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Effect of Soaking, Cooking, Germination and Fermentation Processing on Proximate Analysis and Mineral Content of Three White Sorghum Varieties (*Sorghum bicolor* L. Moench)

Abd El-Moneim M. R. AFIFY[1], Hossam S. EL-BELTAGI[1,2*], Samiha M. ABD EL-SALAM[3], Azza A. OMRAN[3]

[1]*Cairo University, Faculty of Agriculture, Department of Biochemistry, P. Box 12613, Gamma St, Giza, Cairo- Egypt*

[2]*King Saudi University, Vice-Rectorate for Graduate Studies and Research, SUDLS, Riyadh 11451, Kingdom of Saudi Arabia; lbltg@yahoo.com (*corresponding author)*

[3]*Agricultural Research Center, Food Technology Research Institute, Department of Crops Technology, Egypt*

Abstract

The changes in chemical composition, amylose and minerals content after soaking, cooking, germination and fermentation of three white sorghum varieties, named 'Dorado', 'Shandaweel-6', and 'Giza-15' were investigated. The chemical composition concluded including crude protein, oils, crude fiber and ash. Crude protein content ranged from 10.62 to 12.46% in raw sorghum. 'Shandaweel-6' was the highest variety in crude protein content (12.46%). 'Dorado' was the highest variety in oils and ash (3.91 and 1.45%). 'Shandaweel-6' was the highest variety in crude fiber (1.85%). Amylose content ranged from 18.30 to 20.18% in raw sorghum. Amylose was higher in 'Giza-15' than other varieties. Minerals content *i.e.*, Zn, Fe, Ca, K, Na, Mg, Mn and Cu were investigated. Results indicated that raw 'Dorado' was the highest variety in K, Mg, Ca, Fe and Mn (264.53, 137.14, 33.09, 7.65 and 1.98 mg/100g). While, 'Shandaweel-6' was the highest variety in Zn and Cu (5.02 and 0.84 mg/100 g). Finally 'Giza-15' was the highest variety in P and Na (381.37 and 119.29 mg/100 g). After treatments chemical composition, amylose and minerals were decreased. Processing techniques reduce the levels of antinutritional organic factors, which including phytates, phenols, tannins and enzyme inhibitors by releasing exogenous and endogenous enzymes such as phytase enzyme formed during processing.

Keywords: amylose, chemical composition, minerals, processing, sorghum

Introduction

Sorghum (*Sorghum bicolor* [L.] Moench) one of the most important weaning foods in low-income and high-income countries (Abdel-Rahim and El-Beltagi, 2010; Lonnerdal, 2000; Shallan, 2010a,b; Shehab *et al.,* 2010). It is the king of cereals and is one of the important food crops in dry lands of tropical Africa, India and China (Shobha *et al.*, 2008) as well as Egypt. Sorghum is considered as one of the most adapted summer grain crops to drought and heat; therefore, more than 70% of cultivated area with sorghum is located in Upper Egypt Assiut, Sohage and Fayoum. Sorghum cultivated area in Egypt is about 158,000 hectare producing 880,000 tons of grains with an average of 5.7 tons/ha (FAO, 2009).

The nutrient composition of sorghum indicates that it is a good source of energy, proteins, carbohydrates, vitamins and minerals including the trace elements, particularly iron and zinc, except calcium. Sorghum grain contains minerals such as phosphorus, potassium and magnesium in varying quantities (Dicko *et al.*, 2006).

Deficiencies in iron, iodine, vitamin A and zinc are still major public health problems in developing countries (Müller and Krawinkel, 2005). About 2 billion people are deficient in zinc, billion have iron-deficiency anemia (Black, 2003; Shali *et al.,* 2004; Yip and Ramakrishnan, 2002).

Traditional treatments such as soaking, cooking, germinating and fermenting have been used to improve nutritional quality of the legume (Kayodé, 2006; Traoré *et al.*, 2004).

Food processing technologies can contribute also to the alleviation of micronutrient deficiencies. One of these, germination which is widely used in legumes and cereals to increase their palatability and nutritional value, particularly through the breakdown of certain antinutrients, such as phytate and protease inhibitors (Afify *et al.*, 2011a, 2012a,b). Process operations that reduce the level of antinutritional factors and that minimize the losses of micronutrients are of interest. Mechanical, thermal or biological processes have the potential to improve the nutrient availability in foods (Kayodé, 2006; Steiner *et al.*, 2007).

Wet processing including soaking, germination and fermentation leads to a reduction in phytic acid and increases of the minerals solubility in foods and could thus improve bioavailability of minerals in cereals and legumes

(Afify *et al*., 2011a). The most effective treatments are fermentation and germination (El Maki *et al.*, 2007; Elkhalifa and Bernhardt*,* 2010; Liang *et al.*, 2008).

The objective of this study was to investigate the changes in chemical composition, amylose and minerals content after soaking, cooking, germination and fermentation of three white sorghum varieties as well as improving the availability of minerals.

Materials and methods

Samples and chemicals

Three white sorghum varieties (*Sorghum bicolor* L. Moench), were obtained from the Crops Research Institute, Agricultural Research Center for 'Shandaweel-6', and from Central Administration for Seed Certification (CASC), Ministry of Agriculture and Land Reclamation, Giza, Egypt for 'Dorado' and 'Giza-15'. The grains were carefully cleaned and freed from broken grains and extraneous matter. α-amylase was obtained from Sigma- Aldrich Chemical Co., St. Louis, USA. All chemicals used were of analytical reagent grade.

Treatments

For soaking, sorghum grains were soaked in distilled water for 20 h with a ratio 1:5 w/v and the soaked water changed twice. At the end of soaking period, the soaked water was discarded. The grains were rinsed twice with distilled water and dried in drying oven at 45±5°C. The dried soaked grains were milled and kept at -20°C until analysis. Different treatments were carried out on the soaked grains.

For cooking, soaked grains were cooked by boiling in sufficient amounts of distilled water for 10 min, then submerged in distilled water, and finally dried, milled and kept until analysis.

For germination, soaked grains were germinated, placed in plastic boxes, covered with cotton cloth and left at room temperature for 72 h, and then the germinated grains were dried. The root and shoot portions were manually removed. The grains were milled and kept until analysis.

For fermentation, whole meal flour which obtained from dried soaked grains was cooked by boiling with sufficient amount of distilled water for 10 min. Then the obtained slurry were dried, milled and kept at -20°C until analysis.

Proximate analysis

Moisture, protein, oils, crude fiber and ash contents of the raw sorghum and treatments were determined according to the methods of AOAC (2000). Total carbohydrate was calculated by difference. The estimated parameters were related to the untreated sorghum.

Determination of amylose content

Amylose was determined using the method outlined by Juliano (1971). 0.1 g sample was weighed accurately and putted into 100 ml Erlenmeyer flask, and 1 ml 95% ethanol and 9 ml 1 N NaOH were added. The samples were heated for 10 min in a boiling water bath to gelatinize the starch then were cooled and transferred into 100 ml volumetric flask and brought up to volume with distilled water. Five milliliters of the solution were pipetted into a 100 ml volumetric flask and 1 ml acetic acid (1N) and 2 ml iodine solution (0.2 g iodine and 2.0 g KI in 100 ml of aqueous solution) were added and the volume was made up to 100 ml and left for 20 min. The absorbance was measured at 620 nm by using spectrophotometer. Amylose content was determined by reference to a standard curve by using amylose standard. Amylose content was expressed as g/100g dwt.

Determination of minerals

Two gram of sample was weighed and heated at 550°C. Then the ashes were dissolved with 100 ml 1M HCl. Dissolved ash was analyzed for zinc, iron, calcium, manganese, copper, potassium, sodium and magnesium contents by using methods of AOAC (2000). Perkin Elmer (Model 3300, USA) Atomic Absorption Spectrophotometer was used to determine these minerals. Phosphorus was determined in dissolved ashes according to the method of Trough and Mayer (1939).

Statistical analysis

For the analytical data, mean values and standard deviation are reported. The data obtained were subjected to one-way analysis of variance (ANOVA) and least significant difference (LSD) at $p<0.05$.

Results and discussion

Protein content

Tab. 1 present crude protein content in sorghum before and after treatments. Tab. 1 presents crude protein and free amino acids content in sorghum before and after germination. Protein content ranged from 10.62 to 12.46% in raw sorghum varieties. Protein was significantly higher in 'Shandaweel-6' while 'Giza-15' was the lowest one. These results are in agreement with Dicko *et al.* (2006) and Johnson *et al.* (2010) who found that crude protein content in whole sorghum grain is ranged from 7 to 15% or 10.30 to 14.90%. Moreover, Hamad (2007), Okrah (2008) and Chung *et al.* (2011) reported that sorghum protein content varied from 9.06 to 18.58%, 8.32 to 11.82% and 11.23 to 13.42%, respectively.

The crude protein was decreased after treatments compared with raw sorghum. These results are agreed with Shaker *et al.* (1995) who reported that nutrients loss might be attributed to the leaching of soluble nitrogen, mineral and other nutrients into desired solution. Furthermore, Afify *et al.* (2012b) showed that after germination of white sorghum varieties, crude protein was decreased and free amino acids were increased. There was an increase in valine and phenylalanine amino acids contents and increase in protein solubility after germination. Regarding protein fractions, there was an increase in albumin, globulin and kafirin proteins and a decrease in cross linked kafirin and cross linked glutelin after germination. Also, *in vitro* protein digestibility was significantly increased after germination treatment.

Oils content

Oils content of sorghum before and after treatments presented in Tab. 1. Oil content ranged from 3.58 to 3.91% in raw sorghum and 'Dorado' variety represents the highest value. Sorghum contains 3.39-3.62% and 3.23-3.78%, oil in Sudan and Korea respectively while Nigerian sorghum had 3.90% oil (Adeyeye and Ajewole, 1992; Chung *et al*., 2011; Hamad, 2007). Oil contents were decreased after cooking, germination and fermentation. Results are in agreement with Okrah (2008) who found that oil content of germinated sorghum varied from 1.44-2.57%, while in other study; soaking and fermentation reduce oil content (El Maki *et al*., 2007). The reduction may be due to the fact that biochemical and physiological changes occurred during germination; such changes require energy to proceed, and therefore part of the seed oil was utilized for the production of this energy (Afify *et al.,* 2011b; El-Beltagi and Mohamed, 2010; El-Beltagi, 2011; El-Beltagi *et al.,* 2011). Germination and cooking processes caused significant decreases in oil content (Mubarak, 2005).

Afify *et al.* (2012c) mentioned that *Sorghum bicolor* varieties could be additional sources of edible oil due to presence of clinically important saturated and high concentration of unsaturated fatty acids. Sorghum oil contains 13.33 to 14.94% and 85.06 to 86.67% of SFA and Un SFA, respectively. Most of fatty acids percentage changed after soaking, cooking, germination and fermentation.

Crude fiber content of sorghum at different treatments

Results in Tab. 1 demonstrate that crude fiber contents ranged from 1.50 to 1.85% in raw sorghum while, 'Shandaweel-6' represents the highest value and significantly different than the other two varieties. These results are in agreement with Moharram and Youssef (1995) mentioned that crude fiber content of sorghum grains differ from 0.90-4.20. These findings are close to Pontieri *et al.* (2011) who found that crude fiber content ranged from 0.99 to 1.71 in different sorghum varieties. On the other hand, Hamad (2007) and Chung *et al.* (2011) reported that sorghum crude fiber ranged from 1.21 to 1.39% and 1.83-2.82%, respectively.

After different treatments, crude fiber content was non significantly decreased except for cooked 'Shandaweel-6' and fermented sorghum which were significantly reduced. Changes in fiber content may attribute to the fact that part of the seed fiber may be solubilized enzymatically during seed germination (El Maki *et al*., 1999). Alemu (2009) observed that sorghum crude fiber was decreased after fermentation.

Ash content

Concerning ash content, the data in Tab. (1) showed that ash ranged from 1.43 to 1.45% in raw sorghum and 'Dorado' represents the highest value. These results are in

Tab. 1. Proximate analysis of sorghum at different treatments (% on dwt)*

Treatments	Moisture	Crude protein	Fat	Crude fiber	Ash
Raw					
'Dorado'	8.38±0.12[b]	10.90±0.14[c]	3.91±0.25[ab]	1.50±0.01[cde]	1.45±0.01[ab]
'Shandaweel-6'	8.76±0.11[a]	12.46±0.11[a]	3.66±0.15[bc]	1.85±0.02[a]	1.43±0.04[ab]
'Giza-15'	8.48±0.22[b]	10.62±0.20[cd]	3.58±0.22[c]	1.60±0.02[bcd]	1.44±0.01[ab]
Soaking					
'Dorado'	6.07±0.06[e]	10.57±0.31[d]	4.10±0.27[a]	1.40±0.01[def]	1.32±0.01[c]
'Shandaweel-6'	6.56±0.20[c]	12.30±0.01[ab]	3.78±0.01[bc]	1.76±0.08[ab]	1.26±0.01[d]
'Giza-15'	6.18±0.09[de]	9.82±0.06[f]	3.53±0.22[c]	1.50±0.19[cde]	1.42±0.04[b]
Cooking					
'Dorado'	6.55±0.10[c]	10.40±0.10[de]	2.13±0.05[e]	1.35±0.06[efg]	1.30±0.04[c]
'Shandaweel-6'	6.55±0.10[c]	12.16±0.08[a]	2.46±0.05[d]	1.63±0.10[bc]	1.22±0.04[de]
'Giza-15'	6.35±0.01[cd]	9.77±0.29[f]	2.31±0.21[de]	1.51±0.18[cde]	1.43±0.02[ab]
Germination					
'Dorado'	6.37±0.05[cd]	10.25±0.20[e]	1.70±0.09[f]	1.62±0.20[bc]	1.42±0.03[b]
'Shandaweel-6'	5.82±0.11[f]	12.10±0.10[b]	2.28±0.11[de]	1.90±0.14[a]	1.20±0.07[i]
'Giza-15'	5.33±0.10[g]	9.77±0.09[f]	1.66±0.04[f]	1.74±0.21[ab]	1.49±0.01[a]
Fermentation					
'Dorado'	5.45±0.14[g]	10.62±0.12[cd]	1.39±0.04[g]	1.15±0.08[g]	1.07±0.01[g]
'Shandaweel-6'	5.35±0.13[g]	12.07±0.15[b]	1.36±0.03[g]	1.35±0.04[efg]	1.23±0.02[de]
'Giza-15'	5.43±0.05[g]	10.38±0.16[de]	1.25±0.03[g]	1.24±0.01[fg]	1.19±0.04[ef]
LSD	0.1964	0.2745	0.2555	0.1995	0.0557

* dwt basis= dry weight basis. Values are mean of three replicates ±SD, number in the same column followed by the same letter are not significantly different at 0.05 level

agreement with Moharram and Youssef (1995) mentioned that ash and crude fiber contents of sorghum grains differ from 1.30-3.40 and 0.90-4.20%, respectively. Pontieri *et al*. (2011) who found that ash content ranged from 0.77 to 1.39% in different sorghum varieties. Morover, Chung *et al.* (2011) found that 1.43 to 1.92%. On the other hand, Hamad (2007) reported that sorghum ash ranged from 1.51-2.06%.

After treatments, ash content was decreased than raw sorghum. These results are in agreement with Okrah (2008) who found that ash content of germinated sorghum varied from 0.28-1.70%. Gernah *et al*. (2011) found that germination of grains decrease ash content. While, Mubarak (2005) reported that germination and cooking processes caused significant decreases in ash content. Alemu (2009) observed that sorghum ash was significantly decreased after fermentation.

Amylose content

Tab. (2) displays amylose content of sorghum before and after treatments. Amylose content ranged from 18.30 to 20.18% in raw sorghum. Amylose was higher in 'Giza-15' than other varieties. Results are in agreement with Wong *et al.* (2010) who reported that sorghum amylose content ranged from 5.70% to 31.90% in different sorghum varieties. Singh *et al.* (2010) found that sorghum amylose content ranged from 11.20 to 28.50% in different sorghum varieties.

After different treatments, amylose content ranged from 17.77 to 19.98%, 17.04 to 17.72%, 16.51 to 17.82% and 17.59 to 18.02% depending on the type of treatment; for soaking, cooking, germination and fermentation treatments, respectively.

Tab. 2. Amylose content of sorghum at different treatments (g/100 g dwt)

Treatments	Amylose
Raw	
'Dorado'	18.30±0.11^{bc}
'Shandaweel-6'	19.25±1.25^{ab}
'Giza-15'	20.18±0.51^{a}
Soaking	
'Dorado'	17.77±0.19^{cd}
'Shandaweel-6'	18.60±0.60^{bc}
'Giza-15'	19.98±0.11^{a}
Cooking	
'Dorado'	17.04±0.41^{de}
'Shandaweel-6'	17.65±0.46^{cd}
'Giza-15'	17.72±0.52^{cd}
Germination	
'Dorado'	16.51±1.11^{e}
'Shandaweel-6'	17.59±0.14^{cd}
'Giza-15'	17.82±0.04^{cd}
Fermentation	
'Dorado'	17.59±0.37^{cd}
'Shandaweel-6'	18.02±0.53^{cd}
'Giza-15'	17.70±0.30^{cd}
LSD	0.9293

Values are mean of three replicates ±SD, number in the same column followed by the same letter are not significantly different at 0.05 level

Hotz and Gibson (2007) reported that α-Amylase activity is also increased during germination of cereals, especially sorghum and millet. This enzyme hydrolyzes amylose and amylopectin to dextrin's and maltose, while simultaneously enhancing their energy and nutrient densities. Osungbaro *et al.* (2010) observed a decrease in amylose content of fermented sorghum flour.

Macro- elements content

Tab. 3 shows macro- elements content *i.e.*, phosphorus (P), potassium (K), magnesium (Mg), sodium (Na) and calcium (Ca) of sorghum before and after different treatments. Results indicated that raw 'Dorado' was the highest variety in K, Mg and Ca (264.53, 137.14 and 33.09 mg/100 g). While, 'Giza-15' was the highest variety in P and Na (381.37 and119.29 mg/100 g). In addition Tab. 3 shows the values of total phosphorus of raw sorghum which varied from 334.46 to 381.37 mg/100 g dwt. Adeyeye and Ajewole (1992) and Ragaee *et al.* (2006) found that sorghum contains 278.0 and 349.9 mg/100 g for P, 239.9 mg/100 g for K, 187.7 and 195.0 mg/100 g for Mg and 24.3 and 27.3 for Ca, respectively. Hamad (2007) found that raw sorghum contain 198.80 to 387.78 mg/l00 g potassium and 5.17 to 11.26 mg/100 g calcium. Macro-elements content were decreased after treatments.

Macro-elements content were decreased after treatments. Alemu (2009) reported that sorghum phosphorus and calcium were decreased after fermentation.

Micro- elements content

Tab. 4 shows micro- elements content *i.e.*, iron (Fe), zinc (Zn), manganese (Mn) and cupper (Cu) of sorghum before and after treatments. Results indicated that raw 'Dorado' was the highest variety in Fe and Mn (7.65 and 1.98 mg/100 g). While 'Shandaweel-6' was the highest variety in Zn and Cu (5.02 and 0.84 mg/100 g).

From Tab. 4, it could be noticed that the Fe content ranged from 5.54 to 7.65 mg/100 g for raw sorghum, while the Zn content ranged from 3.99 to 5.02 mg/100 g raw sorghum, these findings are in agreement with those findings of Jambunathan (1980) who reported that Fe content ranged from 2.60 to 9.60 mg/100 g in samples of about 100 varieties of sorghum. Kayodé (2006) reported that Fe concentration of the sorghum grains ranged from 3.00 to 11.30 mg/100 g while Zn concentration ranged from 1.10 to 4.40 mg/100 g. In general, cereals high in phytate tend to have higher iron content. Adeyeye and Ajewole (1992) and Ragaee *et al.* (2006) found that sorghum contains 1.80 and 1.2 for Mn and 0.3 and 0.2 mg/100 g for Cu, respectively. Hamad (2007) found that raw sorghum contain 3.43 to 4.58 mg/100 g iron and l.48 to 2.78 mg/100 g zinc. Micro-elements content were decreased after treatments. Lestienne *et al.* (2005) reported that up to 40% of Fe content of sorghum grain may be lost as a result of

Tab. 3. Macro-elements content of sorghum at different treatments (mg/100 g dwt)*

Treatments	P	K	Mg	Na	Ca
			Raw		
'Dorado'	376.09±3.03^{a}	264.53±4.05^{a}	137.14±5.38^{a}	110.95±2.50^{b}	33.09±3.09^{a}
'Shandaweel-6'	334.46±1.89^{c}	230.20±2.71^{c}	120.10±0.50^{d}	70.56±0.60^{e}	26.59±0.21^{b}
'Giza-15'	381.37±4.51^{a}	259.03±5.50^{a}	131.02±2.69^{b}	119.29±0.80^{a}	22.91±3.10^{c}
			Soaking		
'Dorado'	358.65±3.00^{b}	248.43±5.76^{b}	126.35±3.03^{bc}	70.48±0.60^{e}	26.74±1.47^{b}
'Shandaweel-6'	275.75±5.39^{f}	163.92±4.57^{g}	108.13±3.75^{f}	69.09±2.32^{e}	18.90±1.69^{de}
'Giza-15'	300.73±3.99^{d}	229.90±2.50^{c}	126.71±3.08^{b}	108.09±3.81^{b}	16.51±0.60^{ef}
			Cooking		
'Dorado'	298.21±4.58^{e}	184.01±3.24^{e}	101.78±2.78^{g}	78.15±4.45^{d}	13.15±3.09^{fg}
'Shandaweel-6'	201.39±1.44^{j}	121.99±3.71^{i}	114.03±0.50^{e}	65.87±3.52^{e}	16.74±3.58^{ef}
'Giza-15'	249.28±3.13^{g}	172.33±4.01^{f}	119.75±2.88^{de}	84.19±4.77^{c}	14.58±0.35^{fg}
			Germination		
'Dorado'	235.50±5.00^{h}	150.36±5.75^{h}	153.95±3.89^{h}	127.68±2.62^{b}	12.50±1.68^{g}
'Shandaweel-6'	203.14±4.43^{j}	103.18±3.04^{j}	87.14±5.18^{i}	55.79±3.94^{f}	12.50±1.68^{g}
'Giza-15'	275.55±2.80^{f}	153.95±3.89^{h}	127.68±2.62^{b}	49.20±2.74^{g}	18.79±0.10^{de}
			Fermentation		
'Dorado'	254.24±1.50^{g}	194.61±2.16^{d}	100.67±2.24^{g}	56.70±2.35^{f}	20.77±0.93^{cd}
'Shandaweel-6'	200.00±2.82^{j}	126.23±4.10^{i}	97.62±4.75^{gh}	55.06±4.28^{f}	16.83±0.71^{ef}
'Giza-15'	221.31±3.19^{i}	180.04±3.00^{e}	120.60±1.50^{cd}	21.95±2.88^{h}	15.75±0.73^{efg}
LSD	5.75	6.44	5.76	4.87	3.54

*mg/100 g dwt= mg per 100 gram dry weight. Values are mean of three replicates ±SD, number in the same column followed by the same letter are not significantly different at 0.05 level

soaking. The zinc content also decreased significantly, but the reduction did not exceed 30% except on Zn content of 'Shandawell-6'.

Reduction after soaking may be attributed to leaching of iron and zinc ions into the soaking medium (Saharan *et al.*, 2001). Viadel *et al.* (2006) found that cooking processes affect mineral contents and their solubility and also the contents of other components that can affect mineral solubility. Alemu (2009) reported that sorghum iron and zinc content were decreased after fermentation. The bio-

Tab. 4. Micro- elements content of sorghum at different treatments (mg/100gdwt)*

Treatments	Fe	Zn	Mn	Cu
		Raw		
'Dorado'	7.65±0.71^{a}	4.43±0.05^{ab}	1.64±0.04^{b}	0.55±0.08^{cdef}
'Shandaweel-6'	6.84±0.32^{a}	5.02±0.25^{a}	1.29±0.17^{de}	0.71±0.08^{abc}
'Giza-15'	5.54±1.82^{b}	3.44±0.02^{cd}	1.11±0.05^{fg}	0.53±0.02^{cdef}
		Soaking		
'Dorado'	5.19±0.08^{bc}	3.78±0.33^{bcd}	1.64±0.04^{b}	0.55±0.08^{cdef}
'Shandaweel-6'	4.10±0.17^{de}	3.68±0.48^{cd}	1.29±0.17^{de}	0.71±0.08^{abc}
'Giza-15'	3.98±0.60^{de}	3.44±0.02^{cd}	1.11±0.05^{fg}	0.53±0.02^{cdef}
		Cooking		
'Dorado'	5.19±0.08^{bc}	3.72±0.58^{bcd}	1.06±0.01^{fgh}	0.48±0.06^{defg}
'Shandaweel-6'	4.10±0.17^{de}	3.26±0.21^{cd}	0.99±0.02^{gh}	0.53±0.10^{cdef}
'Giza-15'	3.98±0.60^{de}	3.42±0.03^{cd}	0.89±0.02^{h}	0.56±0.02^{cdef}
		Germination		
'Dorado'	4.71±0.40^{bcd}	3.34±0.03^{cd}	1.06±0.01^{fgh}	0.53±0.02^{cdef}
'Shandaweel-6'	4.16±0.87^{cde}	3.45±0.32^{cd}	0.94±0.01^{gh}	0.66±0.10^{bcd}
'Giza-15'	3.41±0.39^{e}	3.12±0.59^{d}	0.93±0.04^{gh}	0.61±0.03^{bcde}
		Fermentation		
'Dorado'	3.66±0.48^{de}	3.29±0.54^{cd}	0.99±0.02^{fgh}	0.38±0.15^{fg}
'Shandaweel-6'	3.95±0.37^{de}	3.05±0.06^{d}	0.98±0.01^{gh}	0.43±0.16^{efg}
'Giza-15'	3.81±0.30^{de}	3.33±0.11^{cd}	1.03±0.01^{fgh}	0.35±0.03^{g}
LSD	1.0476	0.6631	0.1552	0.1602

*mg/100 gdwt= mg per 100 gram dry weight; Values are mean of three replicates ±SD, number in the same column followed by the same letter are not significantly at 0.05 level availability of iron and zinc were significantly improved as a result of soaking and germination treatments (Afify *et al.*, 2011a).

Conclusions

Based on the results, it could conclude that soaking, cooking, germination and fermentation of sorghum grains is a traditional and simple methods for handling sorghum. 'Shandaweel-6' was the highest variety in crude protein content. 'Dorado' was the highest variety in oil and ash. While, 'Shandaweel-6' was the highest variety in crude fiber. Amylose was higher in 'Giza-15' than other varieties. Besides, raw 'Dorado' was the highest variety in K, Mg, Ca, Fe and Mn. While 'Shandaweel-6' was the highest variety in Zn and Cu. Finely 'Giza-15' was the highest variety in P and Na. After treatments chemical composition, amylose and minerals were decreased. Processing techniques such as soaking, cooking, germination and fermentation reduce the levels of antinutritional organic factors, which including phytates, phenols, tannins and enzyme inhibitors by releasing exogenous and endogenous enzymes such as phytase enzyme formed during processing. Therefore processing increase bioavailability of minerals especially iron and zinc and increase protein digestibility and this could increase great attention of sorghum as a source of food.

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