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Mineral and Vitamin Profiles of Chuck and Sirloin Cuts of Cattle in Ethiopia

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ABSTRACT

Background: Meat plays a crucial role in the human diet as it is a rich source of micronutrients and helps combat malnutrition. The objective of this research was to examine the mineral and vitamin compositions of three different cattle.

Methods: Two methods, Atomic Emission Spectroscopy (AES) and Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES), were employed to evaluate the mineral concentrations present in the meat samples.

Result: The ranges of concentrations of the minerals were Cu (0.001±0.00-0.002±0.00), Fe (0.107±0.00-0.127±0.01), Na (0.469±0.06-0.620±0.06), K (0.054±0.01-0.149±0.02), Zn (0.047±0.01-0.085±0.01), Se (0.040±0.01-0.120±0.03), Mg (0.228±0.02-0.269±0.02) and Ca (0.1108±0.03-0.254±0.01) mg per 100 kilograms. Certain cuts of Ethiopian Boran beef have been shown to contain an abundance of essential minerals, nutrients and fat-soluble vitamins. The ranges for vitamin A, vitamin D and vitamin E are 10.34±0.86 to 17.14±2.39), 0.45±0.06 to 0.89±0.13) and 9.55±1.92 to 15.46±1.86), respectively. The results of the study showed that the sheko cattle variety had higher levels of vitamin D and E than other types of cattle and meat cuts.

Key words: Beef meat, Cattle types, Meat cut, Mineral, Vitamin.

INTRODUCTION

Beef meat holds a prominent position as one of the most important, nutritious and widely consumed products available (Adesina *et al.,* 2020). Given its significance, meat remains a popular dietary choice for many people and its demand continues to rise due to factors such as increasing income, population growth and evolving preferences (Scozzafava *et al.,* 2016).

Insufficient intake of vitamins can lead to metabolic disorders and deficiencies in vitamins A and D are strongly associated with diseases stemming from such deficiencies (Ramalho *et al.,* 2012). A large number of consumers exhibited significant choices for specific meat cuts, which also constituted the majority of their buying portfolios (Scozzafava *et al.,* 2016).

Sirloin and chuck are recognized as desirable meat cuts that are frequently enjoyed by consumers. However, scientific research indicates that specific muscles found in the chuck area can exhibit similar or superior eating quality to rib steaks (Nyquist *et al.,* 2018). Rib and loin steaks, renowned for their tenderness and exceptional taste, are highly coveted in the culinary world (Liu *et al.,* 2022). Furthermore, the differentiation of meat cuts in cattle takes into account factors such as cattle breed, age, climate, husbandry practices, feeding patterns and the level of physical activity during the animal's life (Geletu *et al.,* 2021). In research conducted by Ndebele *et al.* (2005), the study aimed to examine the influence of seasonal changes on the amount of calcium (Ca), phosphorus (P), sodium (Na), copper (Cu) and zinc (Zn) in soil, forage and cattle meat cuts.

Similarly, a study carried out in Basalan, M. (1995) examined the interaction among breed, consumption, carcass contents and the levels of liver copper (Cu), zinc (Zn) and iron (Fe), as well as serum zinc (Zn), copper (Cu), magnesium (Mg) and calcium (Ca), in mature cattle from diverse cattle types. The dairy industry contributes to more than 4% of the country's GDP and provides employment opportunities to millions of people, both directly and indirectly (Ramani *et al.*, 2023). According to (2015) report Goran *et al.* (2015), there is a scarcity of research focusing on the mineral and vitamin content of beef, particularly in relation to zebu meats. Thus, the objective of this study was to assess the mineral and fat-soluble vitamin profiles of sirloin and chuck cuts from Boran, Sheko and Senga cattle in Ethiopia.

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MATERIALS AND METHODS

Study area

The study was carried out at the Department of Food Science and Applied Nutrition, Addis Ababa Science and Technology University and the Ethiopian Conformity Assessment Enterprise. The research took place in targeted regions renowned for cattle farming, where appropriate cattle populations were available. Within these locations, meticulous collection of meat samples from the sirloin and chuck cuts was undertaken. The cattle samples from the Boran breed were collected from the Borana zone, located in the southern rangelands of Ethiopia. In contrast, the Sheko and Senga cattle samples were obtained from the south western region of Ethiopia and the Akobo area of Gambella, respectively (Fig 1). Sample collection was conducted between June 2023 to July 2023 of and Mineral and vitamin analysis was conducted in September 2023.

Meat sample

Forty-eight sirloin and chuck samples from the Boran, Sheko and Senga cattle breeds were collected from regional slaughterhouses in the Borana, Sheka and Gambella zones (Fig 2). The samples were stored at -20°C until analysis.

Reagents

Analytical-grade reagents were used for element analysis. A matrix modifier solution containing $NH_4H_2PO_4$ and Mg $(NO_3)_2$ was prepared. The solution had 0.2 g of $NH_4H_2PO_4$ and 0.07 g of Mg $(NO_3)2•6H_2O$ dissolved in 100 ml of 2% HNO_3. The choice of matrix modifier was based on previous research. The sample was treated with a solution of HCl and HNO_3 (7 ml, total volume 20 ml) and heated to dryness at 100°C. The remaining residue was mixed with 2 ml of 0.5 M HNO_3 and diluted to a final volume of 10 ml with double-deionized water.

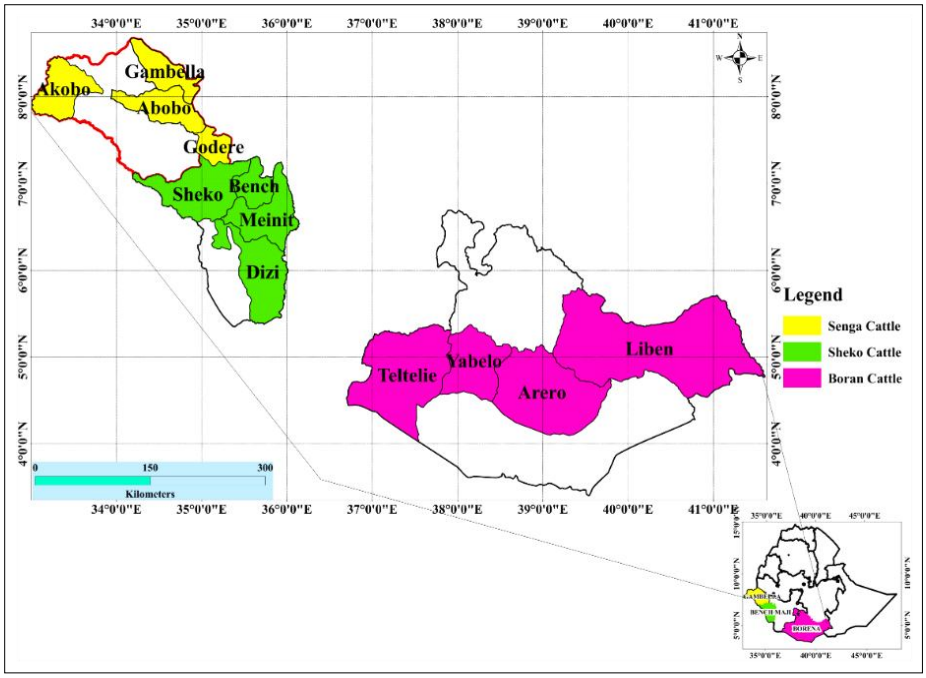

Fig 1: The study area.

Fig 2: Meat samples of Boran (a), Sheko (b) and Senga cattle (c).

Mineral analysis

Using an ETHOS microwave digester, wet digestions were performed on 0.2 g meat samples, consisting of sirloin and chuck cuts. HNO_3 and H_2O_2 were added and the digestion process lasted 40 minutes at 200°C and 1800 watts. The concentrations of macrominerals and microminerals were analyzed using flame atomic absorption spectrometry, while selenium levels were measured using inductively coupled plasma-atomic emission spectrometry. The study considered LOQ, LOD and deuterium background correction during the analysis, with three repetitions. The samples contained milligrams of macro- and micro-minerals per kilogram of wet mass (Domaradzki *et al.,* 2016).

Vitamin analysis

Extraction

A 5 g sample in a flask was cleaned with 70 ml of petroleum ether and then transferred to a separatory funnel along with 20 ml ethanol. The solution was separated into two layers. The flask solution was returned to the funnel and mixed with 70 ml of n-hexane for extraction. After shaking vigorously for 5 minutes, the lower n-hexane layer was collected, while the upper layer was collected separately. The flask was rinsed with petroleum ether and n-hexane, discarding the lower part. The upper n-hexane layer was transferred to a second funnel. Vitamins were detected using standard addition or spiking, with recovery rates exceeding 90%.

HPLC condition used for the analysis

The HPLC system used was a reversed UHPLC PAD configuration with a 4.8×150 mm, 3.5 µm C18 column. The mobile phase consisted of 2% water (A) and 98% methanol (B). The injection volume was 10 ml, the flow rate was 1 ml/min, the column temperature was 25°C and sample temperature was 20°C. The analysis duration was 12 minutes.

Statistical analysis

The statistical analysis of the beef meats was performed using SPSS version 25. This involved the utilization of one-way and two-way ANOVA tests to compare the means. A significance level of $P<0.05$ was considered for determining differences. XLSTAT 2022.4.1.1382 OS software was employed for the principle component analysis.

RESULTS AND DISCUSSION

Mineral profile of meat cuts

It is worth noting that the average sodium content found in the raw beef from our research exceeded those found in raw meat samples from Australia (0.010 mg/100 g), the United Kingdom (0.007 mg/100 g) and Denmark (0.006 mg/100 g), as reported by Belhaj *et al.* (2021). Additionally, as cattle and human beings are intrinsically connected to each other, protection of cattle from diseases and unnecessary suffering should become prime responsibility of human (Kumar *et al.,* 2017).

Table 1: Mean±sd value for mineral (mg/100g) profile of the cattle type and cuts.

Cattle types	Cuts of beef	Minerals									
		Fe	Se	Na	K	Mn	Zn	Cu	Mg	Ca
Boran	Sirloin	0.120±0.03^{a}	0.111±0.04^{b}	0.609±0.06bc	0.141±0.02^{b}	0.001±0.00^{a}	0.085±0.01^{b}	0.001±0.00^{ab}	0.265±0.01^{c}	0.254±0.01^{c}
	Chunk	0.127±0.01^{a}	0.098±0.04^{b}	0.479±0.09^{a}	0.149±0.02^{b}	0.001±0.00^{b}	0.058±0.01^{a}	0.002±0.00^{ab}	0.269±0.02^{c}	0.250±0.03^{c}
Senga	Sirloin	0.116±0.03^{a}	0.120±0.03^{b}	0.620±0.06^{c}	0.147±0.02^{b}	0.001±0.00^{ab}	0.043±0.03^{a}	0.002±0.00^{b}	0.229±0.01^{a}	0.160±0.04^{b}
	Chunk	0.114±0.01^{a}	0.106±0.04^{b}	0.555±0.03^{b}	0.144±0.02^{b}	0.001±0.00^{ab}	0.054±0.04^{a}	0.002±0.00^{b}	0.248±0.06^{b}	0.164±0.04^{b}
Sheko	Sirloin	0.114±0.00^{a}	0.066±0.03^{a}	0.564±0.03^{b}	0.053±0.02^{a}	0.001±0.00^{a}	0.065±0.02^{ab}	0.001±0.00^{a}	0.228±0.02^{a}	0.108±0.03^{a}
	Chunk	0.107±0.00^{a}	0.040±0.01^{a}	0.469±0.06^{a}	0.054±0.01^{a}	0.001±0.00^{a}	0.047±0.01^{a}	0.001±0.00^{a}	0.234±0.01^{ab}	0.116±0.01^{a}

*Means with different letters in a column were significantly different at $P<0.05$.

Iron

The iron concentrations found in the meat cuts were reliable, with the findings reported by Boccie *et al.* (2005) at 0.427±0.1 mg/100 g. However, the results reported by Pilarczyk (2014) were significantly different from the current study.

Magnesium

Magnesium is an essential mineral with important and extensive roles in human health, including muscle and nerve function, immune system function and bone health (Pilarczyk, 2014). In the current study, the Boran chuck cut exhibited the highest average magnesium (Mg) concentration, while the Senga sirloin cut showed the lowest average concentration, as indicated in Table 1. These findings align with the results reported by Destefanis *et al.* (1997), which showed a comparable Mg concentration of 0.28 mg/100 g. The Mg values for the cattle types and cuts, namely, Boran (sirloin (0.265±0.01) and chunk (0.269±0.02), Senga (sirloin (0.229±0.01) and chunk (0.248±0.06)) and Sheko (sirloin (0.228±0.02 mg/100g) and chunk (0.234±0.01 mg/100 g), are stated in Table 1. There was a significant difference ($p<0.05$) between the meat samples of Boran and Senga and Boran and Sheko cattle. The values of Mg were comparable to those reported by Destefanis *et al.* (1997). The difference in mineral concentration is probably due to the breed factor. According to Tizioto *et al.* (2014), the breed had a significant influence on trace elements of Mg ($P<0.001$).

Potassium

The highest value for K was 0.149±0.02 mg/100 g and the lowest was 0.053±0.02 mg/100 g for Boran chunk and Sheko sirloin cuts, respectively (Table 1). A significant difference ($p<0.05$) was observed between Sheko and the two cattle types (Boran and Senga). There was no significant difference ($p>0.05$) between the meat samples of Boran and Senga. The mean K content in raw beef of the two cuts of the three cattle types Boran (sirloin and chunk), Senga (sirloin and chunk) and Sheko (sirloin and chunk)

Table 2: Mean±sd value for vitamin (µg/100 g) profile of the cattle type and cuts.

Cattle types	Cuts of beef	Vitamins		
		Vit-A	Vit-D	Vit-E
Boran	Sirloin	9.55±1.92^{a}	0.52±0.19^{a}	10.46±1.24^{a}
	Chunk	9.64±51.60^{a}	0.45±0.06^{a}	10.34±0.86^{a}
Senga	Sirloin	12.69±0.80^{b}	0.70±0.20^{b}	14.31±4.40^{b}
	Chunk	13.16±1.45^{b}	0.76±0.21^{bc}	16.55±4.34^{bc}
Sheko	Sirloin	14.54±2.07^{c}	0.84±0.18^{bc}	16.13±3.42^{bc}
	Chunk	15.46±1.86^{c}	0.89±0.13^{c}	17.14±2.39^{c}

*Indicated that means are statistically different ($p<0.05$) across the column.

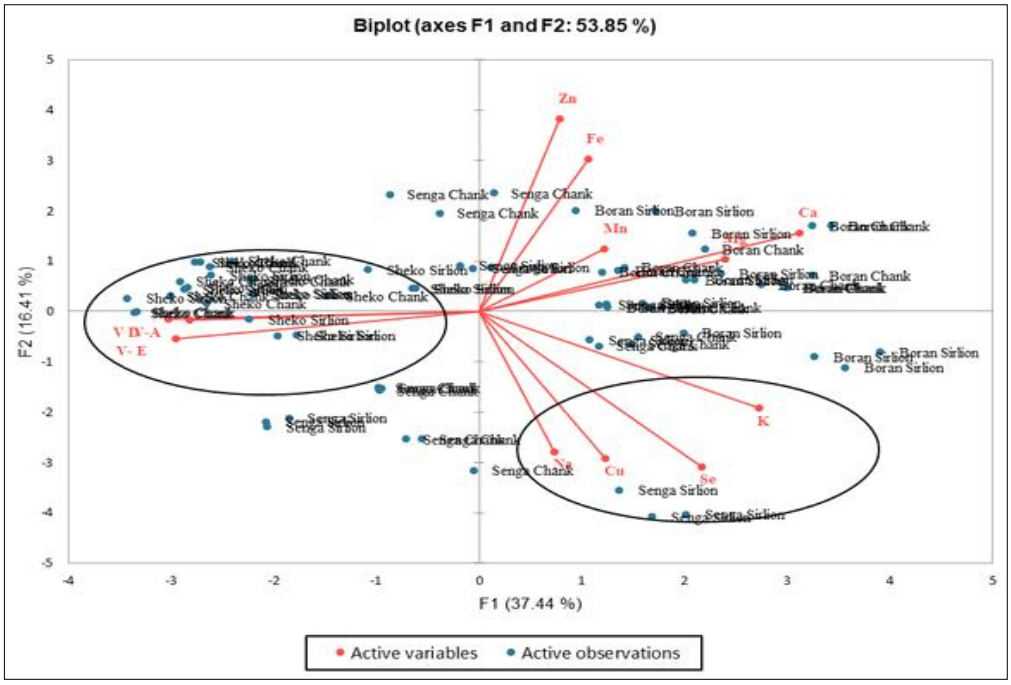

Fig 3: Principal component analysis predictive biplots of minerals and fat soluble vitamins over cattle types and cuts.

was 0.141±0.02, 0.149±0.02, 0.147±0.02, 0.144±0.02, 0.053±0.02 and 0.054±0.01 mg/100 g, respectively, which was higher than the report on beef and pork (267.41 ppm) (Basalan, 1995). These values were comparable with commercial beef samples (152±15 mg kg^{-1}) reported by Flowers *et al.* (2018). Boran chuck had the highest average potassium (K) concentration among cuts, while Sheko sirloin had the lowest (Table 1). However, Stojanovic *et al.* (2017) a reported higher K content in beef (217.51 mg/100 g) compared to our findings. These elements affect beef mineral content and muscle-related processes, potentially influencing meat quality (Fallow *et al.,* 2017).

Selenium

Selenium (Se) is an important mineral with health benefits (Sakowski *et al*., 2022). Cabrera found similar selenium concentrations in Hereford and Braford meat in our study. Tang *et al*. (2021) observed varying selenium levels in different beef brands. Ramos *et al.* (2012) noted higher selenium content in cattle meat from mineral-rich grazing areas. The mean concentrations of Se in the three cattle types of meat cuts (sirloin and hunk) ranged from Boran, Senga and Sheko and were 0.098±0.04-0.111±0.04, 0.106±0.04-0.120±0.03 and 0.040±0.01- 0.066±0.03 mg/100 g, respectively (Table 1). There was a significant difference ($p<0.05$) between Sheko and Boran as well as Sheko and Senga in selenium content among the meat samples, but there was no significant difference between Boran and Senga cattle types. The report of Hailu *et al.* (2022) was not in agreement with the current study on the Hereford (0.42 and 1.20 mg/kg wet tissue) and Braford breeds (0.49 and 1.3 mg/kg wt). The current study showed that there is a lower selenium concentration in the cuts of all the selected cattle types. Almani *et al.* (2020) reported that the higher prevalence of Se deficiency in Ethiopian cattle might be used to differentiate the Se content in the meat. In addition, the Composition of feeds also affects the contents of the meat (Rajkumar *et al.,* 2023).

Manganese

No breed differences were observed in this study. Hereford cuts had manganese concentrations of 0.05-0.17 mg/kg and Branford cuts had concentrations of 0.04-0.48 mg/kg, based on Almani *et al.* (2020). In contrast to Tang *et al*. (2021), the study found higher manganese levels.

Copper

The findings conveyed by Arthington *et al.* (2021), with a copper concentration of 0.65 mg/kg or 0.0006 mg/g, were lower than the results found in this study for Senga cuts.

Zinc

Between Boran sirloin and Sheko sirloin as well as both Boran sirloin and Boran chuck, a significant difference ($p<0.05$) was found. These findings align with the research conducted by Goran *et al.* (2015) at 23 to 72.7 mg/kg.

Table 3: Pearson ctypes and cuts orrelation matrix among minerals and fat soluble vitamins of cattle.

Variables	Fe	Se	Na	K	Mn	Zn	Cu	Mg	Ca	V-A	V D	V-E
Fe	1											
Se	-0.077	1										
Na	-0.004	0.361	1									
K	0.036	0.712*	0.311	1								
Mn	0.290	-0.039	-0.226	0.315	1							
Zn	0.722*	-0.126	-0.005	-0.051	0.092	1						
Cu	0.742*	0.390	0.244	0.348	0.310	-0.339	1					
Mg	0.126	0.252	-0.137	0.322	0.110	0.108	0.137	1				
Ca	0.366	0.324	0.026	0.537	0.303	0.368	0.187	0.868*	1			
V-A	-0.266	-0.548	-0.034	-0.587	-0.163	-0.223	-0.219	-0.415	-0.685	1		
V D	-0.069	-0.392	-0.166	-0.562	-0.228	-0.155	-0.118	-0.535	-0.662	0.804*	1	
V-E	-0.216	-0.351	-0.189	-0.458	-0.178	-0.165	-0.099	-0.551	-0.644	0. 798*	0.712*	1

Fe= Iron, Se= Selenium, Na= Sodium, K= Potassium Mn= Manganese, Zn= Zinc= Cu= Copper, Mg= Magnesium, Ca= Calcium, V-A= Vitamin A, V –D= Vitamin D, V- E= Vitamin E.
*Correlation is significant at p<0.01.

Table 4: Eigen analysis of the loadings of the significant principal components (PCs) for the vitamins and minerals.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12
Eigenvalue	4.66	1.97	1.33	1.16	0.71	0.63	0.46	0.38	0.30	0.20	0.13	0.06
Variability (%)	38.81	16.43	11.12	9.67	5.95	5.24	3.83	3.14	2.49	1.70	1.12	0.50
Cumulative %	38.81	55.25	66.37	76.04	81.99	87.23	91.05	94.19	96.68	98.38	99.50	100.00

Fat soluble Vitamins

Vitamin E

Vitamins are defined as a group of complex organic compounds that are required for normal physiological functions and are found in very small amounts in natural foods. Vitamin E is a fat-soluble vitamin, is essential for the integrity of the reproductive, muscular, circulatory, nervous and immune systems Cabrera *et al*. (2010). Table 2 shows a significant difference ($p<0.05$) in Sheko chuck samples. Previous research found similar vitamin E concentrations in Boran cattle meat Cabrera *et al*. (2010). This aligns with findings from Uruguay and Argentina. In another study, extensive farming systems had higher vitamin E levels compared to intensive farming systems Amani *et al.* (2015). Additionally, the level of vitamin E is influenced by the exposure to pasture land. In which, meat from animals fed pasture contained higher levels of á-tocopherol than meat from animals fed concentrate without additional vitamin E supplements. This observation has been confirmed both in Uruguay and Argentina Bilandži´c *et al.* (2020). In the report Driskell *et al*. (2010), beef from extensive systems (EXT2 and EXT3) had the highest vitamin E content, whereas beef from intensive systems (INT1) had the lowest. It has been shown that animals kept on pasture have higher concentrations of vitamin E in their muscles.

Vitamin A

Table 2 shows significant differences ($p<0.05$) in the cuts of the three cattle breeds Daley *et al.* (2010). It was found that pasture-raised Hereford meat had higher β-carotene levels (0.45 g/100 g) compared to concentrate-raised meat (0.06 g/100 g), consistent with previous reports. Retinol levels did not vary with different feeding regimens, as reported by Vito *et al.* (2015).

Vitamin D

Table 2 presents the average vitamin D content for Boran, Senga and Sheko cattle. A significant difference ($p<0.05$) was observed among the different meat samples, consistent with the findings reported by Cashman *et al.* (2022). Small amount of vitamin D was might be due to different type of cattle or breed structure and implementation of various cattle developmental programmes could also affect the composition (Hamadani *et al*., 2020).

Correlation between mineral concentration and fat soluble vitamin of meat

The analysis showed a positive correlation ($r = 0.722$) between zinc and iron levels in the meats. Consistent with Hazell (1982) darker meats like beef and lamb have zinc and iron levels over twice as high as lighter meats like pork and chicken.

A significant correlation ($p<0.01$) was observed between copper and zinc, as well as between iron and zinc in various cattle types and cuts (Table 3), with correlation coefficients of $r = 0.722$ and $r = 0.742$, respectively. Vitamin D and E content also showed a significant correlation ($p<0.01$), with correlation coefficients of $r=0.804$ and $r=0.798$, respectively (Table 3). Additionally, there was a significant ($p<0.01$) correlation between vitamin D and vitamin E, with a coefficient of $r = 0.912$.

Descriptive principal component analysis: The plot visually represented the association between closely related variables, with the angle between them indicating the strength of their correlation. Fig 3 captured 53.85% of the total variation, with PC1 accounting for 37.44% and PC2 accounting for 16.41% of the variability.

The outcomes of the principal component analysis (PCA) for the nine main components (PC) are summarized in Table 4. The outcomes revealed that the first three principal components account for 66.37% of variability.

CONCLUSION

The results of the current study suggested that the mineral content differs among different types of cattle and also depends on the specific cut, such as sirloin and chuck. The beef obtained from Boran cattle showed significantly elevated levels of iron (Fe), manganese (Mn), magnesium (Mg), zinc (Zn) and calcium (Ca), while exhibiting notably lower levels of copper (Cu), selenium (Se), potassium (K) and sodium (Na). Conversely, meat sourced from Sheko cattle demonstrated higher contents of fat-soluble vitamins such as Vitamins A, D and E. Furthermore, the mineral concentrations in the analyzed tissue samples allowed for distinct grouping through principal component analysis (PCA).

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Conflict of interest

The authors report that there are no competing interests to declare.

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