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Characterization of Nutritional, Anti-nutritional, and Mineral Contents of Twenty-seven Sorghum Varieties Grown in Different Parts of Somali Region, Eastern Ethiopia

Abdulkarim Mohammed Ali[1,2], Mohammed Sharif Ali[1,3], Mahamed Dol Ateye[1,2], Hodo Mohamed[1], Najma Tahir Mohamud[1] and Shamsedin Mahdi Hassan[1,2,4*]

[1]*Somali Region Pastoral and Agro-pastoral Research Institute, Food Science and Nutrition Research Directorate, Jigjiga, Ethiopia*
[2]*Department of Food Science and Nutrition, College of Dryland Agriculture, Jigjiga University, Jigjiga, Ethiopia*
[3]*Department of Plant Science, College of Dryland Agriculture, Jigjiga University, Jigjiga, Ethiopia*
[4]*Department of Postharvest Management, College of Agriculture and Veterinary Medicine, Jimma University, Jimma, Ethiopia*

***Correspondence to:**
Shamsedin Mahdi Hassan
Somali Region Pastoral and Agro-Pastoral Research Institute,
Food Science and Nutrition Research Directorate,
Jigjiga, Ethiopia.

Department of Food Science and Nutrition,
College of Dryland Agriculture,
Jigjiga University,
Jigjiga, Ethiopia.

Department of Postharvest Management,
College of Agriculture and Veterinary Medicine,
Jimma University,
Jimma, Ethiopia.
E-mail: shamsedinmahdi1@gmail.com

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Abstract

The study aimed to evaluate the proximate, mineral, and anti-nutritional content of various sorghum landraces in the Somali region of Ethiopia. Twenty-seven samples were collected, ground, and stored at 4 °C in airtight bags. The proximate composition, including crude protein, fat, fiber, moisture, carbohydrate, total energy, and minerals (calcium (Ca), iron (Fe), magnesium (Mg), and zinc (Zn)), were analyzed using Association of Official Analytical Chemists (AOAC) methods. Anti-nutritional factors, such as tannins and phytate, were determined using standard procedures. Based on the results, the moisture, ash, fiber, protein, fat, and carbohydrate contents were in the range of 6.13 - 11.20%, 1.32 - 3.59%, 1.15 - 2.79%, 6.90 - 14.20%, 2.77 - 4.19% and 66.44 - 79.13% respectively. The Ca, Mg, Fe, and Zn content of sorghum were in the range of 11.06 - 24.91 mg/100 g, 99.50 - 170.10 mg/100 g, 2.67 - 7.99 mg/100 g and 0.84 - 4.09 mg/100 g respectively. Regarding the anti-nutritional content, tannins and phytate content were in the range of 0.22 - 4.08 mg/g and 2.76 - 5.25 mg/g respectively. Significant differences ($p < 0.05$) were observed for all macro- and micronutrients and anti-nutritional factors, likely due to varietal, agro-ecological, and farming system differences. These findings suggest most local sorghum varieties have favorable ash and fiber levels, though some lack adequate protein. Fortifying or biofortifying protein could enhance sorghum's value as a staple, supporting food security and nutrition in the Somali region.

Keywords

Sorghum, Macronutrients, Micronutrients, Anti-nutrients

Introduction

Sorghum (*Sorghum bicolor* L.) is the world's fifth most significant cereal crop, with an annual global production of approximately 5.3 million metric tons [1]. It serves as a key staple food in Africa, Central America, and South Asia, and is extensively used as animal feed worldwide. In the United States, sweet sorghum is primarily a raw material for grain ethanol production, while countries like China, the Philippines, and India utilize it for sugar ethanol production. Additionally, several nations have explored sorghum's potential as a renewable resource for biofuels and industrial chemicals [2]. Although mainly consumed by humans and livestock, sorghum has recently gained attention as a source of fermentable sugars for sustainable fuel and chemical production [3].

Sorghum contains various secondary metabolites, including phenols, plant sterols, and policosanols, which are recognized for their antioxidant properties and potential health benefits. Its nutritional profile includes protein (4.4 - 21.1%), fat (2.1 - 7.6%), crude fiber (1.0 - 3.4%), carbohydrates (57.0 - 80.6%), starch (55.6 - 75.2%), and minerals (1.3 - 3.5%). Furthermore, sorghum is rich in phenolic compounds with antioxidant properties and is a suitable option for individuals with coeliac disease [4]. In Ethiopia, sorghum ranks as the third most important cereal crop, following teff and maize [5]. It is a staple in many diets, particularly in the Somali region, where it is often consumed as injera (a type of flatbread) and porridge, frequently mixed with other grains [6, 7].

Regarded as one of the most nutritious food crops, sorghum is rich in minerals, energy, protein, vitamins, fiber, and phenolic compounds. Its gluten-free nature is particularly beneficial for populations in semi-arid tropical areas [8-10]. Sorghum is also a vital source of minerals like Fe and Zn for economically disadvantaged communities in Ethiopia. Despite its nutritional value, the nutrient content and composition of sorghum can vary significantly based on genotype and cultivation conditions [11-14]. Research has identified genetic variation in nutritional composition among sorghum landraces from Ethiopia, Malawi, Tanzania, and Zambia [11, 15]. Variability in protein content has also been documented among sorghum genotypes from South Africa and Ethiopia [13, 16]. Additionally, both genetic factors and environmental conditions influence the starch content and composition of sorghum [11, 16-18]. The mineral content is similarly affected by the growing location and country of origin [14].

Agricultural research in developing nations has primarily focused on increasing crop yields to alleviate hunger, often neglecting improvements in nutritional value. Consequently, malnutrition remains a significant public health challenge, particularly in Ethiopia, where Fe and Zn deficiencies are prevalent, contributing to 45% of child mortality in affected areas [19]. Approximately 2 billion people worldwide suffer from deficiencies in essential micronutrients like Fe and vitamin A, which leads to malnutrition as they rely on staple foods to combat hunger [20].

Addressing malnutrition through plant breeding [21, 22] requires a comprehensive understanding of grain quality and composition across various crop genetics. Leveraging the genetic diversity of crops, particularly sorghum landraces, is crucial for enhancing nutritional quality and combating malnutrition. Despite the widespread use of sorghum in the Somali region, there is limited comprehensive information on the nutritional and anti-nutritional profiles of its landraces. This research aims to evaluate the genetic diversity of sorghum landraces in terms of macronutrients, micronutrients, and anti-nutritional factors, identifying nutritionally superior landraces for developing complementary foods to address malnutrition in the area.

Materials and Method

Sample collection and preparation

The Somali region of Ethiopia comprises eight distinct agro-ecological zones with altitudes ranging from 300 to 2000 m above sea level, offering diverse agricultural opportunities. These zones include areas categorized as tepid to cool arid mid-highlands, tepid to cool sub-moist mid-highlands, hot to warm sub-moist lowlands, and hot to warm arid lowlands. Each zone is characterized by its specific climate, soil composition, and topography, which collectively affect crop growth. For instance, the tepid to cool aid mid-highland experiences temperatures between 15 °C and 20.82 °C and receives annual rainfall of 800 - 1200 mm, while the hot to warm arid lowlands are marked by higher temperatures ranging from 21 °C to 27 °C and lower rainfall levels. To comprehensively assess the region's agricultural potential, scientists gathered 27 intact and pest-free sorghum samples from various kebeles across these zones. The samples were then cleaned, ground, sieved, and stored at 4 °C for subsequent analysis.

Proximate composition analysis

The proximate compositions, including moisture, ash, crude protein, crude fat, and crude fiber content, were determined following the AOAC methods [23]. Specifically, the methods used were moisture (925.05), crude protein (979.09), crude fiber (920.169), crude fat (920.39), and ash (941.12) [23]. The total carbohydrate content was calculated using the following equation:

Carbohydrate % = 100% - (moisture % + protein % + fat % + fiber % + ash%) (1)

The energy value (kcal) of each sample was determined using the Atwater factor method, calculated with the following equation:

E.V = (9 × crude fat %) + (4 × crude protein %) + (4 × carbohydrate %) (2)

Additionally, mineral content, specifically Ca, Mg, Fe, and Zn, was quantified using atomic absorption spectrophotometry (Approved Methods of the American Association of Cereal Chemists) [24]. The levels of tannins and phytates were evaluated using the methodologies described by Maxson and Rooney [25] and Vaintraub and Lapteva [26], respectively.

Statistical analysis

Experiments were conducted in pairs (except where noted), and outcomes are presented as the average ± standard deviation. To determine statistical significance, one-way analysis of variance (ANOVA) was employed, followed by Duncan's test. Data analysis was carried out using Genstat version 18.0. A p value of less than 0.05 was considered statistically significant.

Results and Discussion

Proximate composition of different sorghum varieties

The moisture content ranged from 6.13% (Mansugi 017 from Gursum district Adade kebele) to 11.20% (Hadhuudh cad 01 from Sagag district Hara Howd kebele), as shown in table 1. Our findings confirmed that the varieties of sorghum tested were not exposed to deterioration due to mold growth or any damage related to wetness. This could be attributed to a moisture level of less than 15% [27]. There were significant differences among some sorghum samples ($p < 0.05$). Mean-

Table 1: Proximate composition of different sorghum varieties.

Haricot bean varieties	Results in percentage (100 g)						
	Moisture	Ash	Fiber	Protein	Fat	CHO	Energy
Mansugi 017	6.13 ± 0.85^{a}	1.32 ± 0.08^{a}	$2.01 \pm 0.21^{g-k}$	$7.71 \pm 0.23^{c-f}$	$3.71 \pm 0.19^{e-i}$	79.13 ± 1.15^{o}	380.7 ± 3.71^{m}
Casse 023	6.18 ± 0.87^{a}	$3.03 \pm 0.12^{g-j}$	2.79 ± 0.23^{o}	$7.56 \pm 0.25^{b-d}$	3.28 ± 0.17^{b}	77.17 ± 1.14^{lm}	$368.4 \pm 3.42^{i-k}$
Fandishe 026	6.94 ± 0.46^{b}	$2.98 \pm 0.21^{f-j}$	2.75 ± 0.24^{no}	9.40 ± 0.32j-1	$3.400.18 \pm 0^{ij}$	$73.94 \pm 1.92^{g-i}$	369.3 ± 3.33^{jk}
Soole (Maamo Ture) 014	7.11 ± 0.56^{b}	$2.95 \pm 0.18^{f-j}$	1.15 ± 0.18^{a}	6.90 ± 0.2^{1a}	3.26 ± 0.17^{b}	78.63 ± 1.64^{no}	371.5 ± 3.50^{kl}
CilmiJaamca 012	7.23 ± 0.39^{b}	$2.39 \pm 0.22^{b-g}$	1.16 ± 0.17^{a}	8.25 ± 0.22^{gh}	$3.66 \pm 0.19^{d-h}$	77.30 ± 1.32^{lm}	375.1 ± 3.12^{l}
Hadhuudh Cad 011	7.31 ± 0.74^{bc}	3.33 ± 0.24^{ij}	$1.45 \pm 0.11^{a-c}$	7.21 ± 0.21^{ab}	$3.94 \pm 0.20^{h-j}$	76.76 ± 1.74^{lm}	371.3 ± 3.12^{kl}
Wagare 022	7.74 ± 0.26^{cd}	3.59 ± 0.25^{j}	$2.57 \pm 0.22^{l-o}$	9.82 ± 0.28^{lm}	$3.85 \pm 0.18^{g-i}$	72.44 ± 1.42^{e}	$363.6 \pm 2.98^{f-h}$
Cabdidayr 019	7.91 ± 0.43^{de}	$2.08 \pm 0.16^{b-d}$	$1.99 \pm 0.14^{f-j}$	8.99 ± 0.32^{ij}	$3.87 \pm 0.18^{g-i}$	75.16 ± 1.13^{jk}	371.4 ± 3.11^{kl}
Elles 024	7.91 ± 0.47^{de}	$2.61 \pm 0.21^{d-h}$	$1.99 \pm 0.12^{f-j}$	8.99 ± 0.27^{ij}	$3.62 \pm 0.17^{c-g}$	$74.88 \pm 1.84^{i-k}$	$368.0 \pm 2.88^{h-k}$
Shaqqee/KufaKas/kor u saydhe 027	$8.09 \pm 0.46^{d-f}$	$2.73 \pm 0.23^{d-i}$	$2.69 \pm 0.19^{m-o}$	8.17 ± 0.25^{gh}	$3.62 \pm 0.17^{c-g}$	$74.77 \pm 1.73^{h-k}$	$364.4 \pm 2.69^{f-i}$
Car i Liq 025	$8.16 \pm 0.68^{d-f}$	$2.93 \pm 0.26^{f-j}$	$2.21 \pm 0.20^{h-l}$	8.65 ± 0.28^{hi}	$3.96 \pm 0.16^{h-j}$	$74.09 \pm 1.06^{g-i}$	$366.6 \pm 3.02^{g-j}$
Hadhuudh Cas 010	8.17 ± 0.72^{df}	$2.20 \pm 0.21^{b-e}$	1.40 ± 0.10^{ab}	6.86 ± 0.21^{a}	$3.67 \pm 0.17^{d-h}$	77.70 ± 1.71^{mn}	371.3 ± 3.38^{kl}
Casse Cad 013	$8.18 \pm 0.43^{d-f}$	$2.97 \pm 0.22^{f-j}$	$1.55 \pm 0.11^{b-e}$	9.56 ± 0.28^{kl}	$3.45 \pm 0.14^{b-e}$	$74.30 \pm 1.32^{g-j}$	$366.5 \pm 2.60^{g-j}$
Dhawdhaw 015	$8.18 \pm 0.48^{d-f}$	$2.32 \pm 0.20^{b-f}$	$1.55 \pm 0.11^{b-e}$	$7.71 \pm 0.27^{c-e}$	$3.71 \pm 0.18^{e-i}$	76.55 ± 1.52^{l}	370.4 ± 3.03^{jk}
Hadhuudh Cas 03	8.38 ± 0.49^{ef}	$1.88 \pm 0.14^{a-c}$	$2.34 \pm 0.21^{j-m}$	11.19 ± 0.35^{o}	$3.49 \pm 0.14^{b-f}$	72.71 ± 1.70^{ef}	$367.1 \pm 3.45^{g-k}$
Hadhuudh Cas 04	8.40 ± 0.69^{ef}	$2.49 \pm 0.23^{c-g}$	$2.38 \pm 0.20^{k-n}$	11.21 ± 0.36^{o}	$3.42 \pm 0.15^{b-e}$	72.12 ± 1.11^{de}	$364.0 \pm 3.29^{f-i}$
Hadhuudh Cas 02	8.43 ± 0.84^{ef}	$2.73 \pm 0.25^{d-i}$	$1.83 \pm 0.13^{c-g}$	8.36 ± 0.28^{gh}	3.26 ± 0.12^{b}	75.39 ± 1.34^{k}	$364.3 \pm 3.25^{f-i}$
Hadhuudh Cas 07	8.52 ± 0.75^{f}	$3.25 \pm 0.28^{h-j}$	$1.63 \pm 0.11^{b-f}$	9.27 ± 0.29^{jk}	3.36 ± 0.13^{bc}	$73.98 \pm 1.94^{g-i}$	$363.2 \pm 2.89^{e-g}$
Bullo 016	10.05 ± 0.64^{g}	3.33 ± 0.29^{ij}	$1.66 \pm 0.10^{b-g}$	7.41 ± 0.23^{bc}	$3.87 \pm 0.18^{g-i}$	$73.69 \pm 1.64^{f-h}$	359.2 ± 2.69^{de}
Hadhuudh Cas 06	10.07 ± 0.46^{g}	$2.31 \pm 0.23^{b-f}$	$1.92 \pm 0.14^{e-i}$	10.11 ± 0.32^{mn}	$3.45 \pm 0.14^{b-e}$	72.14 ± 1.12^{de}	$360.0 \pm 2.60^{d-f}$
Hadhuudh Cas 08	10.25 ± 0.82^{g}	$2.36 \pm 0.24^{b-g}$	$1.48 \pm 0.11^{a-d}$	8.16 ± 0.26^{eg}	$3.87 \pm 0.17^{g-i}$	$73.87 \pm 1.83^{g-i}$	$363.0 \pm 2.61^{e-g}$
Faaraxgasle 020	10.75 ± 0.68^{h}	$1.88 \pm 0.17^{a-c}$	$2.29 \pm 0.19^{j-l}$	$7.92 \pm 0.24^{d-g}$	$3.62 \pm 0.16^{c-g}$	73.55 ± 1.53^{fg}	358.4 ± 2.62^{cd}
Axmedcumer 09	10.77 ± 0.59^{h}	$3.31 \pm 0.24^{h-j}$	$1.86 \pm 0.16^{d-h}$	10.11 ± 0.34^{mn}	3.25 ± 0.12^{b}	70.70 ± 1.71^{c}	352.5 ± 2.52^{b}
Hadhuudh Cad 05	10.78 ± 0.68^{h}	$3.31 \pm 0.25^{h-j}$	$2.43 \pm 0.20^{l-o}$	10.41 ± 0.36^{n}	4.19 ± 0.11^{j}	68.87 ± 1.83^{b}	354.8 ± 2.96^{bc}
Axmadsaay 021	11.02 ± 0.75^{h}	$2.88 \pm 0.22^{e-j}$	2.74 ± 0.21^{no}	8.29 ± 0.29^{gh}	$3.79 \pm 0^{f-i}$	71.28 ± 1.24^{cd}	352.4 ± 3.02^{b}
Dhaga Adag 018	11.09 ± 0.66^{h}	1.78 ± 0.16^{ab}	$2.29 \pm 0.14^{j-l}$	8.94 ± 0.27^{ij}	$3.39 \pm 0^{b-d}$	72.52 ± 1.51^{e}	$356.3 \pm 2.86^{b-d}$
Hadhuudh Cad 01	11.20 ± 0.58^{h}	$2.91 \pm 0.22^{f-j}$	$2.48 \pm 0.16^{l-o}$	14.20 ± 0.42^{p}	2.77 ± 0^{a}	66.44 ± 1.42^{a}	347.5 ± 3.08^{a}

Note: a - p is the significant difference among some sorghum samples (i.e., $p < 0.05$).

while, no significant difference was observed between some varieties, such as Shaqqee 027, Car I liq 025, Hadhuudh cas 010, Casse Cad 013, Dhawdhaw 015, Bullo 016, Hadhuudh Cas 06, Hadhuudh cas 08, and Soole 014 and Cilmi Jaamca 012 at $p > 0.05$. The moisture content of a study by Tasie and Gebreyes [28] different varieties of sorghum in Ethiopia is between 9.66 - 12.94%, while that of Bazie et al. [29] which in Burkina Faso is between 10.43 - 12.44% which contradicts the current study. The other research in China by Htet et al. [30] indicated a moisture content of 8.04 - 9.66% which is still in contradiction with the current research but is better comparable, as can be seen from the above research results. This difference might be due to agro-ecological differences, farming systems, relative humidity during the experiment, and other reasons. About the ash content, the lowest content was registered for mansugi 017 from Gursum district Adade kebele) 1.32%), while the highest was recorded for wagare 022 from Gursum District Adade kebele (3.59%). Significant differences were observed among some of the sorghum samples, such as mansugi 017 and hadhuudh cas 04, and between wagare 022 and dhaga adad 018 ($p < 0.05$). The result obtained by this research is in contradiction with the study done in China by Htet et al. [30] which was in the range of 1.31 - 1.91%, and the research in Ethiopia by Tasie and Gebreyes [28] which range of 1.39 - 2.29%. The difference might be due to the nature of the soil where these varieties grow, agro-ecology, agronomic packaging used, farming practices, and varietal differences. Other researchers also reported variable values of ash for the sorghum varieties tested: 0.77 - 1.39% [31] and 1.51 - 2.06% [32]. Most of the sorghum samples had nearly similar amounts of ash which was insignificant at $p < 0.05$, as indicated in table 1.

The crude fiber content was in the range of 1.15% - 2.79% for Soole/Maamo Ture 014 from Gursum district Adade kebeles and Casse 023 from Gursum district Adade kebeles, respectively. Significant differences were observed among some sorghum samples under study, such as Cilmi Jaamac 012 and Casse Cad 013, Hadhuudh Cas 06 and Dhaga Adag 018, Hadhuudh Cas 03 and Casse 023, and others at $p < 0.05$. The difference might be due to varietal differences, farming management/treatment during the trial, and the original sources of these seeds. The result obtained is in contradiction with the research done by Tasie and Gebreyes [28], which is in the range of 2.16 - 8.58% but appears comparable with research done by Htet et al. [30] which is in the range of 1.58 - 2.20%. The variability may be attributed to the environment, soil type, genotype variability of sorghum, and methods. Varieties with a higher amount of crude fiber might not be good for food consumption because it binds minerals, making them unavailable for absorption [33], and this binding could produce essential mineral imbalances and deficiencies. In contrast, it can be useful in products that require hydration to improve yield and modify texture and viscosity owing to its water and oil-holding capacity [34].

Sorghum is widely used in the Somali region for human consumption and is considered an inexpensive source of protein. Sorghum is an exogenous factor that influences protein digestibility after cooking. The proteins of cooked sorghum are much less digestible than those of other similarly cooked cereals, such as wheat and maize. It is caused by both non-protein and protein components, as reported by Duodu et al. [8, 35]. With respect to crude protein content, Hadhuudh Cad 01 from Sagag district Hara Howd kebele had the highest crude protein content (14.20%), whereas Hadhuudh Cas 010 from Dh/Bur district Hodaale had the lowest crude protein content (6.86%). The crude protein content was significantly different among some of the sorghum samples, such as Hadhuudh Cas 05 and Hadhuudh Cad 01, Hadhuudh 010 and Bullo 016, Shaqqee 027 and Cabdidayr 019, and others at $p < 0.05$, as indicated in table 1. No significant differences were observed among some of the sorghum samples under study, such as Hadhuudh Cas 010 and Soole 014, Hadhuudh Cas 03 and Hadhuudh Cas 04, Axmedcumer 09 and Hadhuudh Cas 06, Dhaga Adag 018 and CabdiDayr 019, and some others at $p < 0.05$. The present findings agree with those of [36, 37], who reported crude protein contents ranging from 3.25 - 14.53% and 10.30 - 14.90%, respectively. Furthermore, Tasie and Gebreyes [28], Chung et al. [31], and Okrah [38] reported that sorghum protein contents varied from 8.20 - 16.48%, 11.23 - 13.42%, and 9.06 - 18.58%, respectively. The observed difference in protein content may be attributed to environmental and genotypic differences [39]. Varieties with the highest protein content can be considered for food product development to combat protein malnutrition and for breeders to improve sorghum nutritional quality.

Hadhuudh Cad 05 from Adaadle district Bilyolow kebele has the highest in crude fat content (4.19%) while Hadhuudh Cad 01 from Sagag district Hara howd kebele has the lowest in crude fat content (2.77%) as indicated in table 1. Like most of the other nutrient contents, significant differences were observed among some of the sorghum samples, such as AxmedCumer 09 and Hadhuudh Cad 01, Wagare 022 and Hadhuudh Cad 05, Dhaga Adag 018 and Mansugi 017, and some other samples at $p < 0.05$. The result of fat content is in line with the research done by [28-30] which is in the range of 2.48 - 4.59%, 2.48 - 4.40% and 2.98 - 5.14% respectively. However, there were no significant differences among (AxmedCumer 09, Hadhuudh Cas 02, Soole 014, and Casse 023), (Cilmijaamac 012 and Hadhuudh Cas 010), (Wagare 022, Bullo 016, Cabdidayr 019, and Hadhuudh Cad 011), and some others at $p < 0.05$.

Carbohydrates provide most of the energy in the diet of most individuals. It is a desirable source of energy because it provides easily available energy for oxidative metabolism in the body. Hadhuudh cad 01 Sagag district Hara howd kebeles had the lowest carbohydrate content (66.44%), whereas Mansugi 017 from Gursum district Adade kebeles had the highest carbohydrate content (79.13%). The carbohydrate content is not significantly different among sorghum samples such as (Wagare 022 and Dhaga Adag 018), (Hadhuudh Cas 08, Fandishe 026, Hadhuudh Cas 07, and Car i Liq 025), (Hadhuudh 011, Casse 023, and CilmiJaamac 012) and some others at $p < 0.05$. Significant differences were observed ($p < 0.05$) for some of the sorghum samples in this study like (Hadhuudh Cas 01, Hadhuudh Cad 05, and AxmedCumer 09), (Hadhuudh Cas 02 and DHawdhaw 015), (Mansugi 017 and Casse Cad 013) and some other samples ($p < 0.05$). The results obtained were consistent with those of [28-30] who found that the carbohydrate content varied from 67.58 - 76.41%, 73.25 - 79.36%, and 71.63 - 78.46%, respectively.

Lastly, the energy obtained from 100 g of sorghum samples was calculated using the standard formula in kcal. The results obtained were in the range of 347.5 - 380.7 kcal/100 g for Hadhuudh 01 from Sagag district Hara howd kebeles and Mansugi 017 from Gursum district Adade kebeles respectively. There were significant differences among some of the sorghum samples in this study, such as (Hadhuudh Cad 015 and Bullo 016), (Cilmi Jaamac 012 and Mansugi 017), (Hadhuudh Cad 01 and Faaraxgasle 020), and some others at $p < 0.05$. The difference in energy obtained was due to the variability in their nutrient contents. The energy obtained is not significantly different among some of the sorghum samples such as (Axmedsaay 021 and Axmedcumer 09), (Hadhuudh Cas 010, Hadhuudh Cad 011, Cabdidayr 019, and Soole 014), (Hadhuudh cas 07 and Hadhuudh Cas 08) and some other sorghum samples at $p < 0.05$. Bazie et al. [29] reported the energy in kcal unit from 100 g of sorghum on the research done on 35 cultivars of sorghum in Burkina Faso in between 355.63 - 370.26 kcal/100 g and Tasie and Gebreyes [28] reported in between 329.05 - 364.24 kcal/100 g. The results of the current study are consistent with those mentioned above, which is expected for most cereal crops.

The mineral content of different sorghum varieties

The mineral contents of the different sorghum varieties are indicated in table 2. Ca is necessary for the building and maintenance of strong bones and teeth. The average Ca level makes up approximately 2.3% of a person's body weight. Bullo 016 from Gursum district of Adede kebele has the lowest Ca content (11.06 mg/100 g) while Hadhuudh Cas 04 from Adaadle Bilyolow kebeles has the highest Ca content which is 24.91 mg/100 g. Significant difference were observed among some of sorghum samples under study such as Dhawdhaw 015 and Hadhuudh cad 05, Hadhuudh Cas 06 and Hadhuudh Cas 03, Bullo 016 and Fandishe 026, Hadhuudh Cas 07 and Axmedcumer 09 and Hadhuudh Cas 04 at $p < 0.05$. Research by Tasie and Gebreyes [28] on 35 varieties of sorghum in Ethiopia indicated a Ca content in the range of 9.594 mg/100 g - 67.158 mg/100 g. Other research reports Shegro et al. [11] from 31 landraces of sorghum also show the highest and the lowest Ca concentration varying from 477.50 mg/kg - 207.50 mg/kg, respectively, and it is comparable to our findings. On the other hand, from the report of Badigannavar et al. [37], Ca concentration for the popular varieties of sorghum ranged from 7.96 mg/100 g - 38.78 mg/100 g, and for the 91 - germ plasma concentration, Ca varied from 2.10 mg/100 g - 255.26 mg/100 g.

The Mg content is in the range of 99.5 mg/100 g - 170.1 mg/100 g for Axmedcumer 09 from Birkot district Baka kebele and Hadhuudh Cad 01 Sagag district Hara howd kebele respectively as shown in table 2. The Mg content was significantly different among Soole 014 and Hadhuudh Cad 01, Mansugi 017 and Hadhuudh Cas 06, Axmedcumer 09 and Casse 023 and many others at $p < 0.05$, as indicated in table 2. The result of the current study is relatively different from the research done by Badigannavar et al. [37] who found a concentration of Mg ranging from 65.00 - 375.26 mg/100 g and 750 mg/kg - 1506.3 mg/kg another study reported by Tasie

Table 2: Minerals content of different sorghum varieties.

Sorghum varieties	Results in (mg/100 g)			
	Ca	Mg	Fe	Zn
Bullo 016	11.06 ± 0.92^{a}	$124.40 \pm 2.92^{e-g}$	2.67 ± 0.29^{a}	$1.30 \pm 0.11^{c-e}$
Cabdidayr 019	11.41 ± 0.98^{ab}	128.80 ± 2.96^{g}	3.31 ± 0.30^{ab}	$1.61 \pm 0.13^{e-h}$
CilmiJaamca 012	11.65 ± 0.99^{ab}	$115.70 \pm 2.43^{b-e}$	2.83 ± 0.24^{ab}	$1.43 \pm 0.12^{c-f}$
Wagare 022	11.70 ± 0.89^{ab}	112.80 ± 2.32^{bc}	3.17 ± 0.31^{ab}	$1.14 \pm 0.10^{a-c}$
Dhaga Adag 018	$11.94 \pm 0.97^{a-c}$	101.10 ± 2.29^{a}	$4.50 \pm 0.50^{c-g}$	2.29 ± 0.21^{kl}
Axmadsaay 021	$11.94 \pm 0.89^{a-c}$	125.80 ± 2.98^{fg}	$3.91 \pm 0.34^{b-f}$	$1.97 \pm 0.15^{i-k}$
Shaqqee/KufaKas/kor u saydhe 027	$11.94 \pm 0.96^{a-c}$	$122.50 \pm 2.99^{d-g}$	$4.49 \pm 0.42^{c-g}$	$1.67 \pm 0.13^{f-i}$
Casse 023	$12.04 \pm 1.02^{a-c}$	128.90 ± 2.97^{g}	$5.33 \pm 0.52^{g-j}$	$1.43 \pm 0.12^{c-f}$
Casse Cad 013	$12.04 \pm 1.03^{a-c}$	124.80 ± 2.91^{fg}	$4.83 \pm 0.44^{e-h}$	$1.74 \pm 0.14^{f-i}$
Car i Liq 025	$12.04 \pm 1.10^{a-c}$	125.80 ± 2.99^{fg}	$3.91 \pm 0.35^{b-f}$	$1.58 \pm 0.13^{e-h}$
Elles 024	$12.04 \pm 1.08^{a-c}$	125.10 ± 2.96^{fg}	$4.67 \pm 0.43^{d-g}$	$1.61 \pm 0.13^{e-i}$
Faaraxgasle 020	$12.16 \pm 1.06^{a-c}$	$122.10 \pm 2.86^{d-g}$	$4.73 \pm 0.43^{d-h}$	$1.67 \pm 0.13f^{-i}$
Fandishe 026	$12.62 \pm 1.12^{b-d}$	124.90 ± 2.69^{fg}	$5.82 \pm 0.54^{h-}j$	$1.72 \pm 0.14^{f-i}$
Mansugi 017	$13.02 \pm 1.21^{c-e}$	101.80 ± 2.04^{a}	$3.67 \pm 0.33^{a-d}$	$1.20 \pm 0.11^{b-d}$
Hadhuudh Cas 02	$13.41 \pm 1.40^{d-f}$	125.20 ± 2.95^{fg}	6.00 ± 0.61^{ij}	2.33 ± 0.21^{l}
Soole (Maamo Ture) 014	$13.61 \pm 1.60^{d-f}$	138.90 ± 3.01^{h}	$3.50 \pm 0.32^{a-c}$	$1.53 \pm 0.13^{d-g}$
Hadhuudh Cas 08	$13.77 \pm 1.13^{d-f}$	$115.30 \pm 2.03^{b-d}$	$3.83 \pm 0.34^{a-e}$	$2.17 \pm 0.20^{j-l}$
Hadhuudh Cad 011	14.14 ± 1.41^{ef}	$118.70 \pm 2.14^{b-f}$	$3.50 \pm 0.33^{a-c}$	$1.39 \pm 0.12^{c-f}$
Hadhuudh Cas 010	14.15 ± 1.32^{ef}	109.90 ± 1.98^{b}	3.00 ± 0.30^{ab}	0.84 ± 0.04^{a}
Dhawdhaw 015	14.30 ± 1.31^{f}	$120.10 \pm 2.78^{c-g}$	$4.61 \pm 0.43^{c-g}$	$1.85 \pm 0.14^{g-j}$
Hadhuudh Cad 05	15.43 ± 1.52^{g}	$120.70 \pm 2.82^{c-g}$	$4.99 \pm 0.45^{f-i}$	$2.12 \pm 0.20^{j-l}$
Hadhuudh Cas 06	15.65 ± 1.51^{g}	110.60 ± 2.01^{b}	3.28 ± 0.31^{ab}	0.92 ± 0.05^{ab}
Hadhuudh Cas 03	15.74 ± 1.42^{g}	$117.80 \pm 2.56^{b-f}$	6.17 ± 0.61^{j}	3.31 ± 0.31^{m}
Hadhuudh Cad 01	18.42 ± 1.63^{h}	170.10 ± 2.72^{i}	7.99 ± 0.75^{k}	4.09 ± 0.40^{n}
Hadhuudh Cas 07	20.27 ± 1.90^{i}	$111.80 \pm 2{,}64^{bc}$	7.66 ± 0.73^{k}	3.10 ± 0.31^{m}
Axmedcumer 09	24.77 ± 1.95^{j}	99.50 ± 1.68^{a}	$5.83 \pm 0.54^{h-j}$	$1.91 \pm 0.15^{h-j}$
Hadhuudh Cas 04	24.91 ± 1.99^{j}	99.90 ± 1.76^{a}	6.23 ± 0.61^{j}	$1.91 \pm 0.15^{h-j}$

Note: a - n is the significant difference among some sorghum samples (i.e., $p < 0.05$).

and Gebreyes [28] who found the Mg content from 62.09 mg/100 g - 207.53 mg/100 g. This difference might be due to differences in ash content, nature of the soil, farming system, agroecology, and others.

Fe is a core element in the synthesis of haemoglobin and myoglobin. Its deficiency is strongly related to anaemia, mental disorders, immune problems [40], children's cognitive ability, poor pregnancy quality, and lower working capacity in adults [41]. With respect to Fe content, Bullo 016 from Gursum district of Adede kebele has the lowest in Fe content (2.67 mg/100 g) while Hadhuudh Cad 01 from Sagag district Hara howd kebele has the highest in Fe content 7.99 mg/100 g. The Fe content was significantly different among sorghum samples under study Hadhuudh Cas 02 and Hadhuudh Cas 07, Bullo 016 and Axmadsaay 021, Ellies 024 and Fandishe 026, and many others ($p < 0.05$). The result obtained in the research reported by Risks [42] who found that the Fe content ranged from 4.70 - 14.05 mg/100 g, and the one reported in Deosthale et al. [39], the Fe concentration study on 12 varieties of sorghum from Tanzania showed Fe content in the range of 5.50 mg/100 g - 182 mg/100 g. The result of the research mentioned above is somewhat different from the current research for which its Fe content is in the range of 2.67 - 7.99 mg/100 g.

Zn deficiency is ranked in the top five risk factors of disease and death in developing countries [42]. Zn deficiency causes dermatitis, growth retardation, diarrhoea, mental disturbances, and recurrent infections [43]. This deficiency is generally related to diet consumption with low or high levels of Zn in phytates. Zn is a good reducing agent. It can easily form complexes with other compounds, including carbonates, phosphates, sulfates, oxalates, and phytates. An important function of Zn is an essential cofactor for more than 70 enzymes [44]. Fin Zn content of different sorghum samples is presented in table 2. Hadhuudh cad 01 from Sagag district Hara howd kebele has the highest in Zn content which is 4.09 mg/100 g while Hadhuudh Cas 010 has the lowest in Zn content is 0.84 mg/100 g. The Zn content was not significantly different among some of the sorghum samples like Hadhuudh Cad 011, Cilmi Jaamac 012, and Casse 023, Faaraxgasle 020, Shaqqee 027, Fandishe 026, Casse Cad 013, and Dhawdhaw 015, Axmadsaay 021 and Hadhuudh Cad 05, and some other samples at $p < 0.05$. However, significant differences were observed in Zn content among other sorghum samples, such as Hadhuudh Cas 010 and Mansugi 017, Hadhuudh Cas 02 and Hadhuudh Cad 01, Bullo 016 and Elles 024, and many other sorghum samples. The current research result is in accordance with the research done by Tasie and Gebreyes [28], who found Zn concentrations ranging from 0.698 mg/100 g - 6.484 mg/100 g.

Anti-nutritional factors of different sorghum varieties

Food crops with high anti-nutritional content may not be good for food consumption because of their negative impact on nutrient availability and digestibility unless processed very well. In addition, the sensory properties of the food product may not be acceptable due to bitterness characteristics. Tannin is the most abundant anti-nutritional factor in sorghum [45]. The anti-nutritional contents of different sorghum samples are shown in table 3. The tannins content of sorghum is in the range of 0.22 mg/g - 4.08 mg/g for Hadhuudh 05 from Adaadle district of Bilyolow kebele and Hadhuudh Cad 01 from Sagag district of Hara Howd kebele respectively. Significant differences were observed among some sorghum samples, such as Casse 023 and Axmedcumer 09, Hadhuudh Cad 05 and Hadhuudh Cas 08, Elles 024 and Hadhuudh Cad 01, and some other samples at $p < 0.05$. When it comes to phytate, Hadhuudh Cas 010 from Dagahbur district of Hodale kebele has the highest phytate content (5.25 mg/g) while Hadhuudh Cad 01 from Sagag district of Hara howd kebele has the lowest phytate content which is 2.76 mg/g. The phytate content of sorghum samples was significantly different for some of the samples in this study Hadhuudh Cad 01 and Mansuge 017, Hadhuudh cad 05 and Cilmi Jaamac 012, Axmadsaay 021 and Hadhuudh Cas 010, and some others at $p < 0.05$. The current study result of tannin content is almost in line with the research report by Radhakrishnan and Sivaprasad [46], who found a tannin content of 10 mg/100 g - 351 mg/100 g, which contradicts the research done by Tasie and Gebreyes [28], who found it between 1.3660 - 3337.2 mg/100 g. Multiple phenolic hydroxyl groups of tannins may form stable complexes with proteins, metal ions, and other macromolecules, such as polysaccharides [47, 48], and reduce the digestibility of proteins and the availability of nutrients in the gut.

Table 3: Anti-nutritional factors of different sorghum varieties.

Sorghum varieties	Results (mg/g)	
	Tannins	Phytate
Hadhuudh Cad 05	0.22 ± 0.02^{a}	2.98 ± 0.24^{ab}
Hadhuudh Cad 011	0.40 ± 0.03^{ab}	5.06 ± 0.51^{f}
Dhawdhaw 015	0.47 ± 0.04^{ab}	3.44 ± 0.32^{a-c}
Bullo 016	0.47 ± 0.04^{ab}	3.46 ± 0.33^{a-c}
Mansugi 017	0.48 ± 0.05^{ab}	3.68 ± 0.33^{bc}
Cabdidayr 019	0.64 ± 0.06^{a-c}	3.46 ± 0.32^{a-c}
Hadhuudh Cas 08	0.76 ± 0.07^{b-d}	3.46 ± 0.32^{a-c}
Soole (Maamo Ture) 014	0.77 ± 0.07^{b-d}	4.12 ± 0.40^{c-e}
Dhaga Adag 018	0.83 ± 0.08^{b-d}	3.45 ± 0.31^{a-c}
Wagare 022	0.87 ± 0.06^{b-d}	3.44 ± 0.32^{a-c}
Hadhuudh Cas 06	0.96 ± 0.08^{b-d}	4.14 ± 0.42^{c-e}
Casse Cad 013	1.06 ± 0.10^{cd}	3.47 ± 0.32^{a-c}
Faaraxgasle 020	1.06 ± 0.10^{cd}	3.68 ± 0.33^{bc}
Hadhuudh Cas 07	1.17 ± 0.93^{c-e}	4.61 ± 0.43^{d-f}
Fandishe 026	1.19 ± 0.95^{c-e}	3.62 ± 0.33^{a-c}
Hadhuudh Cas 010	1.22 ± 0.98^{d-f}	5.25 ± 0.51^{f}
Hadhuudh Cas 02	1.23 ± 0.99^{d-f}	4.13 ± 0.40^{c-e}
Elles 024	1.25 ± 0.88^{d-f}	4.85 ± 0.44^{ef}
Shaqqee/KufaKas/kor u saydhe 027	1.64 ± 0.96^{e-g}	3.46 ± 0.32^{a-c}
Hadhuudh Cas 04	1.67 ± 0.78^{e-g}	3.66 ± 0.33^{a-c}
Axmadsaay 021	1.74 ± 0.99^{fg}	3.90 ± 0.34^{b-d}
Car i Liq 025	1.74 ± 0.86^{fg}	3.90 ± 0.35^{b-d}
CilmiJaamca 012	1.89 ± 0.99^{g}	4.17 ± 0.41^{c-e}
Hadhuudh Cas 03	2.09 ± 0.98^{g}	3.88 ± 0.34^{b-d}
Casse 023	2.10 ± 0.96^{g}	3.43 ± 0.32^{a-c}
Axmedcumer 09	3.95 ± 1.01^{h}	4.83 ± 0.44^{ef}
Hadhuudh Cad 01	4.08 ± 1.04^{h}	2.76 ± 0.23^{a}

Note: a - h is the significant difference among some sorghum samples (i.e., $p < 0.05$).

Conclusion

This study examined 27 sorghum landraces and varieties from the Somali region. The data indicated that all varieties had moisture content below 12%, suggesting resistance to mold. The high ash content across all varieties reflects their rich mineral content. The fiber, carbohydrate, and fat contents were high, while protein content ranged from 6.90% - 14.20%. Mineral analyses showed substantial amounts of Ca, Mg, Fe, and Zn. Antinutritional factors like tannins and phytates varied, consistent with most cereals. Significant differences were found in macronutrient and micronutrient anti-nutrients across varieties ($p < 0.04$). The average nutrient content was 8.72% moisture, 2.66% ash, 2.02% crude fiber, 8.94% crude protein, 3.58% crude fat, and 74.08% carbohydrate. Nutrient composition variations may be due to varietal differences, agro-ecological factors, farming systems, and management practices. Future research should include amino acid profiling, mineral analysis, and phenolic content analysis. Strategies like biofortification should be employed to address deficiencies in certain sorghum components. These findings can guide crop breeding programs in selecting sorghum varieties with optimal nutrient profiles and influence agrarian policies to enhance food security and nutrition in the region.

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None.

Conflict of Interest

None.

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