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Proximate Composition, Antinitritional Factors and Mineral Content and Availability of Selected Legumes and Cereals Grown in Sudan

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Abstract: The proximate composition, antinutritional factors and mineral content and availability of various cereals and legumes cultivars were studied. Legumes include faba bean and white bean while cereals includes millet and sorghum. Results showed that, on average, apart from protein and carbohydrate, the proximate composition of all legumes and cereals were slightly differed. The protein content of faba bean cultivars was significantly higher ($p \leq 0.05$) than those of white bean and cereals. Sorghum cultivars had significantly higher values of carbohydrate ($p \leq 0.05$) than millet and legumes cultivars. Antinutritional factors varied between cultivars and even within cereals and legumes. Phytate content varied from 233 to 991.11 mg/100g and phytate/phosphorus percent varied from 82 to 225% while polyphenols varied from 198.43 to 676.21 mg/100g. Minerals content and availability differed between the cultivars. Ca content and availability were higher in legumes compared to cereals while phosphorus content and availability were higher in cereals. White bean and millet had higher Fe content compared to other cultivars with higher availability recorded in millet. Among trace minerals, Co had a higher availability (87%) in millet cultivars compared to other ones.

Key words: Faba bean, white bean, millet, sorghum, minerals, antinutrients

INTRODUCTION

Knowledge of the chemical composition of foods is key to recommendation is used at the macro-level in planning food demand and supply, and at the micro-level in developing prescribed diets as well as in determing and correcting the nutritional value of a given diet. Sorghum comes first in volume of cereals produced. It is the staple food for people of the semiarid areas of Africa, particularly the low-income groups[1]. It is also a principal source of alcoholic beverages in many countries[2] and feed for livestock[3]. Despite the documented potential, relative to other common cereals like maize and rice, sorghum has low nutritional value and inferior organoletpic qualities [1]. Pearl millet is a staple food for a large section of the population in Asian and African countries and besides supplying calories and proteins in the diet, pearl millet is a good source of essential minerals. Legumes have a high protein content and they are an important source of cheap protein in many African countries where animal protein is expensive. These seeds are second in importance to cereals as sources of food but they are two to three times richer in protein than cereals and are often used in crop rotation and intercropping[4]. It is well recognized that food grain legumes such as common beans, lentils and kidney beans, represent the main supplementary protein source in cereal starchy food-based diets consumed by large sectors of the population living in the developing countries. Cereals and legumes are rich in minerals but the bioavailability of these minerals is usually low due to the presence of antinutritional factors such as phytate and polyphenols[5].An adequate mineral absorption is important especially for infants children, elderly people and people in clinical situation[6]. The presence of antinutritional factors such as enzyme inhibitors, hemagglutinin, flatulence factors, polyphenols, tannin and phytic acid, which inhibit the proteolytic activity of the digestive enzymes such as pepsin and trypsin as well as the availability of minerals[7]. Polyphenols can form complexes with metal cations through carboxylic and hydroxylic groups and thus interfere with the intestinal absorption of minerals[5]. Phytate content in legumes has been involved in reducing bioavailability of minerals and inhibiting the activity of several enzymes[7]. Phytate is widely distributed in plants, especially in seeds; with high concentration in mature legumes, cereal grains, and oil seeds[8,9]. In this study we would like to study the chemical composition, antinutritional factors and minerals contents and availability of cearls and legumes grown in Sudan.

MATERIALS AND METHODS

Source and germination of seeds: Seeds of millet (*Pennisetum glaucum*) cultivars Ashana and Dahabaya

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were obtained from ElObied Agricultural Corporation, Western Sudan. Sorghum (*sorghum biocolor*) cultivars (locally known as Wad Ahmed and Tabat) were obtained from Pioneer Company, Khartoum, Sudan. Faba bean *(Vicia faba l.)* cultivars (Bsabir, Hudieba-72) and white bean (*Phaseolus vulgaris*) cultivars (Serge, Giza and RO21) were obtained from Hudieba Agricultural Research Station, Sudan. The seeds were carefully cleaned and freed from broken and extraneous matter. The seeds were milled into fine flour to pass a 0.4 mm mesh size screen.

Chemical composition: Proximate composition: Protein, moisture, ether extract, ash and crude fiber contents were determined as described in the AOAC methods[10]. Carbohydrate content was determined by difference.

Total minerals determination: Minerals were extracted from the samples by dry ashing method that described by Chapman and Pratt[11]. The amount of iron, zinc, manganese, Cobalt and copper were determined using Atomic Absorption Spectroscopy (Perkin- Elmer 2380). Ammonium Vandate was used to determine phosphorus along with Ammonium Molybdate method of Chapman and Pratt [12]. Calcium and Magnisum were determined by titration method that described by Chapman and Pratt [11]. Sodium and potassium were determined by flame photometer (CORNIG EEL) according to AOAC[10] .

Hcl-extractability of minerals (*in vitro* availability): Minerals in the samples were extracted by the method described by Chauhan and Mahjan[13]. One gram of the sample was shaken with 10 mL of 0.03 M HCl for 3 h at 37 °C and then filtered. The clear extract obtained was oven dried at 100 °C and then dry acid digested. The amount of the extractable minerals was determined by the methods described above.

Phytic acid determination: Phytic acid content was determined by the method described by Wheeler and Ferrel [14] using two grams of a dried sample. A standard curve was prepared expressing the results as Fe $(NO_3)_3$ equivalent. Phytate phosphorus was calculated from the standard curve assuming 4:6 iron to phosphorus molar ratio.

Polyphenols determination: Total polyphenols were determined according to PurssionBluespectrophotometric method[15] with a minor modification. Sixty milligrams of ground sample were shaken manually for 1 min in 3.0 mL methanol. The mixture was filtered. The filtrate was mixed with 50 mL of distilled water and analysed within an h. About 3.0 mL of 0.1 M $FeCl_3$ in 0.1 M HCl were added to 1 mL of the filtrate followed immediately by timed addition of 3.0 mL of freshly prepared $K_3Fe(CN)_6$. The absorbance was monitor on a spectrophotometer (Pye Unicam SP6-550 UV) at 720 nm after 10 min from the addition of 3.0 mL of 0.1 M $FeCl_3$ and 3.0 mL of 0.008 M $K_3Fe(CN)_6$. A standard curve was prepared expressing the result as tannic acid equivalent i.e. amount of tannic acid (mg100g) which gives a color intensity equivalent to that given by polyphenols after correction for blank.

Statistical analysis: Each determination was carried out on three separate samples and analyzed in triplicate and figures were then averaged. Data was assessed by the Analysis Of Variance (ANOVA)[16]. Duncan's multiple range test was used to separate means. Significance was accepted at $p \leq 0.05$[17].

RESULTS AND DISCUSSION

Chemical composition: Cereals include sorghum and millet and legumes include faba bean and white bean. Results showed that the dry matter of the cultivars exceeded 90% except for sorghum cultivar Wad Ahmed (89.2%). Higher dry matter content was recorded for white bean cultivar, RO21 (95.8%) and sorghum cultivar, Tabat (95.3%) (Table 1). Legumes generally are very rich in protein and contained protein double that obtained for sorghum or millet cultivars. The protein content of faba bean cultivars significantly ($p \leq 0.05$) differed from that of white bean and sorghum and millet cultivars. Sorghum cultivars had the least content of protein compared to other cultivars. It has been reported that legumes have high protein content and they are an important source of cheap protein and they are second in importance to cereals as sources of food but they are two to three times richer in protein than cereals[4]. Fiber content varied between the cultivars with a maximum value obtained for faba bean cultivar, Bsabir (7.4%) and a minimum value for sorghum cultivar, Tabat (2.3%). Millet cultivar, Ashana was observed to contain higher amount of fat (6.1%) compared to legumes and other cereal cultivars with a minimum value recorded foe faba bean cultivar, Hudieba-72 (1.3%). Legumes generally were rich in ash content with a maximum value reported for white bean cultivar; Giza-3 (4.5%) while sorghum cultivar, Tabat reported minimum value (1.2%). However, sorghum cultivars were found to contain higher amount of carbohydrates (71.4 and 80.7%) followed by millet cultivars with least content in legumes. Results revealed that legumes are rich in protein, fiber and ash while cereals are rich in fat and carbohydrates. Sika *et al.*[18] reported similar results for Moroccan cereals and legumes.

Antinutritional factors: Phytate contents of the cultivars varied from 291.15 to 991.11 mg/100g while polyphenols

Table 1:Chemical composition (%) of legume and cereal cultivars

Cultivars		Dry matter	Protein	Fibre	Fat	Ash	Carbohydrate
Faba bean							
	Hudieba-72	94.0(±0.63)^{a}	29.5(±0.24)^{a}	5.7(±0.02)^{b}	1.3(±0.23)^{d}	3.3(±0.11)^{b}	54.20(±0.82)^{e}
	Bsabir	94.6(±0.16)^{a}	30.2(±0.30)^{a}	7.4(±0.34)^{a}	1.6(±0.11)^{d}	3.1(±0.02)^{b}	52.30(±0.43)^{e}
White bean	Serage	93.0(±0.40)^{b}	21.3(±0.52)^{d}	3.1(±0.01)^{d}	1.5(±0.02)^{d}	4.3(±0.27)^{a}	62.70(±0.44)^{c}
	Giza-3	94.5(±0.40)^{a}	24.9(±0.66)^{c}	4.2(±0.02)^{c}	2.1(±0.12)^{c}	4.5(±0.22)^{a}	58.70(±0.59)^{d}
	R021	95.8(±0.25)^{a}	26.8(±0.12)^{b}	4.2(±0.12)^{c}	2.5(±0.19)^{c}	4.4(±0.25)^{a}	57.80(±0.32)^{d}
Millet	Ashana	92.4(±0.03)^{b}	12.8(±0.10)^{e}	2.6(±0.05)^{e}	6.1(±0.03)^{a}	1.8(±0.01)^{c}	69.04(+0.06)^{b}
	Dahabaya	91.8(±0.06)^{b}	11.7(±0.37)^{e}	2.4(±0.06)^{e}	5.4(±0.13)^{a}	1.6(±0.01)^{c}	70.67(+0.20)^{b}
Sorghum	Wad Ahmed	89.2(±0.20)^{c}	10.8(±0.25)^{f}	2.7(±0.20)^{e}	3.5(±0.25)^{b}	1.8(±0.10)^{c}	71.40(±0.04)^{b}
	Tabat	95.3(±0.20)^{a}	7.5(±0.30)^{g}	2.3(±0.29)^{e}	3.4(±0.36)^{b}	1.2(±0.15)^{c}	80.70(±0.03)^{a}

Values are Means±SD. Means not sharing a common superscript letter in a column are significantly different at (p<0.05) as assessed by Duncan's Multiple Range test

Table 2: Antinutritional factors content (mg/100g), phosphorus and phytate/P percent of two legumes and cereals cultivars

Cultivars		Phytic acid	Phosphorus	Percent phytate/P	Polyphenols
Faba bean	Hudieba-72	291.15(±0.13)^{g}	197.0(±0.61)^{g}	148	322.08(±0.13)^{d}
	Bsabir	298.91(±6.02)^{f}	208.0(±0.12)^{e}	144	338.64(±0.06)^{c}
White bean	Serage	457.69(±5.78)^{c}	204.0(±3.61)^{f}	225	225.74(±0.04)^{f}
	Giza-3	352.51(±0.02)^{e}	210.0(±1.63)^{e}	167	676.21(±0.01)^{a}
	RO21	396.33(+0.07)^{d}	185.0(±3.71)^{h}	213	218.94(±0.01)^{g}
Millet	Ashana	969.30(±0.00)^{b}	1107.0(±1.71)^{b}	88	306.65(±2.92)^{e}
	Dahabaya	991.11(±0.00)^{a}	1148.0(±2.1)^{a}	86	445.88(±2.94)^{b}
Sorghum	Wad Ahmed	265.00(±0.30)^{h}	303.0(±2.00)^{c}	87	220.23(±0.40)^{g}
	Tabat	233.00(±0.40)^{i}	283.0(±2.31)^{d}	82	198.43(±0.60)^{h}

Values are Means±SD, 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: Total (mg100g) and available (%) major minerals of legume and cereal cultivars

		Na		K		Mg		Ca		P	
Cultivars		Total	Available	Total	Available	Total	Available	Total	Available	Total	Available
Faba bean	Hudieba-72	27(±0.2)^{b}	70(±0.2)^{b}	1037(±2.3)^{d}	8(±0.7)^{e}	255(±2.5)^{d}	22(±0.4)^{f}	427(±1.4)^{a}	34(±1.9)^{c}	197(±0.6)^{g}	8(±0.6)^{c}
	Bsabir	36 (± 1.9)^{a}	74 (± 0.3)^{a}	1031 (±1.9)^{d}	13 (± 0.2)^{d}	289 (± 2.3)^{c}	24(± 0.2)^{ef}	423 (± 0.7)^{a}	50 (±0.10)^{a}	208 (± 0.1)^{e}	2 (± 0.11)^{e}
White bean	Serage	24 (± 0.1)^{c}	36 (± 0.01)^{f}	1291 (±1.1)^{b}	12 (± 0.01)^{d}	289(± 1.7)^{c}	26 (± 1.4)^{e}	377 (± 1.4)^{b}	44(± 1.84)^{b}	204 (± 3.6)^{f}	6 (± 0.10)^{d}
	Giza-3	23 (± 0.3)^{c}	51 (± 0.55)^{e}	1151 (± 3.3)^{c}	9 (± 0.11)^{e}	311 (± 2.7)^{a}	41 (± 0.5)^{d}	346 (± 3.2)^{c}	32 (± 2.8)^{d}	210 (± 1.6)^{e}	5 (± 0.02)^{d}
	RO21	27 (± 0.2)^{b}	50 (± 0.01)^{e}	1319 (± 2.7)^{a}	13 (± 0.11)^{d}	300 (± 0.9)^{b}	38 (+ 0.1)^{d}	321 (± 0.5)^{d}	24 (± 0.9)^{e}	185 (± 3.7)^{h}	6 (± 0.2)^{d}
Millet	Ashana	16(±0.7)^{e}	73(±0.90)^{a}	434(±3.3)^{e}	71(±1.9)^{a}	93(±0.3)^{e}	56(±0.8)^{b}	53(±0.4)^{e}	32(±0.6)^{d}	1107(±1.7)^{b}	35(±0.3)^{b}
	Dahabaya	19(±0.28)^{d}	64(±1.61)^{d}	452(±1.37)^{f}	70(±0.61)^{a}	75(±1.36)^{f}	60(±2.1)^{a}	54(±0.73)^{e}	33(±0.2)^{cd}	1148(±2.1)^{a}	36(±0.3)^{b}
Sorghum	WadAhmed	6(±0.20)^{f}	67(±2.80)^{c}	450(±2.00)^{f}	46(±6.40)^{c}	59(±5.70)^{h}	46(±0.08)^{c}	11(±1.5)^{f}	33(±0.9)^{cd}	303(±2.0)^{c}	43(±1.0)^{a}
	Tabat	7(±2.0)^{f}	64(±2.20)^{d}	442(±2.4)^{g}	51(±6.7)^{b}	63(±1.0)^{g}	56(±1.6)^{b}	11(±1.5)^{f}	33(±0.9)^{cd}	283(±2.3)^{d}	45(±1.5)^{a}

Values are Means±SD, Means in a column not sharing a common superscript letter are significantly (P< 0.05) different as assessed by Duncan's multiple range test.

Table 4: Total (mg100g) and available (%) trace minerals of legume and cereal cultivars

		Na		K		Mg		Ca		P	
Cultivars		Total	Available	Total	Available	Total	Available	Total	Available	Total	Available
Faba bean	Hudieba-72	6.1(±0.1)^{d}	13(±0.4)^{e}	2.2(±0.2)^{b}	8(±0.6)^{f}	3.2(±0.4)^{a}	7(±0.5)^{e}	0.7(±0.1)^{b}	21(±1.5)^{b}	1.2(±0.1)^{c}	21(±0.2)^{h}
	Bsabir	6.3(±0.2)^{d}	18(±0.8)^{c}	2.8(±0.1)^{ab}	14(±1.2)^{e}	2.1(±0.5)^{b}	8(±0.9)^{e}	0.9(±0.5)^{a}	18(±1.0)^{c}	1.7(±0.2)^{a}	40(±0.8)^{d}
White bean	Serage	11.4(±0.1)^{a}	16(±2.7)^{d}	2.7(±0.3)^{ab}	16(±0.9)^{d}	3.8(±0.5)^{a}	5(±0.5)^{f}	0.7(±0.2)^{b}	5(±0.1)^{d}	1.6(±0.2)^{ab}	31(±0.7)^{f}
	Giza-3	9.2(±0.14)^{b}	12(±0.3)^{e}	2.6(±0.1)^{ab}	8(±1.16)^{f}	3.4(±0.7)^{a}	8(±0.7)^{e}	0.6(±0.1)^{b}	19(±0.4)^{c}	1.5(±0.2)^{b}	35(±0.5)^{e}
	RO21	9.4(±0.09)^{b}	8(±1.3)^{f}	2.6(±0.1)^{ab}	21(±2.4)^{c}	2.0(±0.3)^{b}	15(±0.2)^{d}	0.5(±0.1)^{c}	17(±0.1)^{c}	1.2(±0.1)^{c}	26(±0.4)^{g}
Millet	Ashana	10.7(±0.9)^{a}	27(±0.2)^{a}	1.8(±0.1)^{c}	43(±0.3)^{b}	1.3(±0.1)^{c}	48(±0.5)^{a}	0.6(±0.1)^{b}	25(±0.6)^{a}	0.1(±0.0)^{f}	87(±0.9)^{a}
	Dahabaya	7.5(±0.2)^{c}	24(±0.3)^{b}	1.26(±0.0)^{c}	45(±0.5)^{b}	1.6(±0.1)^{c}	46(±0.3)^{b}	0.5(±0.02)^{c}	22(±0.4)^{b}	0.06(±0.0)^{f}	87(±0.2)^{a}
Sorghum	WadAhmed	3.8(±0.1)^{e}	4(±0.4)^{h}	3.2(±0.1)^{a}	48(±0.6)^{a}	3.9(±0.3)^{a}	41(±2.3)^{c}	00.00	00.00	0.21(±0.0)^{d}	67(±2.8)^{c}
	Tabat	4.5(±0.2)^{e}	6(±0.5)^{g}	3.5(±0.2)^{a}	54(±5.7)^{a}	3.5(±0.1)^{a}	46(±4.7)^{b}	00.00	00.00	0.18(±0.02)^{e}	72(±0.6)^{b}

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

varied from 218.94 to 676.21 mg/100g (Table 2). Results of the present study were similar to those reported by Abdalla *et al.*[19] and Kheterpaul and Chauhan[20]. Significant (p≤ 0.05) variations in phytic acid and polyphenols contents among different genotypes can be attributed to both genetic and environmental conditions[8]. Legumes contained appreciably high amount of protein, which was observed to be associated with phytate content as the protein content increased, phytate levels also increased[21]. However, millet cultivars contained protein lower than that of legumes, it contained higher amount of phytate compared to legumes. For phosphorus, investigation showed a minimum value of 185.0 mg/100g and a maximum value of 1148.0 mg/100g (Table 2). Values obtained were in the range reported by Abdalla *et al.*[19] for millet cultivars. The percentage of phytic acid/total P for legume cultivars ranged from 144% to 225% with an average value greater than 100% while that of sorghum and millet from 86 to 88% and from 82 to 87%, respectively. Chauhan *et al.*[13] 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.*[21] 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[22]. Millet cultivars contained higher amount of phytate followed by whit bean, sorghum and faba bean cultivars while polyphenols were higher in white bean cultivar, Giza-3 followed by millet cultivars, faba bean, and sorghum cultivars. Results indicated that there was a good correlation between protein content and phosphorus content as indicated by higher percentage of phytate/P of legume cultivars.

Minerals content and availability: Major minerals content and availability were significantly ($p \leq 0.05$) varied between the cultivars (Table 3). Na content ranged from 6 to 36 mg/100g with a minimum value obtained for sorghum cultivar, WadAhmed and maximum one for faba bean cultivar, Bsabir while its availability ranged from 36 to 74% with a minimum value obtained for white bean cultivar, Serge and maximum one for faba bean cultivar, Bsabir. Potassium, Magnesium and Calcium contents were significantly ($p \leq 0.05$) higher in legume cultivars compared to cereals. However, the availability of such minerals except Ca was found to be significantly ($p \leq 0.05$) higher in cereals. Millet cultivars were found to be very rich in P content with availability less than 50%. Legumes recorded very low values for the available P. Lower values of available minerals may be attributed to the presence of antinutritional factors in the cultivars, which were reported to have an adverse effect on minerals bioavailability. It has been reported that cereals and legumes are rich in minerals but the bioavailability of these minerals is usually low due to the presence of antinutritional factors such as phytate and polyphenols[5]. However, millet cultivars were very rich in antinutrional factors, the availability of most major minerals was greater than the other cultivars. This difference may be attributed to qualitative differences in antinutrient between the cultivars as well as quantative differences. Trace minerals content and availability were significantly ($p \leq 0.05$) varied between the cultivars (Table 4). Fe content ranged from 3.8 to 11.4 mg/100g with a minimum value obtained for sorghum cultivar, WadAhmed and maximum one for white bean cultivar, Serge while its availability ranged from 4 to 27% with a minimum value obtained for sorghum cultivar, WadAhmed and maximum one for millet cultivar, Ashana. Zn, Mn, Cu and Co contents were significantly ($p \leq 0.05$) higher in legume cultivars compared to cereals. However, the availability of such minerals was found to be significantly ($p \leq 0.05$) higher in cereals. Lower values of available trace minerals may be attributed to the presence of antinutritional factors in the cultivars, which were reported to have an adverse effect on minerals bioavailability. It has been reported that cereals and legumes are rich in minerals but the bioavailability of these minerals is usually low due to the presence of antinutritional factors such as phytate and polyphenols [5]. However, millet cultivars were very rich in antinutrional factors, the availability of most trace minerals was greater than that of the other cultivars. This difference may be attributed to qualitative differences in antinutrient between the cultivars as well as quantative differences.

CONCLUSIONS

Investigation of different legumes and cereal cultivars indicated that legumes are good source of protein while cereals are good source of carbohydrates. Despite it contained higher amount of antinutritional factors, cereals especially millet had higher amount of available major and trace minerals compared to legume cultivars. Such informations are useful to construct food composition table.

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