Food Chemistry **39** (1991) 99–107

Studies on Millets: Proximate Composition, Mineral Composition, and Phytate and Oxalate Contents

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(Received 10 October 1989; revised version received and accepted 24 January 1990)

ABSTRACT

*Grain samples of six varieties of common millet (*Panicum miliaceum*), three varieties of finger millet (*Eleusine coracana*) and four varieties of foxtail millet (*Setaria italica*) were analyzed for their proximate composition, mineral composition and phytate and oxalate contents. The average protein contents of common millet, finger millet and foxtail millet were 14·4, 9·8 and 15·9%, respectively. The crude fibre content of the millets ranged from 3·2 to 4·7%. In general, the mineral contents were high compared with those of other common cereal grains. In particular, the high level of calcium (0·24%) in finger millet was noteworthy. The high contents of phytic acid (0·50–0·70%) in millets present grounds for concern, in view of its interference with several minerals. The oxalate contents (21–29 mg/100 g dry weight) of the millets were low. Considerable between- and within-millet differences were observed with regard to most nutrients analyzed. The overall results are suggestive of the underexplored potential of millets as sources of dietary nutrients.*

INTRODUCTION

The term 'millet' is used for several small-seeded annual grasses that are of minor importance in the West but a staple in the diets of African and Asiatic people (Casey & Lorenz, 1977). The popularity of these crops arises from their wide adaptability to soil and climatic conditions, and is of special significance to semi-arid and arid regions because of their short growing

Food Chemistry 0308-8146/90/$03·50

seasons (Schery, 1963). Five millet types are common: common millet (*Panicum miliaceum*), Foxtail millet (*Setaria italica*), Finger millet (*Eleusine coracana*), Pearl millet (*Pennisetum typhoideum*) and Barnyard millet (*Eichinochloa frumentacea*).

The role that the millets play in the nutrition of the rural people of the semi-arid and arid tropics has always been underestimated. This is possibly because they contribute very little to any national or international commerce. Generally millets are consumed widely as subsistence or emergency foods. The world-wide food shortage in recent years has aroused renewed interest in millet as evidenced by the release of improved millet cultivars in South Asia. However, little published information is available on the nutritional composition of these new cultivars.

All cereal grains are known to be rich in phytic acid (Reddy *et al.*, 1982). Phytate has been implicated in binding certain minerals, particularly divalent ions, thus making these biologically less available (Reinhold *et al.*, 1975). Very little published material is available regarding the phytate content of millets compared with other cereal grains. There are no reports in the literature about the oxalate content of millets, which is of nutritional importance because of interference with calcium availability (Hodgkinson, 1977). Knowledge of these antinutritional factors is important to predict their value as mineral sources.

In the present study, several improved varieties of common millet, finger millet and foxtail millets were analyzed for their proximate and mineral compositions. The phytate and oxalate contents are also reported.

MATERIALS AND METHODS

Sample identification

The study included six varieties of common millet, three varieties of finger millet and four varieties of foxtail millet. The grain samples were obtained from state-owned breeding stations where the millets were grown under recommended cultural conditions. The source, seed colour and seed weights of the varieties are given in Table 1. Since the samples were obtained directly from seed-breeding stations, they can be considered representative of the varieties concerned.

Sample preparation

One kilogram samples of all millet types were cleaned to remove extraneous matter and were washed thoroughly with distilled water to remove adhering

TABLE 1
Source, Seed Colour and 1 000 Grain Weight of Millet Varieties

Varieties	*Source*	*Seed colour*	*1 000 grain weight (g)*
Common Millet			
BR 7	ICAR[a]	Yellow	4·48
Heen Mineri	DARS[b]	Very dark grey + yellow	1·60
IPM 1006	DARS	Yellow	4·10
MS 2420	DARS	Yellow	4·30
MS 4872	ICAR	Light yellowish brown	4·66
Raum 1	ICAR	Pale yellow	3·86
Finger Millet			
CO 10	DARS	Dark red	2·82
KM 1	DARS	Dark red	3·12
MI 302	DARS	Very dusty red	3·05
Foxtail Millet			
KHS 1	DARS	Yellow	2·63
SIC 1	ICAR	Very pale brown	2·76
SIC 7	ICAR	Yellow	2·70
SIC 15	ICAR	Yellow	2·84

[a] Indian Council for Agricultural Research, Pune, India.
[b] Dry zone Agricultural Research Station, Maha Iluppallama, Sri Lanka.

impurities. The samples were then dried at 60°C in an oven to a constant weight.

The grains were ground in a Wiley Laboratory mill to pass through a 60 mesh sieve. Finger millet was ground as the whole grain, since it is consumed in that form. Dehulled samples were used in the case of the other two millet types. Dehulling was performed manually by rubbing the grains in a clothbag and winnowing. The ground samples were stored at 4°C in airtight containers prior to chemical analyses.

Chemical analysis

Proximate composition was determined by the official methods of the Association of Official Analytical Chemists (1975): moisture (AOAC, 14·004), ash (AOAC, 14·006), nitrogen (AOAC, 2·049), crude fat (AOAC, 14·018), and crude fibre (AOAC, 7·054). Protein was determined as Kjeldahl nitrogen $\times 6{\cdot}25$. Carbohydrate (nitrogen-free extract) contents were calculated by the difference method.

Mineral analyses were carried out on samples digested with perchloric and nitric acids. Total phosphorus was estimated colorimetrically using ammonium vanadate (Chapman & Pratt, 1961). All other minerals were determined using an atomic absorption spectrophotometer (Perkin–Elmer 2830).

Phytic acid was estimated by the colorimetric method of Wheeler and Ferrel (1971) as modified by Reddy *et al.* (1978). The method described by Abaza *et al.* (1968) was employed to determine the total and water-soluble oxalates.

RESULTS AND DISCUSSION

The proximate composition of the millets are summarized in Table 2. The average protein contents of common millet, finger millet and foxtail millet

TABLE 2
Proximate Composition of Common, Finger and Foxtail Millets (%)[a]

Varieties	*Moisture*	*Dry weight basis*				
		Crude protein	*Crude fat*	*Crude fibre*	*Ash*	*Carbohydrate*
Common Millet						
BR 7	9·27	15·2	4·5	3·5	2·8	74·0
Heen Mineri	10·38	12·3	5·4	3·9	2·1	76·3
IPM 1006	10·77	14·4	5·6	4·2	2·3	73·5
MS 2420	10·87	13·3	5·1	4·3	2·5	74·8
MS 4872	10·20	14·8	5·3	4·2	2·4	73·3
Raum 1	9·72	16·3	6·1	3·6	2·7	71·3
Average ± SE	10·20 ± 0·25	14·4 ± 0·6	5·4 ± 0·2	3·9 ± 0·1	2·5 ± 0·1	73·8 ± 0·9
Finger Millet						
CO 10	12·54	9·5	1·5	4·5	2·7	81·8
KM 1	12·52	10·6	1·6	4·2	2·5	81·1
MI 302	12·13	9·2	1·6	4·3	3·1	81·8
Average ± SE	12·40 ± 0·13	9·8 ± 0·4	1·6 ± 0·02	4·3 ± 0·1	2·8 ± 0·2	81·5 ± 0·2
Foxtail Millet						
KHS 1	10·16	15·8	7·5	4·7	2·3	69·7
SIC 1	8·69	14·8	6·5	4·7	2·3	71·7
SIC 7	8·33	16·6	9·3	3·2	1·8	69·1
SIC 15	9·78	16·5	7·3	4·3	2·7	69·2
Average ± SE	9·24 ± 0·43	15·9 ± 0·4	7·7 ± 0·6	4·2 ± 0·4	2·1 ± 0·1	70·1 ± 0·6

[a] Each value is a mean of three determinations.

were 14·4, 9·8 and 15·9%, respectively. Compared with the protein contents of rice, wheat, corn and sorghum (FAO, 1972), these values are similar or higher. Marked varietal differences in protein contents were observed within each millet. The values of protein ranged from 12·3–16·3, 9·2–10·6 and 14·8–16·5% for common millet, finger millet and foxtail millet, respectively. Comparable data on varietal differences are lacking for common millet and foxtail millet, but the range of protein in finger millet has been reported to vary from 5·6 to 11·8% (Deosthale *et al.*, 1970; Pore & Magar, 1977).

The crude fat contents of common millet, finger millet and foxtail millet were 5·4, 1·6 and 7·7%, respectively. The values for common millet and foxtail millet are high compared to other cereal grains (FAO, 1972) and explain why these millets become rancid within a few days of milling unless stored in airtight containers. The crude fat contents of millets in this study are within the ranges reported by others (Mahadevappa & Raina, 1978; Pore & Magar, 1977; Lorenz & Hwang, 1986). Varietal differences with regard to crude fat were small.

The crude fibre content of the millets ranged from 3·2 to 4·7%, which is higher than those reported for other common cereals (FAO, 1972). The millet types differed markedly in their contents of carbohydrates. The carbohydrate content of finger millet was higher than those of the other two millets. There was very little varietal influence on the carbohydrate content.

In many parts of Asia, finger millet is often considered to be an anti-diabetic food. It is believed to contain less carbohydrate and more fibre than other common cereal foods. The results of the present study lend some support to this common claim. The carbohydrate content of finger millet is lower and the fibre content is higher than that of rice (FAO, 1972), the major staple in Asia. High fibre levels are known to depress digestibility (Spiller & Shipley, 1977; Monte, 1981) and this may partly explain the anti-diabetic effect ascribed to the finger millet.

The mineral composition and Ca:P ratio of the millets are presented in Table 3. In general, the mineral contents of the millets were high compared to those of other cereal grains (FAO, 1972). The trace minerals, particularly Fe contents, were high. Differences among and within the millets in respect of their mineral contents are also clearly evident from Table 3. Of the three millets studied, finger millet had higher contents of K, Mg and Ca. Trace mineral contents were higher in common and foxtail millets. The contents for most minerals in common millet and foxtail millet were somewhat similar.

Of particular interest is the high level of Ca in finger millet. The Ca content of finger millet (0·24%) was almost ten times higher than those of the other two millets (0·02%). The reported values of Ca for other common cereals also range from 0·01 to 0·05% (FAO, 1972). Due to its high Ca content, the

TABLE 3
Mineral Composition of Common, Finger and Foxtail Millets (dry weight basis)

Varieties	*Major minerals (g/100 g)*					*Ca:P ratio*	*Trace minerals (mg/100 g)*			
	K	*Na*	*Mg*	*Ca*	*P*		*Mn*	*Zn*	*Cu*	*Fe*
Common Millet										
BR 7	0·59	0·08	0·15	0·03	0·34	1:11·3	28	7	4	11
Heen Mineri	0·29	0·04	0·18	0·04	0·23	1: 5·8	8	15	4	28
IPM 1006	0·22	0·03	0·09	0·02	0·21	1:10·5	7	14	4	22
MS 2420	0·20	0·03	0·08	0·02	0·21	1:10·5	8	15	3	31
MS 4872	0·54	0·10	0·18	0·03	0·32	1:10·6	36	7	3	16
Raum 1	0·40	0·08	0·06	0·03	0·23	1: 7·6	27	7	4	13
Average	0·37	0·06	0·12	0·03	0·26	1: 8·6	19	11	4	20
SE	±0·07	±0·01	±0·02	±0·005	±0·02		±5	±2	±0·1	±3
Finger Millet										
CO 10	0·56	0·09	0·14	0·25	0·28	1: 1·1	6	2	3	5
KM 1	0·58	0·08	0·13	0·25	0·20	1: 0·8	4	2	4	5
MI 302	0·57	0·05	0·13	0·24	0·23	1: 0·9	4	2	4	4
Average	0·57	0·07	0·13	0·24	0·24	1: 1	5	2	4	5
SE	±0·01	±0·01	±0·005	±0·005	±0·02		±0·5	±0·0	±0·2	±0·3
Foxtail Millet										
KHS 1	0·29	0·04	0·11	0·02	0·17	1: 8·5	9	15	3	24
SIC 1	0·58	0·07	0·14	0·04	0·24	1: 0	31	8	3	24
SIC 7	0·35	0·13	0·10	0·03	0·30	1: 6	32	7	3	14
SIC 15	0·36	0·07	0·07	0·02	0·36	1:18	32	7	3	13
Average	0·40	0·08	0·10	0·03	0·27	1: 9	26	9	3	19
SE	±0·06	±0·02	±0·02	±0·005	±0·04		±6	±2	±0	±3

TABLE 4
Phytate and Oxalate Contents in Common, Finger and Foxtail Millets
(dry weight basis)[a]

Variety	*Phytic acid (g/100 g)*	*Oxalates (mg/100 g)*	
		Water soluble	*Total*
Common Millet			
BR 7	0·69	11	23
Heen Mineri	0·66	17	23
IPM 1006	0·63	15	23
MS 2420	0·50	13	22
MS 4872	0·64	11	21
Raum 1	0·53	17	23
Average ± SE	0·61 ± 0·03	14 ± 1	23 ± 0·4
Finger Millet			
CO 10	0·45	15	30
KM 1	0·49	15	29
MI 302	0·49	15	29
Average ± SE	0·48 ± 0·01	15 ± 0·0	29 ± 0·3
Foxtail Millet			
KHS 1	0·70	16	26
SIC 1	0·65	28	28
SIC 7	0·65	19	27
SIC 15	0·65	11	25
Average ± SE	0·66 ± 0·01	19 ± 4	27 ± 0·6

[a] Each value is a mean of three determinations.

Ca:P ratio of finger millet was closer to 1:1 whilst those for the other two millets range from 1:6·4 to 1:20.

The phytic acid content of the millets ranged from 0·50 to 0·70% (Table 4). Our values for common millet are higher than those reported by Lorenz (1983). The phytic acid values of millets are higher than those reported for polished rice (Toma & Tabekhia, 1979; Reddy & Salunkhe, 1980), but lower than those reported for wheat (O'Dell *et al.*, 1975) and corn (de Boland *et al.*, 1975).

In common with other cereal grains, phytic acid P constituted the major portion of total P found in the millets. The average percentages of the total P present in the phytic acid form in common millet, finger millet and foxtail millet were 67·3, 60·0 and 69·9%, respectively. For this reason, though the P content of millets is high, its availability at the absorption level would be low.

Phytic acid also has a strong binding capacity and forms insoluble complexes with multivalent cations, including Ca, Mg, Fe and Zn, and renders them biologically unavailable (Reddy *et al.*, 1982). Thus, the phytic acid present in the millets is a nutritional concern. The adverse effects of high phytate content in the millet on Ca absorption have been demonstrated by several workers (Casey & Lorenz, 1977). Kurien (1967) reported that only 43% of the Ca in finger millet was retained by rats.

The content of total oxalate (21–29 mg/100 g dry weight) was found to be low in all three millet types (Table 4). Similar small amounts of oxalates occur widely in many vegetables and fruits and do not pose a nutritional problem (Fasset, 1973). Furthermore, since about 50%–70% of the oxalates are present in the soluble form (Table 4), these could be expected to be leached out during normal cooking (Libert & Franceschi, 1987).

The results of the present analyses show that, as a source of protein, carbohydrate and minerals, the millets are comparable or superior to other common cereal grains. The mineral content of the millets is particularly high, but possible interference with mineral absorption due to their phytate content presents grounds for concern. Since the phytic acid content of foods is reported to be reduced by milling, soaking, cooking, fermentation and breadmaking (Reddy *et al.*, 1982), future studies should focus on reducing the phytic acid content in millets through such processing methods.

ACKNOWLEDGEMENTS

This study was funded by a research grant from the International Foundation of Science, Sweden. The grain samples from ICAR were kindly supplied by Dr Harinarayana, project coordinator/millets, College of Agriculture Campus, Pune 411005, India.

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