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Determination and Quantification of Proximate and Mineral Composition for 20 Improved Sorghum Varieties Grown in Machache, Lesotho

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Abstract

Twenty varieties of improved sorghum were grown in Machache at the Department of Agricultural Research station, located (29˚22'60"S and 27˚52'0"E) in the central foothills of Lesotho in Maseru district. The varieties were planted in a randomized complete block design. At maturity, they were harvested, dried, threshed, milled and analyzed in the crop science laboratory at the National University of Lesotho. The proximate and mineral contents were analyzed from samples in a completely randomized design with three replicates. The proximate composition parameters measured were crude proteins, crude fiber, crude fat, moisture content, and carbohydrates. The minerals analyzed were, phosphorus, sodium, calcium, magnesium, potassium, copper, zinc, iron, and magnesium. The results showed the nutritional contents ranging from (4.7% - 16.16%), (0.35% - 2.10%), (1.25% - 4.00%), (71.60% - 84.06%), (5.53% - 10.18%), for protein, fat, fiber and carbohydrate, and moisture content, respectively. Mineral content ranged from (1342.96 - 3500.34 mg/kg), (25.97 - 185.25 mg/kg), (50.71 - 511.71 mg/kg), (29.35 - 4542.13 mg/kg), (577.19 - 3041.52 mg/kg), (0.25 - 4.07 mg/kg), (1.96 - 18.61 mg/kg), (67.14 - 122.96 mg/kg), (4.73 - 11.39 mg/kg) for phosphorus, sodium, calcium, magnesium, potassium, copper, zinc, iron, and manganese respectively. The following varieties were found to have the highest and appreciable amounts of nutrients and minerals that are crucial in the country diet; protein content was KARI Mtama 1, zinc, IESX 16 2533-SB-SSI-19, and iron IESX 16 2535-SB-SSI-34.

Keywords

Varieties, Sorghum, Proximate, Mineral

1. Introduction

Lesotho is a landlocked country characterized by food insecurity, high levels of malnutrition, and unemployment rate [1]. Most rural people who are resource-poor depend on agriculture for food and as a source of income. Major cereal crops grown in Lesotho are maize, sorghum, wheat, peas, beans, and lentils. Sorghum is ranked the second after staple crop, maize [2]. Sorghum draws more attention from growers and researchers due to its incredible environmental adaptation features such as drought, high temperatures, and soil toxicity variation tolerance [3]. The production of sorghum has been declining in Lesotho on area planted to the crop and yield per ha. Sorghum production has decreased from 84,000 tonnes recorded in 1975 to 22,000 tonnes in 2010 and yield above 1 tonne ha^{-1} constituting only 18% during this period [4].

Production of sorghum in Lesotho is generally affected by climate change effects such as shifts in rainy season, drought and floods, low soil fertility, early frost, late planting, insect pests, and weeds [5]. The major factor with notable impact is the effect of climate change. Traditionally, sorghum is planted from October to mid-November in Lesotho. The first rains' now start at the end of November and beginning of December resulting into reduced growing season. This shift has made most farmers stop growing sorghum. Currently, Lesotho depends on the importation of sorghum seeds for production. The imported seeds show outstanding adaptability features that translate to high yields. However, the majority of these varieties are hybrids and farmers cannot afford to buy seed every year as they are used to open pollinated varieties (OPVs) of sorghum.

Moreover, sorghum plays an important role in Basotho dishes as it is used for bread preparation, leavening agents, porridges, alcoholic beverages, and snack production [6]. Sorghum sour porridge prepared and bottled by ordinary citizens is sold in almost every food shop including the foreign big supermarkets. Not only sorghum is the most commercial and versatile crop in Lesotho, but it also has tons of health benefits in human nutrition. It is a principal source of important nutrients such as proteins, carbohydrates, fats, minerals, and crude fiber which are all necessary for human health and development [7]. Proximate analysis is commonly used for nutrient testing in food crops. The analysis includes proteins, fats, moisture, fiber, ash, and carbohydrate [8]. The proximate and mineral content of sorghum is influenced by the environment, genotype, and their interactions [9] [10], found that there was a significant genotype × environment interactions effect on mineral content, showing the need for selecting genotypes based on the local environment to increase the nutritional value of the crop under drought.

The International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), develops varieties for semi-arid conditions. Their priority is on traits such as drought tolerance, short to medium maturity duration, low external input requirements and climate-change resilient crops. Kenya is the regional hub for Africa while countries like Malawi and Zimbabwe are sub-reginal offices and research centers to cater for climatic conditions in Southern Africa. The material given by the center are expected to be availed to farmers at no cost after the trials and seed multiplication.

The varieties bring hope to the country's poor production, none of them has been comprehensively tested and profiled for nutritional purposes as the quality of grain is dependent on the variety and the growing conditions [11]. Therefore, this study is intended to determine and quantify the proximate, and mineral content of 20 improved varieties of sorghum sourced from Kenya.

2. Methodology

2.1. Sample Collection and Preparation

The twenty improved sorghum varieties were planted in randomized complete block design at the Department of Agricultural Research station in Machache. The station is situated (29˚22'60"S and 27˚52'0"E) in the central foothills of Lesotho in Maseru district. The trial was planted under rainfed conditions. Fertilizer (N:P:K) 6:2:1 (31) was applied at 300 kg/ha during planting and weeding was done twice using hand hoes. At maturity, the varieties were harvested, and transported to the National University of Lesotho into the Crop Science laboratory where they were dried, and manually threshed. The threshed samples were cleaned by hand, eliminating foreign materials, and cracked grains. The grains were then rinsed with tap water followed by distilled water. The grain was spread on a clean surface layered with soft absorbent paper for drying overnight at apartment temperature. For individual variety, 200 g of pure cleaned seed samples were packed into plastic bags for analysis.

2.2. Proximate Composition

2.2.1. Proximate Analysis

Proximate analysis was carried out using the Association of Official Agricultural Chemists protocols (AOAC) [12] [13].

2.2.2. Moisture Content

The standard method of AOAC 925:10 was used. Two grams (2 g) of each ground sorghum sample was measured in the pre-weighted clean crucible, and placed in the oven and heated to 130˚C for an hour. Then the samples were removed and cooled in desiccators at room temperature. Finally, the samples were re-weighed and the procedure of drying and cooling was done at 30 minutes interval until the differences between the consecutive weighing were less than 1 mg. The lowest weight (W_2) was recorded and the moisture content was calculated as follows:

$$\text{Moisture}(\%) = \frac{(W_1 - W_2) * 100}{SW}$$

where W_1 is the weight of the cap and fresh sample, W_2 is the weight of the dry sample and cap and SW is the sample weight.

2.2.3. Ash Content Determination

The methods of AOAC 923:03 also known as dry ashing method was used to determine the ash content. Five grams (5 g) of sorghum flour was transferred to a spotless pre-weighed crucible. The sample underwent heating to 550˚C in a muffle furnace. The sample was taken out of the furnace after it had burned to light gray, and underwent cooling in the desiccator at room temperature and weighed. The formula below was used to estimate the ash content.

$$\text{Ash content}(\%) = \frac{W_3 - W_1}{W_2 - W_1}$$

where W_1, is the weight of the empty dish and, W_2 is the weight of the dish and fresh sample, and W_3 is the weight of the crucible plus the weight of the sample after oven-drying.

2.2.4. Protein Content

The protein content was determined by the Kjeldahl method (AOAC, 2001.11). The protein content was estimated using a sample size of 5 grams weighed into 50 milliliter Kjeldahl flask, and 8 milliliters of concentrated sulphuric acid (H_2SO_4) was added with 2 grams of copper and potassium sulphate mixture (catalyst). The samples were digested until a pure colourless solution resulted. Afterward, the digested samples were distilled using Kjeldahl distiller and distilled steam (ammonia gas) was collected with 25 milliliters of 2% boric acid containing 3 ml of mixer indicator. The distilled samples were titrated by 0.1 N hydrochloric acid (HCL) until the first appearance of pink color. Finally, the percentage crude protein was computed using the following formula below.

$$\text{Crude protein} = \frac{(a * b * 14 * 6.25) * 100}{W}$$

where "a" and "b" are the normality of acid and the volume of standard acid in milliliters, corrected for the blank (that is, the sample minus blank) respectively while 6.25 is the conversion factor for protein from percentage nitrogen and 14 is atomic weight of Nitrogen.

2.2.5. Fat Content

The method of AOAC 945:16 also known as Soxhlet extraction method, was used to estimate fat. The previously prepared thimble was loaded with two grams (2 g) of powdered sorghum sample. The thimble was plugged with absorptive, fat-free cotton wool. Prior to fat extraction, the Soxhlet equipment was assembled and the petroleum ether spirit was added to half of the flask. Afterwards the extraction resumed and went on for four hours. After the extraction time has elapsed, the remining ether in the flask was removed using rotary evaporator. The remaining solvent was evaporated at 103˚C for 30 minutes. The flasks were afterwards reweighed after being dehydrated and cooled in a desiccator. The fat content was then calculated by the formula below.

$$\text{Fat content}(\%) = \frac{(W_F - W)*100}{SW}$$

where W_F is the weight of the receiver flask and fat deposit, W is the weight of the empty receiver flask only and SW is the weight of the sample used.

2.2.6. Fiber Content

Fiber content determination was estimated according to the AOAC, 978.10 method. The chemical reagents for analysis were prepared separately in 500 ml conical flask, (0.128 M and 0.313 M of sulfuric acid and sodium hydroxide solutions, respectively). The 200 ml of sulphuric acid was poured into conical flask. Then 2 g of sample was added in the acid. The sample was boiled for 30 minutes and during boiling, the sample was periodically agitated. Afterwards, when boiling time elapsed, the boiled sample was filtered with a cotton cloth to drain the acid solution. To ensure that there were no remaining residues in the flask, the flask was rinsed with hot water and filtered. Thereafter, the filtrate on cotton cloth was washed with hot water to remove acid residue completely. The previously boiled sample was transferred into another clean conical flask. The same procedure was followed using 0.313 M sodium hydroxide solution. After draining excessive sodium hydroxide, the filtrate was collected using crucible. The crucible was placed on a hot plate to remove excess water from the sample and drying continued by placing the sample in a hot air oven at 230˚C for 2 hours. After 2 hours, the hot crucible was put in the desiccator and after 20 minutes, it was weighed (W_1). The sample was then taken to the muffle furnace at 550˚C for 2 hours. The crucible was removed from the furnace after 4 hours and taken into desiccator to cool and then the crucible was weighed and the weight (W_2) was recorded.

The total fiber was calculated as follows;

$$\text{Crude Fiber }\% = \frac{(W_1 - W_2)*100}{SW}$$

where, SW is the sample weight.

2.2.7. Total Carbohydrates

Carbohydrates were determined by carbohydrates by difference method whereby measured fat, fiber, protein, ash and moisture percentages were subtracted from 100% [8]. This was computed as follows:

Total carbohydrates = 100 − (Moisture % + protein % + Ash % + Fat %)

2.2.8. Mineral Content Composition

The standard method used for mineral content determination was wet digestion method by [7]. The 0.5 grams of sample was taken and digested with 5 ml concentrated nitric acid (HNO_3) and 1 milliliter of concentrated perchloric acid

($HClO_4$). The digested sample was filtered and made up to 100 milliliters in a standard flask. The minerals (Sodium, Potassium, Magnesium, Calium, Manganese, Zinc, Iron and Copper) were detected using an atomic absorption spectrophotometer (PerkinElmer, PinAAcle 500) except for phosphorus which was determined using the UV-visible spectrophotometric method.

2.3. Statistical Analysis

The data collected was subjected to one way Analysis of Variance (ANOVA) using the Statistical Package for Social Sciences (SPSS Version 20). Duncan's significant difference test was used for mean separation at $p < 0.05$. The analyzed data was reported as means of three replicates and showed significant differences by the use of different superscripts.

3. Results and Discussion

3.1. Proximate Composition

The proximate analysis of improved varieties of sorghum is summarized in **Table 1**. The protein, fats, fiber, moisture, and carbohydrate content in the current study were significantly different among varieties at ($p < 0.05$). The percentage protein varied from 4.73 to 16.16. In the human body, protein plays an important role in growth and development as it provides the body with essential amino acids [14]. The results presented in the table for crude protein are in accordance with the conclusion by [15], and [16] who recorded 4.27 - 6.06 g/100g, and 8.20 to 16.48 g/100g, respectively. Most of the varieties including Macia (8.16%) which is our local check, have protein content above the minimum standard requirement for quality grain (7.0%) as documented by [17]. In contrast, the protein content recorded in the current study is comparatively lower than the protein content in protein-rich grains such as beans (21.23% - 23.83%) and peas (21.63% - 28.13%) [18] [19].

Fats are important nutritional components as they provide the body with energy. They also mediate the absorption of some important vitamins and add flavor to food [20]. The fat content ranged from 0.35% to 2.10%. The values from the results are lower as compared to previous studies which are (2.42 g/100g, 2.48 - 4.60 g/100g, and 6.72 - 9.26 g/100g) as reported by [21] [22] and [15] respectively. On the other hand, the results are in line with the results documented by [23] who recorded 1.56 g/100g. The ash content from the current study ranged from 0.15% - 2.76%. Ash content of sorghum measures the presence of minerals content in it and different varieties recorded different ash content values. The results obtained in this study conform with what was found by [8], (1.12% to 1.68%) and [16] which were (1.12% to 2.29%).

Dietary fiber plays an important role in human health. High-fiber-content food prevents development of coronary heart disease, hypertension, obesity, stroke, and gastrointestinal diseases [24]. In the current study, fiber content ranged from 1.25% - 4.00%. The fiber content captured in the current study

Table 1. Proximate composition of 20 improved sorghum varieties in (%).

Variety	Protein	Fats	Ash	Fiber	Moisture content	Carbohydrates
17028-SSI-SSI-13	10.10^{bc}	0.95^{d-f}	2.26^{a-c}	2.25^{b-f}	5.94^{jk}	78.50^{bc}
17052-SSI-SS-5	6.64^{cd}	1.15^{c-e}	1.01^{ef}	2.75^{b-e}	6.97^{gh}	81.49^{a-c}
IESX 16 2524-SB-SSI-27	6.51^{cd}	1.45^{ef}	2.76^{a}	1.75^{d-f}	6.47^{hi}	81.07^{a-c}
IESX 16 2524-SB-SSI-30	9.84^{b-d}	2.00^{ab}	1.12^{ef}	2.13^{c-f}	7.65^{f}	77.26^{c}
IESX 16 2525-SB-SSI-6	6.21^{cd}	1.50^{a-d}	1.98^{a-d}	2.50^{b-f}	8.09^{d-f}	79.71^{a-c}
IESX 16 2531-SB-SSI-16	6.50^{cd}	1.78^{a-c}	1.97^{a-d}	1.50^{ef}	8.77^{bc}	79.48^{a-c}
IESX 16 2533-SB-SSI-17	8.38^{cd}	1.50^{a-d}	1.25^{d-f}	2.25^{b-f}	7.95^{ef}	78.68^{bc}
IESX 16 2533-SB-S.SI-19	9.06^{b-d}	1.20^{cd}	0.15^{g}	2.00^{c-f}	8.99^{bc}	78.59^{bc}
IESX 16 2533-SB-SSI-7	8.89^{b-d}	0.35^{f}	1.50^{c-e}	2.75^{b-e}	7.87^{ef}	78.64^{bc}
IESX 16 2535-SB-SSI-27	4.73^{d}	0.45^{ef}	2.25^{a-c}	2.00^{c-f}	7.10^{g}	83.46^{ab}
IESX 16 2535-SB-SSI-34	5.80^{cd}	1.80^{a-c}	1.00^{ef}	2.50^{b-f}	8.49^{cd}	80.41^{a-c}
IESX 16 2535-SB-SSI-8	15.95^{a}	1.40^{a-d}	1.25^{d-f}	1.75^{d-f}	10.18^{a}	69.46^{a-c}
IESX 16 2536-SB-SSI-1	6.51^{cd}	2.10^{a}	2.50^{ab}	2.50^{b-f}	5.53^{k}	80.86^{a-c}
MACIA X CR 35:5-SB-SSI-15	7.69^{cd}	1.13^{c-e}	0.50^{fg}	3.25^{a-c}	7.95^{ef}	79.48^{a-c}
R 8602 X GADAM-SB-SSI-65	13.48^{ab}	1.43^{a-d}	1.37^{de}	3.00^{a-d}	8.38^{c-e}	72.33^{d}
R 8602 X IS 11167-SB-SSI-15	5.86^{cd}	1.30^{b-d}	1.25^{d-f}	1.25^{f}	6.28^{ij}	84.06^{a}
KARI Mtama 1	16.16^{a}	1.00^{d-f}	2.26^{a-c}	2.50^{b-f}	6.47^{hi}	71.61^{d}
GADAM	6.04^{cd}	0.85^{d-f}	1.76^{b-e}	4.00^{a}	6.77^{g-i}	80.58^{a-c}
Macia	8.15^{cd}	1.83^{a-c}	1.12^{ef}	2.00^{c-f}	6.99^{gh}	79.90^{a-c}
IS 8193	8.38^{cd}	0.85^{d-f}	1.75^{b-e}	3.50^{ab}	6.96^{gh}	78.56^{bc}
Total	8.54	1.3	1.55	2.41	7.49	78.71
SEM	0.44	0.07	0.09	0.1	0.12	0.48
LSD at $p < 0.05$	2.87	0.38	0.47	0.78	0.32	2.97

Means within the same column with different superscripts are significantly deferent at ($p < 0.05$).

ranged between 1.25% to 4.00%. The results compare favorably with the ones previously documented with a sorghum fiber content of 1.45 g/100g and 2.18 g/100g [15] [23], respectively. [16] recorded the lowest fiber content of 2.17 which is in the range of what was captured in the study; however, the maximum content was 8.59% is comparatively greater than the maximum fiber content in the study.

The twenty varieties scored moisture content ranging between (5.53% - 10.18%). The maximum standard moisture content for sorghum grain is 13% [17]. Moisture content is an important component in the postharvest of grain sorghum. It affects the grain quality and processing. The grain stored with high moisture content is prone to microbial and storage pest infestations which in turn leads to decreased grain quality [25]. Furthermore, grains with less or high moisture during processing can lead to poor grain milling yields [26]. Different varieties have different moisture content and this is as a result of genetic variability among them and it explains why there was variation in moisture content among the varieties studied [27]. The overall moisture content of sorghum grain previously documented in Lesotho was 9.2% [28]. The results in the study are in accordance with results found by [8] who got the moisture ranging from 1.39 to 16.32%. In contrast, the moisture content from the findings was lower compared to the percentage moisture obtained by [15] which ranged between (10.23 to 11.9).

Carbohydrates provide the body with energy. The carbohydrate captured in the study ranged from 71.61% to 84.06% and these results correspond with data previously documented by [29] and [30], which were 74.6 g/100g to 82 g/100g, and 76.51% respectively. In all varieties, Carbohydrates are the most abundant nutritional components among all the analyzed parameters followed by protein content for each variety in the study.

3.2. Minerals

Minerals are crucial in physiochemical processes that occur in the human body for growth and development [31]. Amongst all the minerals found in sorghum, only five macronutrient elements (Potassium, Calcium, Magnesium, Sodium, and Phosphorus) and four micronutrient elements (Zinc, Iron, Manganese, and copper) were assessed and the results presented in **Table 2** and **Table 3**. All the 20 improved sorghum varieties showed a significant difference of measured parameters among varieties at $p < 0.05$.

Potassium content in the current study ranged from 577.19 mg/kg to 3041.52 mg/kg. Potassium is essential in the reduction of heart disease-based mortality and lower blood pressure in high-blood-pressure patients [32]. The previous investigation by [33] and [34] profiled potassium content that ranged from (900 - 2146.88 mg/kg and 3.00 - 3.43 g/kg respectively) which were similar to the current study. However, [35] documented 98.98 - 110 mg/kg which is inferior to the results in this study. The maximum content of calcium was 511.69 mg/kg while the minimum content was 50.71 mg/kg. According to [36], calcium is essential for strong bones as it constitutes the larger portion of human bones. It is also essential for nerve impulses and it is associated with osmoregulation in the human body. In the current study, calcium content ranged from 50.71 - 511.69 mg/kg which is in accordance with outcomes from [33] and [37] which ranged from (11.56 - 27.81 mg/kg and 195 - 477.04 mg/kg). On the other hand, [35] profiled calcium from 13.05 - 15.07 mg/kg which is far less than what was profiled in this study.

Sodium content ranged between 25.97 - 185.25 mg/kg. Sodium is an important nutrient in maintaining the osmotic balance of body fluids, helps in glucose absorption, and regulation of body pH [38]. The results compiled in the study are in line with the results filled by [34] and [37] which were (17.33 - 23.15 mg/100g), and (0.03 g/kg), respectively. However, [39] indicated sodium content

Table 2. The macro mineral nutrients of 20 improved sorghum varieties (mg/kg).

Variety	K	Ca	Na	Mg	P
17028-SSI-SSI-13	1076.98^{d-f}	394.47^{a-c}	123.08^{b}	388.73^{e}	2757.78^{d-f}
17052-SSI-SS-5	1048.78^{d-f}	419.41^{ab}	96.26^{d}	29.35^{e}	1379.99^{h}
IESX 16 2524-SB-SSI-27	1702.35^{bc}	252.31^{b-e}	39.45^{i}	310.54^{e}	1824.44^{g}
IESX 16 2524-SB-SSI-30	1446.05^{cd}	396.96^{a-c}	79.31^{e}	2316.60^{b}	3187.41^{b}
IESX 16 2525-SB-SSI-6	613.07^{f}	382.83^{a-d}	59.74^{gh}	582.13^{de}	1765.19^{g}
IESX 16 2531-SB-SSI-16	1351.21^{cd}	184.56^{ef}	67.86^{e-g}	813.94^{de}	2972.59^{b-e}
IESX 16 2533-SB-SSI-17	1253.82^{c-e}	382.00^{a-d}	185.25^{a}	568.42^{de}	1846.67^{g}
IESX 16 2533-SB-SSI-19	1092.35^{d-f}	125.11^{ef}	108.87^{c}	362.67^{e}	3500.34^{a}
IESX 16 2533-SB-SSI-7	2730.10^{a}	51.96^{f}	91.63^{d}	4542.14^{a}	1694.82^{g}
IESX 16 2535-SB-SSI-27	1681.84^{bc}	267.27^{b-e}	176.56^{a}	639.75^{de}	2991.11^{b-e}
IESX 16 2535-SB-SSI-34	1087.23^{d-f}	308.84^{b-e}	110.90^{c}	300.95^{e}	2842.96^{c-e}
IESX 16 2535-SB-SSI-8	1494.75^{cd}	136.75^{ef}	73.22^{ef}	1942.83^{bc}	2646.66^{ef}
IESX 16 2536-SB-SSI-1	2150.87^{b}	204.92^{c-f}	58.14^{gh}	4399.49^{a}	3050.37^{b-d}
MACIA X CR 35:5-SB-SSI-15	1096.19^{d-f}	511.69^{a}	50.32^{hi}	391.47^{e}	2735.55^{d-f}
R 8602 X GADAM-SB-SSI-65	1094.92^{d-f}	177.08^{ef}	25.97^{j}	376.38^{e}	2004.07^{g}
R 8602 X IS 11167-SB-SSI-15	777.10^{ef}	221.55^{c-f}	49.02^{hi}	545.10^{de}	2809.63^{c-e}
KARI Mtama 1	577.19^{f}	299.69^{b-e}	74.38^{ef}	820.81^{de}	1883.70^{g}
GADAM	1102.60^{d-f}	191.62^{d-f}	65.25^{fg}	337.98^{e}	1342.96^{h}
Macia	1343.53^{cd}	50.713^{f}	48.00^{hi}	1411.31^{cd}	2442.97^{f}
IS 8193	3041.52^{a}	164.19^{ef}	76.92^{ef}	683.64^{de}	3142.96^{bc}
Total	1388.12	256.19	83.01	1088.21	2441.11
SEM	65.39	16.54	3.81	128.95	62.81
LSD at $p < 0.05$	149.82	163.77	111.46	798.02	452.26

K: Potassium, Ca: Calcium, Na: Sodium, Mg: Magnesium, P: Phosphorus. *All the means in the same column with the same superscript are not significantly different at $p < 0.05$).

of 0.42 - 0.54 g/kg which is far greater than the one in the current study. Phosphorus content ranged from 1342.96 to 3500.34 mg/kg. This nutrient element is a constituent in cell membranes. It does not only play a role in cell membrane functioning but also helps in DNA and bone development [33] [34] [40] [41] documented phosphorus content ranged from 2505.83 - 3452.83 mg/kg and 3.43 - 3.52 g/kg which were in accordance with what was documented in the current study (1342.9622 - 3500.34 mg/kg). On the other hand, [37] reported (483 - 521 mg/100g) which contradicted what was documented in the current study.

Magnesium content of different varieties scored 29.35 - 4542.14 mg/kg. Magnesium is an essential macro-nutrient involved in many physiochemical and enzymatic activities inside the body [42]. The results from the study are in accordance with what was profiled by [34] and [37] which were (1.40 - 1.52 g/kg) and

Table 3. Trace mineral elements content of sorghum varieties (mg/kg).

Variety	Cu	Zn	Mn	Fe
17028-SSI-SSI-13	2.74^{d}	14.63^{e}	7.83^{ef}	156.76^{g}
17052-SSI-SS-5	0.25^{m}	17.82^{b}	6.76^{hi}	97.607^{p}
IESX 16 2524-SB-SSI-27	1.39^{h}	5.00^{j}	7.53^{e-g}	67.14^{t}
IESX 16 2524-SB-SSI-30	0.69^{k}	4.17^{kl}	11.39^{a}	208.28^{b}
IESX 16 2525-SB-SSI-6	1.87^{f}	4.42^{k}	7.53^{e-g}	106.37^{m}
IESX 16 2531-SB-SSI-16	1.53^{g}	2.00^{n}	5.83^{g}	135.05^{h}
IESX 16 2533-SB-SSI-17	1.33^{h}	15.67^{c}	7.42^{fg}	102.17^{n}
IESX 16 2533-SB-SSI-19	0.52^{l}	18.61^{a}	7.69^{ef}	131.44^{i}
IESX 16 2533-SB-SSI-7	3.76^{b}	3.95^{l}	7.99^{e}	112.56^{l}
IESX 16 2535-SB-SSI-27	1.11^{i}	14.30^{f}	7.09^{gh}	163.41^{f}
IESX 16 2535-SB-SSI-34	1.56^{g}	13.22^{g}	10.08^{b}	221.26^{a}
IESX 16 2535-SB-SSI-8	0.94^{j}	2.90^{m}	9.56^{c}	125.52^{j}
IESX 16 2536-SB-SSI-1	1.20^{i}	6.00^{i}	9.13^{d}	174.34^{d}
MACIA X CR 35:5-SB-SSI-15	0.64^{k}	14.99^{d}	7.63^{ef}	170.97^{e}
R 8602 X GADAM-SB-SSI-65	0.13^{n}	1.96^{n}	5.86^{g}	100.06^{o}
R 8602 X IS 11167-SB-SSI-15	0.74^{k}	3.93^{l}	4.72^{l}	73.37^{s}
KARI Mtama 1	2.44^{e}	2.98^{m}	6.93^{hi}	85.26^{r}
GADAM	2.66^{d}	14.39^{ef}	6.46^{i}	184.73^{c}
Macia	4.07^{a}	7.67^{h}	9.69^{bc}	122.95^{k}
IS 8193	3.46^{c}	4.00^{l}	5.26^{k}	87.01^{q}
Total	1.65	8.62	7.62	131.31
SEM	0.10	0.53	0.15	3.97
LSD at $p < 0.05$	0.10	0.25	0.43	0.91

*Cu: copper, Zn: Zinc, Mn: Manganese, Fe: Iron. All the means in the same column with the same superscript are not significantly different at $p < 0.05$).

(211 - 225 mg/100g), respectively. On the other hand, the results of the study do not agree with the data recorded by [39] (8.69 - 16.93 g/kg). The copper content ranged from 0.13 to 4.07 mg/kg. The variety with the highest copper content was Macia (4.07 mg/kg) which is our local check. Copper is vital trace element nutrient in the human body as it is associated with the maintenance of connective tissues, the formation of red blood cells, and a well-functioning immune system [43]. It is also crucial, as it assists in the absorption and utilization of iron [44]. From previous studies, some researchers found copper content ranging from 0.94 - 8.01 ug/g and 3.07 - 3.50 mg/kg, respectively [8] [34]. The result documented by [37] which was (0.84 mg/100g) contradicted the results in the current study.

The zinc content ranges between 1.96 to 18.61 mg/kg. The variety with the highest zinc content was IESX 16 2533-SB-SSI-19 (16.05 mg/kg). Zinc is responsible for the activation and functioning of many enzymes like those that are involved in DNA and protein synthesis, and digestion. It is also associated with collagen production which plays a role in tissue repair and wound healing [45]. [8] and [34] recorded zinc content ranging from (6.86 - 59.81 ug/g) and (18.0 - 23.2 mg/kg), respectively. Their results were in line with the ones in the study however the report by [35] contradicts what was concluded in the study. The iron content ranged from 67.14 - 221.26 mg/kg. Iron is an important nutrient as it is involved in many physiological processes in the body. Iron deficiency may lead to fatigue, impaired immune response, and anemia [43]. Accordingly, [46] reported that Lesotho had over 50% of the children younger than five-year-old suffering from anemia, and with these results, there is a lot to be done to supplement iron deficiency into diets. The results in the current investigation are in accordance with the ones from earlier research work by [29] and [47] who reported Fe contents of (12.01 - 16.65 mg/100g) and, (5.50 - 182 mg/kg), respectively. On the contrary, [35] filled 2.44 - 2.50 mg/kg which was lower than the results in this study.

The manganese content ranged from 4.72 - 11.39 mg/kg. Manganese promotes healthy brain metabolism, and bone formation and improves hematopoietic function of the body [48]. The manganese content in the study ranged from 6.46 - 11.39, and IESX 16 2524-SB-SSI -30 scored the highest content. The results in the study were in line with what was found by [33], and [29] who found (11.23 - 20.17 mg/kg) and (11.3 - 30.0 ppm), respectively. On the other hand, [34] has profiled manganese content which is lower compared to the one in this study.

4. Conclusion

Sorghum production has been threatened by climate change constraints, poor soil fertility, and agricultural management [49]. Even under these conditions, some sorghum varieties have performed well with appreciable nutritional content. Determination and quantification of nutritional, and mineral content is an important concept in human nutrition. It serves as a bench mark for food product development, and the outstanding varieties can be used as potential resource for sorghum breeding program. In conclusion to the study, the sorghum varieties showed significant differences in all parameters measured and the differences were as a result of genetic variation among varieties. The proximate estimates of carbohydrates, crude protein, crude fiber, and fats, were present in sorghum in appreciable amounts. Low-income communities in Lesotho like in other developing countries have over a long time been stricken by malnutrition. This can be a result of narrow diversity of food consumed or food with low nutritional value. Introduction of improved varieties with known nutritional value may combat the problem. For instance, in Lesotho, nutrients and minerals that are most deficient are protein, zinc and iron. Introduction of the improved sorghum varieties with promising nutritional value brings hope to resource poor communities. In the current study, one of the varieties that has shown the highest and appreciable protein content was KARI Mtama 1, zinc content (IESX 16 2533-SB-SSI-19) and iron content (IESX 16 2535-SB-SSI-34).

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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