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Effects of Whitening Process on the Quality of Different Grain Sorghum Hybrids

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ABSTRACT

The effect of whitening on the nutritional profile of grain sorghum was examined in this work. Three commercial hybrids, the white seeded 'Albita' and the red seeded 'Zador' along with another red-seeded hybrid check were examined. Grain samples drawn from the grain sorghum crop were whitened using the whitener part of a laboratory rice mill. Tannin content, total scavenger capacity, and total phenol content were determined in the whole grain sample, the whitened grains and the bran fraction. The concentration of essential mineral elements (N, P, K, Mg, Ca, Cu, Mn, Fe, Zn) was also measured in whole grains and whitened grains. Tannin content, scavenging capacity and phenol concentration were significantly different among the hybrids and between grain sample fractions; bran had the highest proportion of these compounds in all genotypes. Differences among hybrids with respect to mineral content were not significant in most of the examined elements. Larger differences between the hybrids were only found for N and Fe content. Whitening did not change the element content of the hybrids.

Keywords: mineral elements, phenols, tannin, total scavenger capacity
Abbreviations: DPPH, 1,1-diphenyl-2-pycrilhydrasil; **FAAS**, flame atomic absorption spectroscopy; **GAE**, gallic acid equivalent; **TE**, Trolox equivalent

INTRODUCTION

Sorghum is a C_4 crop; it is particularly adapted to warm and drought conditions of the semi-arid tropics with only 400-600 mm annual rainfall. Sorghum is also found in temperate regions. Sorghum has a good adaptation to harsh environments and is well suited to heavy soils (Dicko *et. al* 2005).

More than 35% of sorghum is grown directly for human consumption; the rest is used primarily for animal feed, alcohol production and industrial products (FAO 1995; Awika and Rooney 2004). In Hungary, sorghum is primarily grown for animal feed and the harvested area in the country is only about 3000 ha (FAO 2009). An increase in human consumption of sorghum elsewhere may also happen in Hungary because sorghum is being positioned as the favourite alternative food source for people who are allergic to gluten. Sorghum can be puffed, popped, shredded and flaked to produce ready-to eat breakfast cereals (Dicko *et al.* 2006). There are favourable conditions for growing early and middle maturity sorghum hybrids in Hungary. Sorghum cultivation would be desirable from the point of view of crop rotation as well.

Nutritionally, sorghum is comparable to most other cereals. Its starch content ranges from 60 to 70%. The proportion of non-starch polysaccharides is 2-7%, and these components are mainly located in the pericarp and endosperm cell walls (Dicko *et al.* 2006). The protein content in the whole sorghum grain is between 7 and 15% (Beta *et al.* 1995).

Sorghum is a rich source of various phytochemicals including tannins, phenolic acids, anthocyanins, phytosterols and polycosanols, which have high antioxidant activity (Awika and Roony 2004). These compounds are mostly concentrated in the pericarp of sorghum grain (Hahn *et al.* 1984; Awika and Roony 2004). The levels of phenolic acid usually do not correlate with the presence or levels of other phenols (anthocyanins or tannins). However, levels of free phenolic acids tend to be higher in sorghums with pigmented testa (containing tannins) compared to ones without pigmented testa (Waniska *et al.* 1989). Depending on their concentration, these compounds can affect colour, flavour, and nutritional quality of grains and products made from them (Hahn *et al.* 1984). Free radicals play an important role in oxidative stress (Kamath *et al.* 2004). Antioxidants reduce oxidative damage to biomolecules by modulating the effects of reactive oxidants (Duthie *et al.* 1996).

On the other hand, these properties of sorghum are being recognized as having practical health benefits. Consumption of sorghum rich in phytochemicals is thought to reduce the risk of the occurrence of certain types of cancer in humans. Sorghum has a cholesterol-lowering effect, and has benefits against cardiovascular disease (Klopfeinstein *et al.* 1981). Sorghum is also beneficial for fighting obesity because sorghums rich in tannin are widely reported to have reduced caloric availability and hence weight gain in animals (Awika and Roony 2004). Foods made from sorghums containing high tannin also have a longer passage in the stomach (Awika and Roony 2004).

In a study by Ragaee *et al.* (2006), total phenol content of sorghum, expressed as gallic acid equivalent (GAE), was reported as 4128 µg/g and DPPH (1,1-diphenyl-2-pycrilhydrasil) scavenging capacity as 195.8 µmol/g. In plants, phenols serve as natural defence against pests and diseases. Sorghum varieties/hybrids vary widely in their phenolic composition and content and both genetics and environment affect the level and kind of phenolic compounds. Sorghums grown in developed countries are mainly non-tannin types while varieties with low to moderate tannin content are widely grown in developing countries. Moreover, bird-resistant sorghum varieties with high tannin content are occasionally where birds are problematic (Awika and Roony 2004).

Tannins have antinutrient effects (Léder and Monda 1987). They bind to proteins reducing the nutritional value of grain (Griffiths 1985; Léder and Monda 1987). Tannin also chelates iron ions reducing their absorption in foods made from tannin sources (Gillooly *et al.* 1984). Cooking reduces tannin content by 18-69% (Anyango *et al.* 2011).

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Short Communication

Since tannins are concentrated in the testa layer of the grain, removal of the testa should eliminate tannins but complete removal of this layer is complicated and may result in considerable loss of the endosperm (Klopfenstein and Hoseney 1995). It also leads to low flour yield and reduced protein quality (Chibber *et al*. 1978; Reichert 1982).

In Hungary, grain sorghum is mainly grown as a fodder crop. Human utilization of grain sorghum in Hungary is very low. Sorghum is gluten-free, thus foods made from sorghum can be consumed also by persons having gluten allergy or intolerance. In Hungary, the harvested area of sorghum would be desirable from the point of view of crop rotation because sorghum can be grown under unfavourable soil conditions and in drought-stricken areas as well. The aim of our research was to examine sorghum with respect of human consumption, with special emphasis on the antioxidant and element content of sorghum grains.

MATERIALS AND METHODS

Three sorghum hybrids bred in Hungary namely, 'Albita', 'Zádor' and 'GK Emese' were included in this experiment. 'Albita' has a white pericarp while both 'Zádor' and 'GK Emese' have a red pericarp. 'GK Emese' and 'Zádor' are early maturity grain sorghum hybrids while 'Albita' is a medium-late maturity hybrid. The yield capacity of 'Zádor' is between 5 and 8 t ha^{-1} while the yields of GK Emese and 'Albita' hybrids are about 8-10 t ha^{-1}. In Hungary grain sorghum is primarily grown as a fodder crop. For the analysis, 1 g sample was removed from 50 g of homogeneous sample. Grain samples of each hybrid harvested from the 2010 batch produced in Karcag, Hungary, at the University of Debrecen RIF CAAES Karcag Research Institute, were whitened for 60 sec using a No1 Zaccaria model PAZ-1 DT laboratory testing rice mill. For the whitening process we used only the whitener part of the equipment. The whitening process involved removal of the pericarp from samples; this process resulted in 20-25% weight loss.

Data were collected on tannin content from the whole grain sample, the total phenolic content, the 1,1-diphenyl-2-pycril-hydrasil (DPPH) radical scavenging activity, the N, P_2O_5, K_2O, Ca, Mg, Cu, Mn, Fe and Zn content from both whole grain samples and whitened samples. The tannin content was measured according to the MSZ ISO 9648: 1994 Hungarian standard. DPPH radical scavenging activity was measured according to Yamaguchi *et al.* (1998). DPPH as a stable free radical reacts with antioxidants and is converted to 1,1-diphenyl-2-(2,4,6-trinitrophenyl) hydrazine. DPPH has an adsorption at 517 nm and the degree of discoloration indicates the amount of antioxidant compounds. DPPH reagent solution (0.1 mmol/l) was added to the 80% (v/v) methanol extract. Distilled water was used as the blank sample. The reaction mixture was incubated for 30 min at 37°C. The absorbance was read at 517 nm against a blank sample with a Shimadzu photometer. Calibration was done with a Trolox solution. The radical scavenging activity was measured as a decrease in the absorbance of DPPH and given in Trolox units.

Total phenolic content was measured with the Folin-Ciocalteu method according to Singleton *et al*. (1969). The 80% (v/v) methanol extracts were oxidized with Folin-Ciocalteu reagent and neutralized with Na_2CO_3 solution, resulting in a blue compound. The absorbance of the samples was measured at 750 nm with a Shimadzu photometer. Total phenolic content was calculated from a calibration curve made with gallic acid.

The mineral element content of the samples was measured according to the MSZ-08-1783:1983 Hungarian standard. N-content was measured with the Kjeldahl method, K_2O content with FES, while Mg and Ca content with flame atomic absorption spectroscopy (FAAS) after acidic (H_2SO_4-$HClO_4$) digestion. Samples were prepared with microwave digestion for microelemental analysis (Cu, Mn, Fe and Zn content) and measured with FAAS.

RESULTS AND DISCUSSION

Tannin content of sorghum grain extracts

Mean tannin content among test entries was significantly different with the white-seeded hybrid 'Albita', which had a concentration below the detection limit both in the whole grain and the whitened grain samples. Only the bran fraction from 'Albita' contained a measurable level of tannin (0.53 g/100 g) (**Table 1**). The tannin content of hybrids with a pigmented pericarp was 0.6 and 0.93 in the whole grain samples of 'Zádor' and the standard hybrid, respectively, and the variation in the whitened samples showed a similar trend. Tannin concentration was highest in the bran fraction in all hybrids with the levels ranging from 0.53 in 'Albita' to 2.32 in 'Zádor'. The standard hybrid had a mean tannin content of 2.11 in the bran. Generally, whitening reduced tannin content in the samples by 25% but it also caused sample weight loss of about 20-25%. The whitening process removes the pericarp of the sorghum grain where the tannin is concentrated mainly.

Table 1 Tannin concentration (g/100 g) in whole grain, whitened grain and bran of three Hungarian sorghum hybrids.

Hybrids	Whole grain	Whitened grain	Bran
Albita	BDL*	BDL	0.53
Zádor	0.60	0.39	2.32
Standard hybrid	0.93	0.76	2.11
Mean	0.77	0.58	1.65
$LSD_{5\%}$	0.008	0.008	0.028
†$LSD_{5\%}$ (correlation)		0.014	

$LSD_{5\%}$ (between hybrids in the average of treatments: 0.017
$LSD_{5\%}$ (between treatments in the average of hybrids: 0.008
*Below the detection limit

Table 2 Total phenolic content of sorghum hybrids as gallic acid equivalent (GaE) mg/g of extract.

Hybrids	Whole grain	Whitened grain	Bran
Albita	487.17	444.1175	3791.165
Zádor	6860.27	4592.73	23083.57
Standard hybrid	10211.72	7285.50	23383.33
mean:	5853.05	4107.45	16752.69
$LSD_{5\%}$	232.03	196.56	561.79

$LSD_{5\%=}$ 302.20 µg GaE mg/g (correlation)
$LSD_{5\%}$ (between hybrids in the average of treatments: 357.32
$LSD_{5\%}$ (between treatments in the average of hybrids: 174.47

Total phenolic content of different sorghum grain extracts

The total phenolic content of 'Albita' was lower than the total phenolic content of the two red hybrids (**Table 2**). Total phenol content of 'Albita' was < 500 µg/100 g GAE. The whitening process reduced the total phenolic content of 'Albita' by 9%. The total phenol content of the red pericarp hybrids ranged from 4500 to 10211 µg/100 g GAE. Similarly, the total phenolic content of the standard hybrid was the highest among the examined hybrids. The whole grains of the standard hybrid contained 10,211 µg/100 g GAE and the whitening process reduced it to 7285.50 µg/100 g GAE. As a result of whitening, the total phenolic content of 'Zádor' and the standard hybrid was significantly reduced. The total phenolic content of the bran of hybrids with a red pericarp was higher than 23,000 µg/100 g GAE.

DPPH radical scavenging activity of different sorghum grain extracts

DPPH radical scavenging activity and total phenolic content are important factors determining antioxidant activity. Similarly to tannin content and total phenolic content, DPPH radical scavenging activity was lowest in 'Albita'. DPPH radical scavenging activity of whitened 'Albita' grains was below the detection limit (**Table 3**), and DPPH radical scavenging activity of whole grains (38.02 TE µg/g) and bran was also low (216.42 TE µg/g). This parameter of the standard Hungarian bred hybrid was highest; this hybrid had the highest tannin content and total phenolic content as well. The DPPH radical scavenging activity of the red hybrids ranged between 863.97 and 626.24 µg/g as trolox units in

Table 3 DPPH (1,1-diphenyl-2-pycril-hydrasil) radical scavenging activity in different sorghum hybrids grain extracts as trolox equivalent (TE) µg/g.

Hybrids	Whole grain	Whitened grain	Bran
Albita	38.02	BDL*	216.42
Zádor	863.97	626.24	2814.195
Standard hybrid	1099.94	1320.02	2769.17
Mean	667.31	973.13	1933.26
$LSD_{5\%}$	38.56	17.32	83.33

$LSD_{5\%=}$ 51.09 (correlation)
$LSD_{5\%}$ (between hybrids in the average of treatments): 60.41
$LSD_{5\%}$ (between treatments in the average of hybrids: 29.50
*below the detection limit

Table 4 Element content of the different sorghum hybrids.

Elements		Whole grain			$LSD_{5\%}$
		Albita	Zádor	Standard	
N	%	1.53	1.58	1.26	0.096
P_2O_5	%	0.63	0.83	0.69	0.094
K	g/100 g	0.34	0.43	0.37	0.042
Ca	g/1000 g	0.59	0.51	0.61	0.491
Mg	g/1000 g	1.24	1.37	1.07	0.274
Cu	mg/1000 g	7.88	7.48	4.50	0.935
Mn	mg/1000 g	17.65	20.03	23.75	4.596
Fe	mg/1000 g	141.77	89.53	59.00	65.346
Zn	mg/1000 g	14.13	14.80	19.00	65.346
		Whitened grain			$LSD_{5\%}$
		Albita	Zádor	Standard	
N	%	1.63	1.70	1.16	0.144
P_2O_5	%	1.02	1.13	0.75	0.480
K	g/100 g	0.50	0.51	0.39	0.202
Ca	g/1000 g	0.79	0.35	0.40	0.700
Mg	g/1000 g	2.06	1.58	1.11	0.596
Cu	mg/1000 g	8.73	8.10	9.65	3.915
Mn	mg/1000 g	18.83	21.90	28.58	6.370
Fe	mg/1000 g	35.08	35.83	41.25	9.542
Zn	mg/1000 g	15.33	17.08	20.70	4.657

whole grain. The whitening process reduced the DPPH radical scavenging activity of 'Zádor' from 863.97 to 626.24 TE µg/g, but this parameter of the standard hybrid increased to 1320 µg/g as trolox unit.

Element contents of different sorghum grain extracts

Whitening did not change the mineral element contents of the different sorghum hybrids although it decreased the Fe content of grains. However, in 'Albita' and 'Zádor', a significant difference between whole and whitened grains was found (**Table 4**). The Fe content of 'Albita' was higher than that of the standard hybrid in whole grains (141.77 mg/1000 g). The Fe content of 'Zádor' was reduced from 89.53 to 35.83 mg/1000 g. The Fe content of the standard hybrid was reduced slightly.

The N-content of 'Albita' and 'Zádor' was significantly higher than the standard hybrid both in whole and in whitened grains. The N content of 'Albita' and 'Zádor' was 1.53 and 1.58% and whitening increased it to 1.63 and 2.70%. N content of the standard hybrid was between 1.16 and 1.26%.

Further investigations should be carried out regarding the differences in mineral element content between the hybrids and the whitened and whole grains.

CONCLUSIONS

We found that the whitening process decreased the tannin content, the total phenolic content and the DPPH radical scavenging activity significantly, while the element contents did not show significant changes. These compounds were concentrated in the bran.

The tannin content, the total phenolic content and the DPPH radical scavenging activity of 'Albita' hybrid was significantly lower than that of the standard and Zádor. This result can be explained with the tannin-free feature of the white coloured grains followed by a lower antioxidant content.

From the point of view of the food industry, 'Albita' can be consumed without limitation both in whitened form and whole grain. However, because of the low antioxidant content it has a moderate antiradical effect. 'Zádor' with a red pericarp has high antioxidant content and its tannin content falls into the medium range (<1%). In our opinion this hybrid could be considered as a functional food on the basis of its antioxidant and gluten-free features, especially in an anti-obesity diet where a moderate tannin content is favored.

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