Physico-Chemical, Nutritional and Anti-Nutritional Composition of Sorghum Varieties

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Abstract

In Ethiopia, sorghum is the third most important staple cereal crop after teff and maize. In addition, it is mostly used to make Injera and Tella, which are Ethiopian traditional food and alcoholic beverage, respectively. It is also a good source of energy, protein and minerals. In the present study, 35 sorghum varieties were used and subjected to physicochemical and nutrient analysis. The physicochemical and nutritional parameters of sorghum, such as moisture, ash, crude fat, crude protein, total fiber, total carbohydrate, food energy value and anti-nutritional factors, such as tannic acid (tannin), were analyzed. The results showed that most physio-chemical and nutritional values were significantly different ($p \leq 0.05$) for varieties. The moisture content ranged from 9.661 to 12.937 %; ash value from 1.119 to 2.294%, crude fat from 2.481-4596 %, crude fiber from 2.1655 - 8.5865% and protein from 8.201-16.476%. Total carbohydrate and food energy values were found to be 67.558-76.413 % and 329.05-364.24 Kcal, respectively. In addition, the anti-nutritional values of tannin (mg/100g) ranged between 0.381-3342.200mg. This study showed that the physicochemical composition of sorghum varieties was significantly different and, thus, the varieties have different nutritional profile.

Introduction

Sorghum (*Sorghum bicolor* L. Moench) is one of the most important cereals and is 5th in terms of land coverage and production and grown in the semi-arid tropics of the world (Beta *et al*., 2004). It is consumed mostly in northern China, India, and southern Russia, where about 85% of the crop is consumed directly as human food (Dendy, 1995, Dicko *et al*, 2006).

In Ethiopia, sorghum is the third most important staple cereal crop after teff and maize (CSA, 2012) and its productivity could be enhanced through effective breeding

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The nutritional properties of sorghum are unique and variety-dependent. Sorghum is gluten-free, thus, can be consumed by people with celiac disease and it is obvious that relatively low digestibility of both protein and starch with great potential for weight and obesity management due to the presence of some anti-nutritional factors (polyphenol) such as tannin (Dykes and Rooney, 2006). Since sorghum is gluten free, it provides a good basis for gluten-free breads and other baked products like biscuits, snacks and pasta. The yield and nutritional quality of sorghum is affected by a wide array of biotic and abiotic constraints (ICRISAT, 2004) and variety dependent. Therefore, the aim of the present study was to profile the nutritional (chemical composition) and anti-nutritional values of sorghum varieties grown in Ethiopia.

Materials and Methods

Materials

Thirty-five sorghum varieties, which were collected from Melkassa Agricultural Research Center, were used for this study. Seed samples were cleaned manually for dust particles, damaged seeds and strange materials. Equipments, chemicals (analytical grade) and glassware required for this investigation were available in food science and nutrition laboratory at Melkassa Agricultural Research Center.

Nutritional analysis

Sorghum varieties were analyzed for moisture content, ash, fat, fiber, protein, total carbohydrate, food energy value and the anti-nutritional factor of sorghum (tannin) was determined. All the determinations were done in triplicate and the results were expressed as the average value of the triplicate samples.

Moisture content determination (method of AOAC 925:10. (2000)

About 2 g of well-homogenized sorghum flour samples were transferred to dried and weighed dishes. Sample containing dishes were placed in an oven and dried for 1 h at 130°C (until constant weight). Then, the dried samples were removed from the drying oven, cooled in desiccators to room temperature, and reweighed.

$$\boldsymbol{Moisture}(\%) = \frac{(W1 - W2) * 100}{SW}$$

Where, W_1= weight of cap/dish and fresh sample, W_2= weight of dry sample and cap/dish and Sw= sample weight

Total ash content determination (method of AOAC 923:03AOAC (2000))

Four grams of well-homogenized sorghum flour was put in to a clean crucible of predetermined weight. The sample-containing crucible was placed in a muffle furnace, which was adjusted at 550 ^{o}C. The samples were ignited until it became light gray. Then, the samples were removed and cooled in a dedicator at room temperature and weighed.

$$\boldsymbol{Ash}(\%) = \frac{(W1 - W2) * 100}{SW}$$

Where W_1 = Weight of ash + crucible after ashing, W_2 = Weight of empty crucible and S_W = Weight of sample taken

Fat content determination (method of AOAC 945:16(2000)): It was determined by soxhlet extraction method, where 2 gram of sorghum flour was weighted and put into an extraction thimble. The mouth of the thimble was plugged with fat free absorbent cotton wool. The receiver flask of the soxhlet was clean, dried and weighed accurately before the sample was introduced into the soxhlet extractor. The apparatus was assembled and filled with petroleum ether (b.p.35-60°C) spirit to half capacity of the volume of the flask. Then, the extraction was performed for 4 hours, the extracted fat was removed and oil or fat containing flasks were attached it to the rotary evaporator to evaporate the major portion of the solvent. Using dry oven evaporater, the last traces of the solvent was removed at 103 ^{O}C for 30 minutes and the dried flasks that contain fat were cooled in a desiccator and then reweighed.

$$Fat\ (\%) = \frac{(Wf - W) * 100}{SW}$$

Where, WF = weight of the receiver flask and fat deposits, W = weight of empty receiver flask and SW= Weight of sample used.

Table 1: Description of sorghum varieties

Variety	Potential growth area	Purpose of Release	Seed color
Abshir	(Dry lowlands < 1600 masl)	Striga resistance	White
Gobiye			
Abuare		Early	White
Dekeba			
Misikir			
Hormat			
ESH-1		High yielder	White
ESH-3			
Gambella 1107			
Gedo-1			
Red swazi		For Malt	Brown
Macia			White
Teshale		Early, quality	White
Meko-1			
Melkam			
Chiro	Highlands (>1900 masl)	High yielder, Sweet stalk	Brown
AL-70		High yielder, quality	White
Dibaba		High yielder	Brown
Chelenko			
Muyra-1			
Muyra-2			White
Dagim	Intermediate altitudes (1600)	High yielder	Brown
Baji			
Birmash			
Geremew			
IS 9302			

Abamelko(Sartu)		High yielder, disease resistance	
Lalo			
Dano			Orange
Emahoy	Wet lowlands (< 1600 masl)	High yielder, disease resistance	Brown
Adukara			Red

Crude fiber content: was determined by acid digestion method of AOAC (2000), where 2 gram of pre-defatted sample (fat free) sample was transferred into a one-liter (1 liter) beaker. The sample was digested in hot plate for 1 hr with mixture of equal volume of 2.5MH_2SO_4 and 2.5M NaOH. Then, it was filtered by moisturizing with small portion of ethanol. The filtrated (resulting residue) was transferred to a porcelain crucible and dried in an oven at 100^0C until a constant weight, cooled and weighed (W1) and, then, the dried content of crucible was incinerated at 600^0C for 3 hrs in a muffle furnace until all the carbonaceous matters were burnt. The crucible after incinerating was removed cooled and weighed (W2).

$$Fiber\ (\%) = \frac{(W1 - W2) * 100}{SW}$$

Where, W1 = weight in gram of porcelain crucible and sample before ashing, W2 = weight in gram of porcelain crucible containing ash and SW = weight of sample in gram

Protein content: it was determined by Kjeldahl method (AOAC method (2000)), where 0.5 gram of sorghum flour sample was weighed into 50ml kjeldahl flask and 8 ml of concentrated H_2S0_4 was added with one spoon of copper and potassium sulphate mixture catalyst. Samples were digested until pure colorless solution was observed. Then, the digested samples were distilled by using distillation unit and the distilled vapor gas (Ammonia) was collected with 25 ml of a mixture of 2% boric acid indicator (bromocresso green plus methyl red). The distilled sample was titrated by 0.1N HCl until the first appearance of pink color.

$$Crude\,Protien\ (\%) = \frac{(a * b * 14 * 6.25) * 100}{w}$$

Where; -a = normality of the acid; b = volume of standard acid used (ml), corrected for the blank (i.e., the sample titre minus the blank titre); w = sample weight (g); and 6.25 = conversion factor for protein from % nitrogen.

Total carbohydrate: Total carbohydrate content of the sample was determined by difference method by subtracting measured protein, fat, ash and moisture from 100 (Pearson, 1976)

Total Carbohydrate (%) =100 - {Moisture (%) +Protein (%) + Fat (%) + Ash (%)}

Gross food energy: was estimated using the following equation.

$$FE = \{(\%TC-\%CF) \times 4\} + (\% TF \times 9) + (\%TP \times 4)$$

Where, FE = Food energy in Kcal/g, TC = Total carbohydrate, CF = Crude fiber, TF = Total fat and TP = Total protein.

Tannin content: Tannin was determined by using Vanillin-HCL-assay methods using UV-spectrophotometer (Burns, 1971) as modified by Maxson and Rooney (1972). One gram of sample in a screw cap test tube was measured and then 10ml 1%HCl in methanol was added to the tube containing the sample. The tube was put on mechanical shaker for 24 hr at room temperature and centrifuged at 1000 G for 5 minute. One ml supernatant was taken and mixed with 5ml of vanillin-HCl reagent in another test tube, waited for 20 minutes to complete the reaction and, then, the absorbance of the color intensity of the sample was measured using UV-visible spectrophotometer at 500nm.

$$Tannin\ (\mathrm{mg/g}) = \frac{(As - Ab) - intercept)}{Slope * d * w}$$

Where; as= sample absorbance; A_b= blank absorbance; d = density of solution (0.791g/ml) and w = weight of sample in gram.

Statistical analysis

The collected physicochemical and the non-nutritional data were subjected to analysis of variance technique ANOVA for Completely Randomized Design (CRD) and all Pair Wise Comparison tests were used to compare treatment means, whereas the Least Significant Difference (Steel *et al*., 1997) test was used to separate the means at $P<0.05$.

Results and Discussion

Nutritional analysis

The results for each parameter showed that the value of moisture content ranged from 9.661 to 12.937%; ash ranged from 1.119 to 2.294 %; fat from 2.481 to 4.596%; crude fiber from 2.1655 to 8.5865%; protein from 8.201 to 16.476% (Table 2). Moreover, total carbohydrate and food energy value from 67.558 to 76.413% and 329.05 to 364.24 K Cal, respectively (Table 3). The range for moisture, ash, protein and fat contents was consistent with that of Codex Standard 172 and 173 (1989) revised in 1995 (Ivan, 1989). In addition, the results of fiber content were within the same range as reported by Ivan (1989).

As observed in the present study, sorghum is a good source of carbohydrate, energy, protein and minerals and somehow it has good fiber content. The highest ash (total mineral) content (2.294%) was recorded for variety Gobiye and this result was similar with some previous findings. On the other hand, higher protein content was recorded for variety Miskir (16.476%); Muyira-2 (16.180%) and ESH-4 (16.178%). In addition, the other important characteristics of sorghum, which is fiber content, had also higher values for variety Abure (8.5865%); Lalo (8.1615%); Gambella-1107 (8.0665%) and Karimtams (7.8385%). The carbohydrate contents of Emahoy, Dibaba and Assossa-1 were higher with the respective values of 76.413, 76.154 and 76.142 g/100g, while higher energy values were recorded for variety Dagim (364.24 Kcal/g); ESH-1 (360.41Kcal/g); Macia (360.33 Kcal/g); Adukara (359.74Kcal/g) and Assossa-1 (358.40Kcal/g) (Table 3).

Table 2: Proximate compositions of sorghum varieties (g/100g)

Variety	Moisture (%)	% Ash	% Fat	%Crude Fiber	Protein (%)
Abamelko	10.411^{g-j}	1.5100^{b-e}	3.5625^{e-g}	5.6010^{kl}	8.9810^{m}
Abshir	10.984^{cd}	1.6295^{b-e}	4.0005^{cd}	6.9995^{ef}	12.716^{d}
Abure	10.244^{i-l}	1.6010^{b-e}	3.2715^{g-k}	8.5865^{a}	11.541^{f}
Adukara	10.429^{f-j}	1.7140^{b-e}	3.3955^{g-k}	2.1655^{u}	9.0180^{m}
Al-70	11.534^{b}	1.6005^{b-e}	3.9240^{cd}	6.5915^{g}	11.079^{gh}
Assossa-1	10.283^{h-l}	1.1195^{f}	3.2945^{g-k}	3.1150^{qr}	9.1610^{m}
Baji	11.073^{c}	1.4875^{c-e}	3.5120^{e-i}	6.0240^{h-j}	9.8240^{kl}
Birmash	10.806^{c-f}	1.8410^{b}	3.5405^{e-h}	3.4415^{o-q}	10.870^{ghi}
Chelenko	9.9805^{k-n}	1.6450^{b-e}	4.5360^{ab}	5.4420^{l}	10.197^{jk}
Chiro	11.693^{b}	1.7405^{b-d}	3.8305^{de}	6.4280^{g}	11.644^{f}
Dagim	10.637^{d-h}	1.4315^{d-f}	4.5960^{a}	2.6160^{st}	10.675^{hi}
Dano	10.251^{i-l}	1.7365^{b-d}	2.5705^{no}	4.3435^{m}	11.104^{g}
Dekeba	10.555^{e-i}	1.6215^{b-e}	2.5345^{no}	6.5725^{g}	9.9665^{kl}
Dibaba	10.563^{e-i}	1.4605^{c-f}	2.8040^{m-o}	4.0055^{mn}	9.0190^{m}
Emahoy	10.276^{h-l}	1.4720^{c-e}	2.7530^{no}	3.8435^{no}	9.0865^{m}
ESH-1	10.602^{d-i}	1.6140^{b-e}	4.3420^{ab}	3.1080^{qr}	13.572^{c}
ESH-3	12.937^{a}	1.6775^{b-e}	3.1370^{k-m}	7.0445^{ef}	13.648^{c}
ESH-4	11.482^{b}	1.5055^{b-e}	3.2780^{g-k}	2.4015^{tu}	16.178^{ab}
Gambella1107	10.674^{d-g}	1.4255^{d-f}	3.4810^{f-j}	8.0665^{bc}	8.4250^{n}
Gedo	9.9690^{l-n}	1.8015^{bc}	2.7205^{no}	3.3490^{pq}	10.514^{ij}
Geremew	10.453^{f-j}	1.7670^{b-d}	4.2100^{bc}	7.3385^{de}	10.959^{gh}
Gobiye	10.730^{c-g}	2.2940^{a}	3.2905^{g-k}	7.6890^{cd}	13.718^{c}
Hormat	10.476^{f-j}	1.5595^{b-e}	2.6165^{no}	6.3535^{g-j}	12.284^{e}
IS-9302	10.652^{d-h}	1.7100^{b-e}	3.5205^{e-i}	6.4655^{g}	10.697^{ghi}
Jiru	11.488^{b}	1.4900^{c-e}	3.2150^{h-k}	5.3660^{l}	8.2015^{n}
Karimtam	9.6605^{n}	1.6140^{b-e}	2.8440^{l-n}	7.8385^{bc}	15.913^{b}
Lalo	9.7610^{mn}	1.4860^{c-e}	3.2000^{i-k}	8.1615^{b}	9.5955^{l}
Macia	10.398^{g-j}	1.4405^{d-f}	3.8155^{d-f}	2.8480^{rs}	12.447^{de}
Meko	10.110^{j-m}	1.6615^{b-e}	3.8005^{d-f}	3.6010^{op}	12.610^{de}
Melkam	11.724^{b}	1.6695^{b-e}	3.1550^{j-l}	6.3870^{gh}	9.5965^{l}
Miskir	9.9590^{l-n}	1.7295^{b-e}	2.4810^{o}	6.4735^{g}	16.476^{a}
Muyira-1	10.473^{f-j}	1.5140^{b-e}	3.5705^{e-g}	5.9830^{i-k}	9.7425^{l}
Muyira-2	10.355^{g-k}	1.5605^{b-e}	3.8220^{de}	6.6415^{fg}	16.180^{ab}
Red Sewz	10.956^{cd}	1.6370^{b-e}	3.3905^{g-k}	7.0300^{ef}	12.540^{de}
Teshale	10.880^{c-e}	1.3885^{e-f}	3.5735^{e-g}	5.6805^{j-l}	11.072^{gh}
CV	1.77	10.5	4.83	3.59	1.8
LSd (P < 0.05)	0.3834	0.3419	0.3351	0.4031	0.4169

Means followed by different superscripts/letters with in a column are significantly different at P <0.05)

Table 3: Carbohydrate and Energy value of sorghum varieties

Variety	CHO (%)	FE (Kcal/g)	Varieties	CHO (%)	FE (Kcal/g)
Abamelko	75.536^{b-d}	347.73^{gh}	Gambella1107	75.995^{a-c}	336.74^{o-q}
Abshir	70.669^{qr}	341.55^{j-m}	Gedo	74.995^{d-f}	353.12^{d-f}
Abure	73.343^{i-l}	334.63^{pq}	Geremew	72.612^{l-n}	342.82^{i-l}
Adukara	75.444^{b-e}	359.74^{b}	Gobiye	69.966^{rs}	333.60^{q}
Al-70	71.863^{no}	340.72^{k-n}	Hormat	73.063^{j-l}	339.52^{l-o}
Assossa-1	76.142^{ab}	358.40^{b}	IS-9302	73.421^{i-k}	342.29^{j-l}
Baji	74.103^{g-i}	343.22^{i-k}	Jiru	75.606^{b-d}	342.70^{i-l}
Birmash	72.942^{j-l}	353.35^{de}	Karimtam	69.968^{rs}	337.77^{n-p}
Chelenko	73.642^{h-j}	354.41^{c-e}	Lalo	75.957^{a-c}	338.37^{m-o}
Chiro	71.092^{pq}	339.71^{l-o}	Macia	71.899^{m-o}	360.33^{b}
Dagim	72.660^{k-m}	364.24^{a}	Meko	71.819^{op}	357.51^{bc}
Dano	74.338^{f-h}	347.53^{gh}	Melkam	73.855^{hi}	336.65^{o-q}
Dekeba	75.322^{c-e}	337.67^{n-p}	Miskir	69.355st	339.76^{l-o}
Dibaba	76.154^{ab}	349.91^{fg}	Muyira-1	74.701^{e-g}	345.97^{hi}
Emahoy	76.413^{a}	351.40^{ef}	Muyira-2	68.082^{uv}	344.88^{h-j}
ESH-1	69.870^{s}	360.41^{b}	Red Sewz	71.477^{op}	338.46^{m-o}
ESH-3	68.601^{tu}	329.05^{r}	Teshale	73.085^{j-l}	346.07^{hi}
ESH-4	67.558^{v}	354.84^{cd}			
CV	0.52	0.49			
LSD P < 0.05)	0.7676	3.4068			

Means followed by different superscripts/letters with in columns for a given variable are significantly different at P <0.05.

Anti-nutritional factor

The concentration of tannins in sorghum grains ranged from 0.381mg/100g for variety Macia to 3342.200mg/100g for Lalo (Table 4). This result was within the range reported by Codex Standard 173 (1989) revised in 1995. In line with this, it has been reported that phytate and tannin are the most abundant anti-nutritional factors in sorghum especially tannin is present in high concentration (Selle et *al al*., 2010). Thus, restricts use of the crop as a food source, as multiple phenolic hydroxyl groups of tannins may form stable complexes with protein, metal ions or minerals and other macromolecules like polysaccharides (Choct and Hughes, 1999) and reduce the digestively of proteins and availability of the nutrients in the gut.

It was observed that variety Dano and Lalo had significantly higher amount of tannin, which was 2474.7mg/100g and 3342.200mg/100g, respectively, whereas the lowest concentration was observed Teshale; Gambella-1107 and Macia with respective values of 0.8935mg/100g; 0.8200mg/100g and 0.3815mg/100g (Table 4).

Table 4. Tannin content of sorghum (mg/100g) varieties

Variety	Tannin(mg/100g) (dry matter base)	Varieties	Tannin (mg/100g) (Dry matter base)
Abamelko	2443.4^{c}	Gambella-1107	0.8200^{tu}
Abshir	$1.0120^{s\text{-}u}$`	Gedo	$5.0075^{q\text{-}s}$
Abure	15.752^{p}	Geremew	168.65^{l}
Adukara	499.77^{g}	Gobiye	170.02^{l}
Al-70	$4.7050^{q\text{-}t}$	Hormat	7.5560^{q}
Assossa-1	786.15^{e}	IS-9302	176.77^{j}
Baji	126.80^{o}	jiru	253.24^{h}
Birmash	157.25^{m}	Karimtam	13.704^{p}
Chelenko	13.523^{p}	Lalo	3342.2^{a}
Chiro	171.77^{kl}	Macia	0.3815^{u}
Dagim	126.45^{o}	Meko	$1.9730^{r\text{-}u}$
Dano	2474.7^{b}	Melkam	$1.4790^{r\text{-}u}$
Dekeba	5.4095^{qr}	Miskir	$1.3660^{r\text{-}u}$
Dibaba	174.79^{jk}	Muyira-1	207.37^{i}
Emahoy	766.77^{f}	Muyira-2	15.245^{p}
ESH-1	$1.6970^{r\text{-}u}$	RedSwez	901.98^{d}
ESH-3	$1.7575^{r\text{-}u}$	Teshale	0.8935^{tu}
ESH-4	144.75^{n}		
Grand Mean	376.72		
CV	0.53		
LSD (P<0.05)	4.0743		

Means followed by different superscripts/letters within columns are significantly different at P <0.05

Conclusion and Recommendation

In an attempt to profile and quantify the nutritional composition of sorghum varieties grow in Ethiopia and identify the best genotypes, it was observed that there were significant differences among the varieties for chemical composition and anti-nutritional value. The best sorghum varieties were found to be Miskir, Muyira-2 and ESH-4 for protein content, Emahoy, Dibaba and Assosa-1 for carbohydrate, Dagim, ESH-1, Macia, Adukara and Assossa-1 for energy value and Teshale, Gambella1107 and Macia in terms of anti-nutritionals factor (tannin). Hence, it was concluded that such evaluations of different varieties of sorghum are very important for designing and development of products of higher nutritional quality and to help sorghum breeders to further develop varieties with better nutritional values. However, it is recommended that further study on micronutrient content, functional property and phytat content is necessary to have comprehensive information on nutritional quality of the varieties.

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