybdovanadate method. Fe was determined by atomic absorption spectrophotometer (Perkin–Elmer 2380).

Statistical analysis. All data were subjected to statistical analysis, each determination was carried out and analyzed in triplicate and figures were then averaged. Data were assessed by the analysis of variance (Gomez and Gomez, 1984). Duncan multiple range test was used to separate means. Significance was accepted with $p \leqslant 0.05$.

Results and discussion

Moisture, ash, crude protein and oil contents of traditional and modern decorticated pearl millet cultivars

The chemical composition of white and green millet cultivars as affected by decortication method during storage is shown in Table I. Decortication of the cultivars has no significant effect on the moisture content of the cultivars. Also, the moisture values of the two cultivars are almost similar. The moisture content of the grains gradually decreases with the storage time. Ash content of the cultivars grains significantly ($p \leqslant 0.05$) reduces after decortication for both cultivars. No significant difference is found in ash content of the two cultivars. As the storage time progresses, the ash content of the cultivars varies depending on the decortication process and cultivar. At the end of the storage period (60 days), the ash content has reduced drastically but no significant differences are observed between treated and untreated grains. Similar observation in the reduction of ash content was also reported by Ahmed *et al.* (2009) who found that decortication reduced ash contents of two pearl millet cultivars. According to Elnour *et al.* (1998), the use of the traditional decortication procedure in Western Sudan for preparation of pearl millet diet markedly decreased the ash contents and this could be attributed to the separation of mineral rich glumes and the removal of pericarp during the process. The lowest ash contents observed in millet grains treated with modern decortication method may be due to the complete removal of all the outer parts by the method.

The crude protein and oil contents (Table I) reveal that decortications significantly ($p \leqslant 0.05$) decreases the protein and oil contents of the cultivars as compared with untreated cultivars. However, type of cultivar and method of decortication employed have no significant effect on the protein and oil contents of the cultivars. Storage of cultivars lead to gradual reduction in the protein and oil contents with significantly ($p \leqslant 0.05$) lower value obtained after 60 days of storage. Blessing and Gregory (2010) also reported that the protein content in dehulled green cowpea grain was 4.3 percent higher than dehulled sample which was significant.

Cultivar	Decortication method	Storage period (days) 0	15	30	45	60
Moisture						
White	Whole	6.45±0.04	6.17±0.03	5.96±0.03	5.75±0.14	5.50±0.05
	Modern	6.80±0.04	6.61±0.03	6.35±0.05	6.37±0.14	5.48±0.20
	Traditional	7.03±0.10	6.54±0.03	6.47±0.13	6.00±0.08	5.55±0.47
Green	Whole	6.66±0.07	6.12±0.03	6.37±0.53	6.11±0.10	6.15±0.17
	Modern	6.94±0.08	6.85±0.17	6.42±0.38	6.00±0.29	5.92±0.31
	Traditional	7.16±0.05	6.82±0.10	6.58±0.10	6.44±0.06	6.20±0.32
$LSD_{0.05}$				0.3225		
SE±				0.114		
Ash						
White	Whole	2.18±0.06	1.75±0.57	2.17±0.03	1.75±0.12	1.02±0.04
	Modern	1.46±0.06	1.42±0.09	1.60±0.12	1.77±0.13	1.03±0.06
	Traditional	1.52±0.03	1.31±0.24	1.48±0.10	1.74±0.07	1.12±0.10
Green	Whole	2.14±0.13	2.04±0.03	2.17±0.01	1.82±0.05	1.09±0.03
	Modern	1.38±0.04	1.33±0.05	1.42±0.02	1.87±0.01	1.04±0.06
	Traditional	1.40±0.05	1.37±0.03	1.49±0.06	1.72±0.10	1.13±0.07
$LSD_{0.05}$				1.66 ns		
SE±				0.5868		
Crude protein						
White	Whole	12.36±0.14	12.20±0.28	11.75±0.30	10.78±0.47	10.67±0.07
	Modern	11.50±0.15	11.02±0.17	10.87±0.24	10.84±0.17	10.06±0.09
	Traditional	11.24±0.08	11.15±0.17	10.91±0.27	10.27±0.06	10.05±0.08
Green	Whole	12.70±0.26	12.03±0.27	11.97±0.17	11.32±0.12	11.01±0.08
	Modern	11.12±0.17	11.09±0.28	11.09±0.50	10.66±0.14	10.56±0.17
	Traditional	11.40±0.09	11.28±0.20	11.16±0.28	10.58±0.09	10.25±0.15
$LSD_{0.05}$				0.5957*		
SE±				0.2113		
Oil						
White	Whole	5.85±0.14	5.36±0.28	4.96±0.30	4.72±0.47	4.41±0.07
	Modern	5.09±0.15	4.97±0.17	4.59±0.24	4.27±0.17	3.99±0.09
	Traditional	5.01±0.08	4.94±0.17	4.85±0.27	4.59±0.06	4.41±0.08
Green	Whole	5.76±0.26	4.46±0.27	5.15±0.17	4.71±0.12	4.33±0.08
	Modern	4.61±0.17	4.57±0.28	4.59±0.50	4.41±0.14	4.11±0.17
	Traditional	4.90±0.09	4.66±0.20	4.64±0.28	4.50±0.09	4.24±0.15
$LSD_{0.05}$				0.7335*		
SE±				0.254		

Notes: Values are means ± SD. Mean(s) having different superscript(s) in columns and rows are significantly different ($p \leq 0.05$) according to DMRT

Table I. Moisture, crude protein and oil contents (percent) of millet seeds as affected by decortication method and storage period

The results obtained contradicts previous findings that decortication of millet had no significant effect on the protein and fat contents (Lestienne *et al.*, 2005; Bagdia *et al.*, 2011). In addition, the use of traditional decortication method on pearl millet has been reported to have numerous effects on the grain composition but of no significant differences (Hama *et al.*, 2011). The reduction in nutritional composition (ash, protein and fat) could be attributed to the fact that they are mainly located in the peripheral parts of the grains (pericarp and aleurone layer); therefore, removal of the pericarp during decortication leads to reduction in their contents (Hama *et al.*, 2011). Furthermore, the decrease in protein contents may be attributed to the removal of hull and elimination of some of the protein-rich aleurone cells (Abdalla *et al.*, 1998). The losses of fat could be attributed to the separation of the germ during dehulling. Similar findings were reported by Dendy (1995) on pearl millet after dehulling.

Crude fibers, NFE contents and total energy of traditional and modern decorticated pearl millet cultivars

The crude fiber content of untreated grains was significantly ($p \leqslant 0.05$) reduced after decortication for both white and green cultivars grains (Table II). Variation in crude fiber content was observed during storage. Also, no significant difference was observed in the crude fiber content of the two cultivars. At day 0 of storage, decortication has no significant effect on the NFE and total energy of the treated and untreated grains. The NFE and total energy of the two cultivars were similar with no significant effect. As storage continues, the NFE and total energy of the cultivars varied but a significantly ($p \leqslant 0.05$) higher value was observed in the NFE of the cultivars at the end of the storage period. The reduction in crude fiber contents after decortication were in agreement with the results of Abdelnour (2001) and Ahmed *et al.* (2009) who reported that dehulling decreased the fiber contents of pearl millet. This decrease in the two cultivars used might be due to the removal of the bran and the outer layers of the seed that contains this fiber. Pearl millet is a rich source of energy and the value obtained is comparable with commonly consumed cereals like wheat, rice, sorghum and maize.

Antinutrients contents of traditional and modern decorticated pearl millet cultivars

Table III shows the effect of decortication methods on the tannins and phytic acid of millet cultivars during storage. Decortication of the cultivars significantly ($p \leqslant 0.05$) decreases the

		Storage period (days)				
Cultivar	Decortication method	0	15	30	45	60
Crude fiber						
White	Whole	4.62±0.14	4.12±0.28	4.29±0.30	4.04±0.47	4.00±0.07
	Modern	3.77±0.15	3.60±0.17	3.93±0.24	3.82±0.17	3.79±0.09
	Traditional	3.40±0.08	3.56±0.17	4.01±0.27	3.75±0.06	3.69±0.08
Green	Whole	4.65±0.26	4.45±0.27	4.69±0.17	4.60±0.12	4.58±0.08
	Modern	3.04±0.17	3.24±0.28	3.13±0.50	3.00±0.14	2.95±0.17
	Traditional	3.11±0.09	3.58±0.20	3.34±0.28	3.26±0.09	3.18±0.15
$LSD_{0.05}$				0.7221*		
SE±				0.25		
Nitrogen free extract						
White	Whole	68.44±0.14	72.34±0.28	70.85±0.30	72.65±0.47	74.07±0.07
	Modern	71.37±0.15	72.35±0.17	72.35±0.24	72.44±0.17	75.60±0.09
	Traditional	71.77±0.08	72.32±0.17	72.32±0.17	73.61±0.06	74.89±0.08
Green	Whole	68.92±0.26	69.88±0.27	69.56±0.17	71.33±0.12	72.74±0.08
	Modern	72.98±0.17	73.11±0.28	73.50±0.50	73.76±0.14	75.12±0.17
	Traditional	72.01±0.09	72.26±0.20	72.83±0.28	73.55±0.09	75.08±0.15
$LSD_{0.05}$				1.085*		
SE±				0.3755		
Total energy						
White	Whole	376.10±0.14	387.00±0.28	375.10±0.30	376.90±0.47	379.70±0.07
	Modern	377.40±0.15	378.00±0.17	375.30±0.24	372.90±0.17	378.70±0.09
	Traditional	377.00±0.08	377.70±0.17	376.60±0.27	377.00±0.06	379.50±0.08
Green	Whole	378.10±0.26	376.80±0.27	372.10±0.17	373.20±0.12	374.10±0.08
	Modern	377.60±0.17	376.40±0.28	381.40±0.50	378.00±0.14	380.00±0.17
	Traditional	377.60±0.09	375.80±0.20	377.40±0.28	377.80±0.09	379.90±0.15
$LSD_{0.05}$				6.231*		
SE±				2.158		

Notes: Values are means ± SD. Mean(s) having different superscript(s) in columns and rows are significantly different ($p \leqslant 0.05$) according to DMRT

Table II. Crude fiber, nitrogen free extract contents (percent) and total energy (Kcal/mol) of millet seeds as affected by decortication method and storage period

Cultivar	Decortication method	Storage period (days) 0	15	30	45	60
Tannins						
White	Whole	343.91±1.14	259.32±2.11	222.02±1.62	221.31±10.01	162.93±7.01
	Modern	174.43±9.09	158.41±3.05	140.71±3.12	128.14±4.21	105.62±8.01
	Traditional	230.54±7.11	216.05±4.04	181.71±6.05	147.13±4.24	145.06±3.07
Green	Whole	280.73±5.12	203.07±9.07	166.76±2.23	174.81±4.09	153.14±2.15
	Modern	197.81±3.02	172.91±2.06	143.44±5.34	121.29±2.02	108.04±3.01
	Traditional	214.04±5.02	160.02±3.10	158.51±1.05	150.62±7.02	138.64±4.02
$LSD_{0.05}$				5.165*		
SE±				1.826		
Phytic acid						
White	Whole	301.10±6.46	292.30±1.27	269.70±1.14	258.6±4.29	256.80±2.06
	Modern	77.59±11.60	76.88±2.27	76.29±1.31	69.72±1.54	66.54±0.94
	Traditional	95.98±8.09	81.04±1.25	74.91±1.16	71.12±0.48	66.04±2.69
Green	Whole	296.20±1.09	292.30±2.32	271.20±10.39	266.40±4.47	250.70±0.64
	Modern	78.95±1.20	73.82±2.10	70.70±0.71	63.54±3.65	63.42±2.58
	Traditional	90.72±1.07	78.35±2.59	73.83±0.95	70.57±1.05	66.31±0.47
$LSD_{0.05}$				6.365*		
SE±				2.25		

Notes: Values are means ± SD. Mean(s) having different superscript(s) in columns and rows are significantly different ($p \leqslant 0.05$) according to DMRT

Table III. Antinutrients contents (mg/100 g) of millet seeds as affected by decortication method and storage period

tannins and phytic acid of the cultivars grains. The use of modern decortication method significantly reduces the tannins contents in both cultivars as compared with those treated with traditional method. Greater effect of decortication on tannins reduction is observed in white cultivar than in green cultivar. Further reduction in tannins and phytic acid occur as storage continued in both treated and untreated cultivars. At the end of storage period, a significantly lowest tannins content is recorded in cultivars treated with modern decortication method as compared to other samples. However, the phytic acid content of the white cultivar was not affected by the method of decortication used but modern decortication reduced that of green cultivar. Phytic acid is widely found in cereals, legumes, nuts and oil seeds constituting 1 to 5 percent. Decortication reduced the phytic acid content in decorticated grains as found in little millet landrace (Sridevi and Yenagi, 2007). The concentration of tannin in hull portion of grains has been shown in previous studies to reduce after the dehulling process (Egounlety and Aworh, 2003; Léder, 2004). The greater reduction in tannin contents of millet grains treated with modern decortication method may be due to the complete removal of all the hull by the method. It has been reported that dehulling of pearl millet lowered the phytic acid and tannin (Chandrasekara *et al.*, 2012; Krishnan *et al.*, 2012) and this may improve the protein digestibility and mineral contents of the grains. This reduction could be attributed to the fact that they are mainly located in the peripheral parts of the grains and these were removed during decortication (Hama *et al.*, 2011).

Ca, P and Fe contents of traditional and modern decorticated pearl millet cultivars

The Ca, P and Fe contents of millet cultivars as affected by decortication method during storage is presented in Table IV. Decortication affected the Ca, P and Fe contents of the cultivars by significantly ($p \leqslant 0.05$) reducing the mineral content as compared to untreated cultivars. The method of decortication and type of cultivar used had no significant effect on the Ca content at day 0 of storage. However, the P and Fe contents of cultivars treated

Cultivar	Decortication method	Storage period (days) 0	15	30	45	60
Ca						
White	Whole	128.30±4.14	124.31±0.06	118.51±2.54	113.90±1.76	106.22±0.57
	Modern	117.30±0.53	112.80±1.13	108.50±1.87	103.60±1.05	97.82±5.38
	Traditional	118.20±0.96	116.50±6.48	109.20±1.43	103.80±2.28	104.30±1.31
Green	Whole	129.20±0.33	128.60±1.20	121.30±0.84	113.10±5.45	111.60±0.86
	Modern	118.40±0.65	116.30±4.21	116.10±1.44	108.80±6.58	109.30±0.02
	Traditional	115.70±0.46	114.10±5.40	112.30±1.71	106.50±2.02	101.10±2.80
$LSD_{0.05}$				1.6950*		
SE±				5.992		
P						
White	Whole	505.20±0.92	504.10±0.92	492.50±2.34	378.70±2.95	513.50±0.06
	Modern	380.00±0.54	396.70±0.22	355.20±2.51	331.80±2.68	475.00±2.02
	Traditional	482.90±1.25	471.40±4.41	362.60±0.58	373.90±0.59	432.10±0.63
Green	Whole	509.20±0.60	485.90±0.87	393.10±1.15	375.50±0.30	480.10±1.22
	Modern	480.20±3.12	445.20±0.57	378.20±2.48	340.50±1.71	414.70±0.30
	Traditional	502.50±0.76	475.50±0.60	476.20±1.10	309.20±0.26	381.10±5.04
$LSD_{0.05}$				29.18*		
SE±				10.32		
Fe						
White	Whole	4.28±0.53	3.66±0.69	3.98±0.04	3.30±1.41	2.81±5.08
	Modern	3.46±0.74	3.08±0.05	2.77±0.59	2.35±0.55	2.71±2.70
	Traditional	3.86±1.89	3.61±3.00	2.93±0.55	2.67±1.53	2.58±3.46
Green	Whole	5.13±0.62	3.81±1.11	2.81±1.58	2.35±3.35	2.75±1.11
	Modern	3.11±1.17	2.95±0.32	2.66±0.99	2.74±1.44	2.43±3.27
	Traditional	3.77±0.49	2.78±0.97	3.00±1.16	2.40±3.17	2.64±2.34
$LSD_{0.05}$				0.3056*		
SE±				0.108		

Notes: Values are means ± SD. Mean(s) having different superscript(s) in columns and rows are significantly different ($p \leqslant 0.05$) according to DMRT

Table IV.
Ca, P and Fe contents (mg/100 g) of millet seeds as affected by decortication method and storage period

with modern decortication were lower than those treated with traditional decortication method. Storage of the cultivars resulted in gradual decrease in Ca, P and Fe contents. The reduction of calcium, phosphorous and iron after decortication may be ascribed to the high amount of the mentioned minerals in hull portion of the grain. Mubarak (2005) reported a decrease in Ca contents of raw mung bean after dehulling. However, the results of Fe contents obtained were not in agreement with that reported by Ghavidel and Prakash (2007) where dehulling significantly improved the iron content of grain. The application of different decortication method has effect on the P and Fe contents of the cultivars and this may be ascribed to the difference in the reduction of antinutrients, by this method, which bound minerals and reduce their availability in the whole grains. Phytic acid is the major storage form of P in cereals which chelates minerals and prevents their intestinal absorption, therefore the greater reduction of this phytic acid after modern decortication resulted in decrease in the mineral contents.

Conclusion

It can be concluded that decortication reduced the chemical composition, antinutrients and Ca, P and Fe contents of the two pearl millet cultivars with greater effect observed in modern decorticated grains. The type of cultivars used had no significant effect on the properties studied.

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