ELSEVIER

PII: S0308-8146(97)00228-8

Food Chemistry, Vol. 63, No. 2, pp. 243–246, 1998
© 1998 Elsevier Science Ltd. All rights reserved
Printed in Great Britain
0308-8146/98 $19.00+0.00

Proximate composition, starch, phytate and mineral contents of 10 pearl millet genotypes

A. A. Abdalla,* A. H. El Tinay, B. E. Mohamed & A. H. Abdalla

Department of Biochemistry, Faculty of Agriculture, University of Khartoum, Shambat, Sudan

(Received 7 March 1997; revised version received and accepted 3 October 1997)

Ten pearl millet genotypes: IS 91777, IS 91666, IS 91333, IS 89111, IS 880004, IS 843, IS 833, Kabti, YD-X3 and Tihama, were used in this study. Investigations showed that pearl millet contained 88–91% dry matter, 1.6–2.4% ash, 2.6–4.0% crude fibre, 2.7–7.1% oil, 8.5–15.1% crude protein, 58–70% starch and 354–796 mg g^{-1} phytic acid. Mineral contents were 10–80, 180–270 and 450–990 mg g^{-1} Ca, Mg and P, respectively, and 70–110, 4–13, 53–70, 18–23, 10–18 and 70–180 $\mu g\, g^{-1}$ K, Na, Zn, Mn, Cu and Fe, respectively. The percentage of phytate to total phosphorus was found to range from 70–89% with an average of 77%. A linear relationship between phytate and total P existed with a correlation coefficient of 0.9805. © 1998 Elsevier Science Ltd. All rights reserved.

INTRODUCTION

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is one of the most important drought-tolerant crops of the tropical and subtropical regions of the world; it is able to produce good yields of grain under conditions unfavourable to most other cereals.

In Sudan, pearl millet is grown as a multipurpose crop, providing food, feed, construction materials and fuel in the rain-fed areas principally in the western region (Dar-fur and Kordofan); it is also cultivated, but to a limited extent, in the eastern, central and southern parts of the country.

As a cereal for human food pearl millet contributes a great part of dietary nutrients for large segments of people in Africa and Asia, and is often considered highly palatable, and a good source of protein, minerals and energy. Antinutrients (phytic acid and polyphenols), present in considerable amounts (Mahajan and Chauhan, 1987), limit protein and starch digestibilities (Yoon *et al.*, 1983; Carnovale *et al.*, 1988) hinder mineral bioavailability. (Harland and Oberlease, 1987), and inhibit proteolytic (Knuckles *et al.*, 1985) and amylolytic enzymes (Sharma *et al.*, 1978).

The objectives of the present study were to evaluate the chemical composition of 10 pearl millet genotypes and to determine variations in mineral and phytate contents in these cultivars.

*To whom correspondence should be addressed.

MATERIALS AND METHODS

Materials

Ten pearl millet genotypes: IS 91777, IS 91666, IS 91333, IS 89111, IS 880004, IS 843, IS 833 (origin, ICRISAT), Kabti, YD-X3 and Tihama (origin, Yemen) were obtained from the Agronomy Department, Faculty of Agriculture, University of Khartoum. These genotypes had been tested, in hybrid combinations, for grain yield and yield components. Some of them had proved to be of good potential for hybrid production and population improvement (Hazza, 1994).

Preparation of sample

The seeds of each genotye were cleaned from damaged grain and foreign materials and were milled into fine powder, passing a 0.4 mm mesh using a Trecator Cyclotec 1093 Sample Mill. Samples were kept in small clean bottles at 5°C in a refrigerator.

Chemical analysis

Moisture was determined according to AACC (1980). Ash, fibre and oil were determined according to AOAC (1984). Protein (N × 6.25) was determined according to AOAC (1975). Phosphorus was determined by the method of Chapman and Pratt (1982). Minerals were determined by atomic absorption spectrophotometry using an SP 191 Pye–Unicam spectrophotometer.

Starch was determined by the method of dispersal in calcium chloride, followed by iodine speetrophotometry (Kerr, 1950). Phytic acid was estimated by the method described by Wheeler and Ferrel (1971). The results were expressed on a dry matter basis.

Statistical analysis

Three separate samples from each cultivar were taken and analyses on each sample were conducted. Values were averaged. Data were assessed by analysis of variance (ANOVA) (Snedecor and Cochran, 1987) and by Duncan's multiple range test with a probability $p \leq 0.05$ (Duncan, 1955).

RESULTS AND DISCUSSION

Proximate composition and starch content

The proximate composition and starch content of the 10 pearl millet genotypes are shown in Table 1. Dry matter ranged from 88–91%. The results are within the range reported by Varriano-Marston and Hoseney (1980). Ash content ranged from 1.6% (for YD-X3) to 2.4% (for IS 91333). Values obtained were higher than the range of 1.8–1.9% reported by Khatir (1990) for Sudanese varieties, but were near the mean value of 1.9% reported by Monawar (1983). Crude fibre ranged between the minimum value of 2.6% for IS 89111 genotype and the maximum value of 4.0% for Kabti genotype. These values were higher than the range reported by Singh *et al.* (1987). The oil content ranged from 2.7 to 7.1%. All values, except for IS 91777 which had a noticeably low oil content, agreed with values obtained by Lai and Varriano-Marston (1980). Crude protein of the ten genotypes investigated ranged from 8.5% (for IS 880004) to 15.1% (for Kabti). These results were compatible with those obtained by Subramanian *et al.* (1986) who reported a range of 8.6–15.6% for 20 pearl millet cultivars. Means were significantly different ($p \leq 0.05$) from one another except for the pairs: IS 91777 and IS 91666, IS 89111 and IS 833 genotypes.

The starch content was found to range from 59–70%. Values reported here, except for IS 91777 and Kabti, were fairly comparable with the range of 59.4 to 69.5% obtained by Uprety and Austin (1972). There was no significant differences in starch contents for the pairs: IS 91666 and IS 880004; IS 91333 and YD-X3; IS 891 11 and IS 833 genotypes.

Phytic acid and phosphorus content

As shown in Table 2, phytic acid level ranged from 354 to 769 mg g^{-1}. Genotypes IS 880004 and IS 91333 had the highest phytic acid content, while IS 833, IS 843 and Tihama genotypes had the lowest contents. Results of the present investigation were higher than those reported by Simwemba *et al.* (1984). However, Kheterpaul and Chauhan (1991) reported very high levels of 990 mg g^{-1}, while Oke (1965) reported 532 mg g^{-1} for Nigerian pearl millet. Variations in phytic acid content among different genotypes can be attributed to both genetic and environmental conditions (Simwemba *et al.*, 1984).

For phosphorus, investigation showed a minimum value of 450 mg g^{-1} (IS 833) and a maximum value of 990 mg g^{-1} (IS 880004 and IS 91333) (Table 2). IS

Table 2. Relationship between phytic acid content and total phosphorus

Genotype	Phosphorus (mg/100 g)	Phytic acid (mg/100 g)	Percentage of phytate/total P
IS 91777	880 (±0.03)^{b}	618 (±0.00)^{b}	70.0
IS 91666	700 (±0.03)^{c}	530 (±0.88)^{c}	76.1
IS 91333	990 (±0.02)^{a}	795 (±0.00)^{a}	80.1
IS 89111	500 (±0.06)^{de}	442 (±0.00)^{d}	89.2
IS 880004	990 (±0.03)^{a}	796 (±0.88)^{a}	80.2
IS 833	450 (±0.04)^{e}	354 (±0.69)^{e}	78.7
IS 843	490 (±0.04)^{de}	354 (±0.00)^{e}	72.9
Kabti	490 (±0.02)^{de}	355 (±0.44)^{e}	72.2
YD-X3	550 (±0.04)^{d}	443 (±0.88)^{d}	80.9
Tihama	490 (±0.04)^{de}	354 (±0.88)^{e}	73.0

Table 1. Proximate composition and starch content of 10 pearl millet genotypes

Genotype	Dry matter	Ash (%)	Fibre (%)	Oil (%)	Protein (%)	Starch (%)
IS 91777	89.9(±0.23)^{b}	1.9(±0.02)^{d}	3.8(±0.02)^{c}	2.7(±0.10)^{e}	9.1(±0.09)^{g}	70.0(±0.47)^{a}
IS 91666	89.6(±0.20)^{bc}	2.0(±0.03)^{c}	3.8(±0.01)^{c}	7.1(±0.25)^{a}	9.3(±0.09)^{g}	67.3(±0.26)^{b}
IS 91333	90.6(±0.53)^{a}	2.4(±0.02)^{a}	3.9(±0.03)^{b}	4.6(±0.10)^{d}	12.1±(0.09)^{d}	61.0(±0.11)^{e}
IS 89111	90.9(±0.12)^{a}	1.9(±0.02)^{d}	2.6(±0.02)^{f}	5.6(±0.00)^{b}	10.1±(0.18)^{f}	66.2(±0.02)^{c}
IS 880004	88.3(±0.12)^{e}	2.2(±0.01)^{b}	3.7(±0.02)^{d}	5.9(±0.05)^{b}	8.5(±0.24)^{h}	67.0(±0.20)^{b}
IS 833	89.8(±0.20)^{b}	1.8(±0.05)^{e}	3.0(±0.03)^{e}	6.9(±0.35)^{a}	10.4(±0.56)^{f}	66.6(±0.31)^{c}
IS 843	88.7(±0.50)^{de}	1.8(±0.01)^{e}	3.7(±0.05)^{d}	5.2(±0.05)^{c}	11.0(±0.09)^{e}	65.2(±0.04)^{d}
Kabti	89.1(±0.12)^{cd}	1.9(±0.01)^{d}	4.0(±0.08)^{a}	4.7(±0.15)^{d}	15.1(±0.13)^{a}	58.5(±0.02)^{g}
YD-X3	88.6(±0.40)^{de}	1.6(±0.03)^{f}	3.7(±0.03)^{d}	4.8(±0.15)^{d}	12.8(±0.09)^{c}	61.1(±0.03)^{e}
Tihama	89.6(±0.50)^{bc}	2.0(±0.02)^{c}	3.9(±0.04)^{b}	4.8(±0.00)^{d}	13.7(±0.09)^{b}	60.4(±0.03)^{f}

Each value is an average of three replicates expressed on dry weight basis.
Values are means (± standard deviation).
Means not sharing a common superscript letter(s) in a column are significantly different at $p < 0.05$ as assessed by Duncan's multiple-range test.

Table 3. Mineral content of 10 pearl millet genotypes

Genotype	Ca (mg/100 g)	Mg (mg/100 g)	K ($\mu g\,g^{-1}$)	Na ($\mu g\,g^{-1}$)	Zn ($\mu g\,g^{-1}$)	Mn ($\mu g\,g^{-1}$)	Cu ($\mu g\,g^{-1}$)	Fe ($\mu g\,g^{-1}$)
IS 91777	80 ($\pm$0.03)^{a}	180 ($\pm$0.00)^{c}	100 ($\pm$0.00)^{a}	8 ($\pm$0.00)^{a}	60 ($\pm$0.62)^{c}	20 ($\pm$0.15)^{b}	18 ($\pm$0.04)^{a}	70 ($\pm$0.00)^{d}
IS 91666	10 ($\pm$0.00)^{c}	210 ($\pm$0.01)^{bc}	90 ($\pm$0.00)^{a}	7 ($\pm$0.00)^{a}	60 ($\pm$0.02)^{c}	20 ($\pm$0.75)^{b}	10 ($\pm$0.07)^{c}	100 ($\pm$0.01)^{c}
IS 91333	40 ($\pm$0.00)^{b}	250 ($\pm$0.00)^{ab}	110 ($\pm$0.00)^{a}	13 ($\pm$0.00)^{a}	60 ($\pm$0.02)^{c}	23 ($\pm$0.05)^{a}	13 ($\pm$0.03)^{b}	140 ($\pm$0.00)^{b}
IS 89111	50 ($\pm$0.00)^{b}	270 ($\pm$0.00)^{a}	100 ($\pm$0.00)^{a}	9 ($\pm$0.00)^{a}	65 ($\pm$0.05)^{b}	23 ($\pm$0.06)^{a}	10 ($\pm$0.08)^{c}	180 ($\pm$0.01)^{a}
IS 880004	50 ($\pm$0.00)^{b}	210 ($\pm$0.09)^{bc}	100 ($\pm$0.00)^{a}	5 ($\pm$0.00)^{a}	53 ($\pm$0.03)^{d}	23 ($\pm$0.10)^{a}	13 ($\pm$0.07)^{b}	110 ($\pm$0.00)^{c}
IS 833	70 ($\pm$0.01)^{ab}	180 ($\pm$0.00)^{c}	90 ($\pm$0.00)^{a}	9$\pm$ (0.00)^{a}	60 ($\pm$0.010^{c}	23 ($\pm$0.16)^{a}	18 ($\pm$0.04)^{a}	100 ($\pm$0.03)^{c}
IS 843	50 ($\pm$0.01)^{b}	210 ($\pm$0.04)^{bc}	100 ($\pm$0.00)^{a}	6 ($\pm$0.00)^{a}	53 ($\pm$0.01)^{d}	20 ($\pm$0.15)^{b}	13 ($\pm$0.00)^{b}	90 ($\pm$0.01)^{cd}
Kabti	40 ($\pm$0.00)^{b}	210 ($\pm$0.00)^{bc}	80 ($\pm$0.00)^{a}	4 ($\pm$0.00)^{a}	60 ($\pm$0.35)^{c}	23 ($\pm$0.15)^{a}	13 ($\pm$0.15)^{b}	100 ($\pm$0.01)^{c}
YD-X3	50 ($\pm$0.00)^{b}	230 ($\pm$0.00)^{b}	70 ($\pm$0.00)^{a}	4 ($\pm$0.00)^{a}	60 ($\pm$0.35)^{c}	18 ($\pm$0.10)^{c}	10 ($\pm$0.00)^{c}	100 ($\pm$0.01)^{c}
Tihama	50 ($\pm$0.02)^{b}	270 ($\pm$0.03)^{a}	70 ($\pm$0.00)^{a}	6 ($\pm$0.00)^{a}	70 ($\pm$0.15)^{a}	23 ($\pm$0.06)^{a}	13 ($\pm$0.00)^{b}	140 ($\pm$0.00)^{b}

91777, IS 91666, IS 91333 and IS 880004 genotypes were within the range of 630–1350 mg g^{-1} reported by Hoseney *et al.* (1987). The percentage of phytic acid/total P for pearl millet genotypes ranged from 70–89% with an average value of 77%. Chauhan *et al.* (1986) stated that phytic acid represents more than 70% of total P in pearl millet.

Results obtained in this study showed a linear relation between phytic acid and total P (correlation coefficient of 0.9805). Raboy *et al.* (1991) concluded that, in various seeds, phytic acid positively correlates with total P, correlation coefficients being greater than 0.90. Factors that affect the total P content, such as soil available P and fertilizers, can influence the phytic acid concentration (Miller *et al.*, 1980).

Mineral content

The mineral content of the ten genotypes is shown in Table 3. The data indicate that P and Mg were the major mineral constituents in the grain. Calcium content ranged from 10 to 80 mg g^{-1}; it was highest in IS 91777 genotype and lowest in IS 91666 genotype. Genotypes IS 89111, IS 880004, YD-X3, IS 843 and Tihama were similar in Ca content. Values obtained in this study were in the range reported by Hoseney *et al.* (1987). Excluding IS 91666, IS 91333 and Kabti, the present results were in agreement with the range of 50–80 mg g^{-1} obtained by Khatir (1990) for Sudanese local varieties.

Magnesium ranged from 180–270 mg g^{-1}. IS 89111 and Tihama were significantly higher in Mg content compared to all other genotypes except IS 91333. Hoseney *et al.* (1987) reported 70–160 mg g^{-1} Mg for pearl millet.

Potassium ranged from 70–110 $\mu g\,g^{-1}$. The data indicated that all genotypes were similar in their K content. Results obtained in this study are considerably lower compared to the range of 370–860 $\mu g\,g^{-1}$ obtained by Baily *et al.* (1979). The highest value for sodium was 13 $\mu g\,g^{-1}$. There were no significant differences in Na content among all genotypes studied. Higher results (20–49 $\mu g\,g^{-1}$) were reported by Varriano-Marston and Hoseney (1980).

Zinc content ranged from 53 to 70 $\mu g\,g^{-1}$. Genotypes IS 91777, IS 91666, IS 91333, IS 833, YD-X3 and Kabti had the same Zn content (60 $\mu g\,g^{-1}$) and were significantly different ($p \leq 0.05$) from the remaining genotypes. Singh *et al.* (1987) reported 48.5 $\mu g\,g^{-1}$ Zn for pearl millet.

Manganese was found to range from 18–23 $\mu g\,g^{-1}$. Genotypes IS 91333, IS 89111, IS 880004, IS 833, Kabti and Tihama had the same Mn content (23 $\mu g\,g^{-1}$) which was significantly higher than all other genotypes. Also, genotypes IS 91777, IS 91666 and IS 843 had the same value of Mn (20 $\mu g\,g^{-1}$) which is significantly lower than all other genotypes excluding YD-X3. Baily *et al.* (1979) reported 7–22 $\mu g\,g^{-1}$ Mn for 14 inbred lines of pearl millet.

Copper content ranged from 10 to 18 $\mu g\,g^{-1}$. The Cu content of IS 91777 and IS 833 (18 $\mu g\,g^{-1}$) was significantly higher than other genotypes. The Cu content of IS 91666, YD-X3 and IS 89111 (10 $\mu g\,g^{-1}$) was significantly lower than the other genotypes, while IS 91333, IS 880004, IS 843, Kabti and Tihama genotypes had similar Cu contents (13 $\mu g\,g^{-1}$). The values obtained in this study were within the range of 8–21 $\mu g\,g^{-1}$ reported by Baily *et al.* (1979). The iron content ranged from 70–180 $\mu g\,g^{-1}$, which is markedly higher than the range of 61–83 $\mu g\,g^{-1}$ reported by Varriano-Marston and Hoseney (1980).

CONCLUSIONS

The genotypes studied represent new breeding lines which are characterized by wide variability in protein, starch, fibre, ash and phytate contents. This can be advantageously utilized in breeding programmes designed to improve the nutritive quality of pearl millet. Compared to local lines, with the exception of Kabti genotype, the introduced varieties were lower in protein content. This could also be utilized to improve protein contents in otherwise competitive lines.

REFERENCES

AACC (1980) *Approved Methods of American Association of Cereal Chemists*. American Association of Cereal Chemists. Vol. 1 and 2, St Paul, Minnesota, USA.

AOAC (1975) *Official Methods of Analysis*, 12th ed. Association of Official Agricultural Chemists, Washington, DC.

AOAC (1984) *Official Methods of Analysis*, 14th ed. Association of Official Agricultural Chemists, Washington, DC.

Baily, A. V., Piccolo, B., Sumrell, G. and Burton, G. (1979) Amino acid profile, chemical scores and mineral contents of some pearl millet. *Journal of Agriculture and Food Chemistry*, **27**, 1421–1423.

Carnovale, E., Lugaro, E. and Lombardi-Boccia, G. (1988) Phytic acid in faba bean and pea: Effect on protein availability. *Cereal Chemistry* **65**, 114–117.

Chapman, H. D. and Pratt, P. F. (1982) *Methods of Analysis of Soil, Plant and Water*. 2nd ed. Page 170. University of California Agricultural Division, USA.

Chauhan, B. M., Sumeja, N. and Bhat, C. N. (1986) Nutritional value and fatty acid composition of some high yielding varieties of bajra. *Bulletin of Grain Technology* **21**, 41–42.

Duncan, B. D. (1955) Multiple range and multiple F tests. *Biometrics* **11**, 1–42.

Harland, B. F. and Oberlease, D. (1987) Phytate in foods. *World Nutrition and Diet* **52**, 235–259.

Hazza, M. M. (1994) Line X Tester Analysis for the study of heterosis and combining ability in some genotypes of pearl millet (*Pennisetum glaucum*). M.Sc. thesis, University of Khartoum, Sudan.

Hoseney, R. C., Anderson, D. J. and Clark, H. (1987) Sorghum and pearl millet. Nutritional quality of cereal grains: Genetic and agronomic improvement. *Agronomy Monograph* No **28**, 397–456.

Kerr, R. W. (1950) *Chemistry and Industry of Starch*. Academic Press Inc., New York.

Khatir, A. M. (1990) Chemical and rhelogical characterization of traditionally extracted millet starch. M.Sc. thesis, University of Khartown, Sudan.

Kheterpaul, N. and Chauhan, B. M. (1991) Effect of natural fermentation on phytate and polyphenolic content and in-vitro digestibility of starch and protein of pearl millet (*P. typhodeum*). *Journal of Science Food Agriculture* **55**, 189–195.

Knuckles, B. E., Kuzmicky, D. D. and Betschart, A. A. (1985) Effect of phytate and partially hydrolysed phytate on in-vitro protein digestibility. *Journal of Food Science* **52**, 1080–1082.

Lai, C. C. and Varriano-Marston, E. (1980) Lipid content and fatty acid composition of free and bound lipids in pearl millet. *Cereal Chemistry* **57**, 271–274.

Mahajan, S. and Chaulian, B. M. (1987) Phytic acid and extractable phosphorus of pearl millet as affected by natural lactic acid fermentation. *Journal of Science Food Agriculture* **41**, 381–386.

Miller, G. A., Youngs, V. L. and Oplinger, E. S. (1980) Environmental and cultivar effects on oat phytic acid concentration. *Cereal Chemistry* **75**, 189–191.

Monawar, L. Y. (1983) Food value of Sudanese indigenous cereal grain. Ph.D. thesis, University of Khartown, Sudan.

Oke, O. L. (1965) Phytic acid-phosphorus content of Nigerian foodstuffs. *Indian Journal of Medical Research* **53**, 417–421.

Raboy, V., Noaman, M. M., Taylor, G. A. and Pickett, S. G. (1991) Grain phytic acid and protein are highly correlated in winter wheat. *Crop Science* **31**, 63–65.

Sharma, C. B., Goel, M. and Irshad, M. (1978) Myo-inositol hexaphosphate as a potential inhibitor of amylase. *Phytochemistry* **17**, 201–204.

Singh, P., Singh, U., Eggum, B. O., Kumar, K. A. and Andrew, D. J. (1987) Nutritional evaluation of high protein genotypes of pearl millet (*P. americanum* (L.) Leake). *Journal of Science Food Agriculture* **38**, 41–48.

Simwemba, C. G., Hoseney, R. C., Varriano-Marston, E. and Zeleznak, K. (1984) Certain vitamin B and Phytic acid contents of pearl millet (*P. americanum* (L.) leake). *Journal of Agriculture and Food Chemistry* **32**, 31–34.

Snedecor, G. W. and Cochran, W. G. (1987) Statistical Methods 7th ed. The Iowa State University Press Ames, I. A., USA. P. 221.

Subramanian, V., Jambunath, R. and Ramaih, C. D. (1986) Physical and chemical characteristics of pearl millet grains and their relation to Roti quality. *Journal of Food Science* **51**, 1005–1008.

Uprety, D. C. and Austin, A. (1972) Varietal differences in nutritional composition of improved bajra (pearl millet) hybrid. *Bulletin of Grain Technology* **10**, 249–255.

Varriano-Marston, E. and Hoseney, R. C. (1980) Note on mineral content and location in pearl millet. *Cereal Chemistry* **68**, 437–439.

Wheeler, E. L. and Ferrel, R. E. (1971) A method for phytic acid determination in wheat and wheat fractions. *Cereal Chemistry* **48**, 312–320.

Yoon, J. H., Thompson, L. U. and Jenkins, D. J. A. (1983) Factors affecting starch digestibility and glycaemic response with reference to legumes. *American Journal of Clin. Nutrition* **38**, 481–493.