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Full length article

Clinical and laboratory assessment of mineral deficiencies in grazing sheep and goats at Sana'a Governorate, Yemen

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ABSTRACT

Mineral deficiency represents a major health challenge affecting the productivity of small ruminants. This study aimed to evaluate mineral deficiencies in grazing sheep and goats at Sana'a Governorate, Yemen, and their association with hematological and biochemical parameters. A total of 200 local sheep (n=100) and goats (n=100), aged 1–4 years and maintained exclusively on pasture grazing were selected and investigated. Among these, 160 animals (80 sheep and 80 goats) showed signs of mineral deficiencies and considered as affected animals or deficient animals; while, 40 animals (20 sheep and 20 goats) appeared healthy and considered as controls. The clinical examination revealed, In deficient animals, the following clinical signs: easily detached and discolored hair or wool, alopecia, pale mucous membranes, inappetence, emaciation, and lethargy, with significantly elevated ($P<0.05$) pulse and respiratory rates. Hematological analysis revealed significantly decrease ($P<0.05$) of Hb, PCV, RBC, and WBC counts accompanied by increase of RDW and platelet counts. Biochemical evaluation demonstrated significantly decrease ($P<0.05$) levels of Ca, P, Mg, Cu, Fe, Zn, total protein, and albumin in deficient animals compared to controls. The study concluded that naturally grazed sheep in different Sana`a localities, exhibited variable degrees of clinical signs and serum minerals deficiency that led marked deceases in performance and health of animals. Hence, mineral supplementation in the form of mineral mixture or other preparations of these animals is recommended**.** Further studies are also encouraged to explore long-term impacts of mineral supplementation on health, productivity, and reproductive performance in small ruminants in study areas**.**

KEY WORDS: Clinical examination, Mineral deficiency; Sheep and goats, Sana`a, Yemen.

INTRODCTION

Sheep and goats are crucial livestock in Yemen **for** food security, nutrition, income, and as financial assets, especially for rural communities and vulnerable households. They provide meat, milk, and wool, with rural families relying on them to meet daily needs, fund education, and as a safety net during economic crises (Wilson, 2003; Pradyut et al., 2025). Livestock health is a priority for sustaining these livelihoods, which are essential for the resilience of many Yemenis, particularly in the context of the ongoing conflict and collapsing veterinary services. These animals are raised under traditional systems, and the feeding mostly depends largely on available natural pastures and crop residues (UN, 2023).

Minerals are vital for growth and health of animals due to their physiological, catalytic, and regulatory functions processing. Adequate mineral intake supports the proper functioning of bones, teeth, muscles, and nerves, and is essential for enzyme and hormone production. However; their deficiencies can lead to huge health and economic losses. The mineral deficiency occurs as result of inadequate nutrition, poor nutrient absorption, or metabolic disturbances (Baugreet et al., 2017; Asín et al., 2021; Suttle, 2020; Arshad et al., 2021).

Calcium (Ca) is one of the macro-elements required for contraction of muscles (Hu et al., 2018), the transmission of neuron signals (Williams and Smith, 2018), bone formation, and blood coagulation (Wasilewski et al., 2019). Phosphorus (P) is regarded as the second macro-mineral, essential for synthesis of biological components such as nucleic acids, phospholipids, and high energy phosphate complexes (Vorland et al., 2017). Magnesium (Mg) is essential for the activation of kinase and polymerase enzymes (Faraji et al., 2021) as well as the transport of other cations across the cell membrane, including Ca, sodium (Na), and potassium (Mathew and Panonnummal, 2021).

Concerning micro-elements, copper (Cu) is essential for the activation of several key enzymes (Min et al., 2022). It contributes to cellular respiration, the immunological system, lipid metabolism, growth, wool quality, hemoglobin biosynthesis, bone construction, connective tissue development and the synthesis of carbohydrates and proteins. Cu is also essential for the creation of a pigment melanin of leather and wool (İpek and Keskin 2007; Radwinska, and Zarczynska 2014). Zinc (Zn) is necessary for crucial processes including growth, cell health, immune system, neurological system, reproduction, and protein synthesis (Kozat et al., 2007; Maares and Haase 2016; Driessnack et al., 2017; Jin et al., 2023). Iron (Fe) is another trace element needed in nearly all species and plays an important role in hemoglobin formation, neurological transmission (Huang et al., 2018), transport of oxygen and DNA creation and repair (Ito et al., 2021).

Mineral deficiencies are common in sheep and goats grazing on low-quality pastures and raised under conventional systems (Sowande et al., 2008; Kawas et al., 2010; Xin et al., 2011). They may produce clinical disorders with significant consequences on health and survival of animals (Balamurugan et al., 2017). Lack of appetite, emaciation, diarrhea, dehydration, anemia, and pale mucous membranes are more prevalent in sheep that showed a drop in serum levels of Ca, P, Mg, Zn, Cu and Fe (Ibrahim et al., 2017). Trace mineral deficiencies impact the production and performance of sheep and goats (Xin et al., 2011; Lengarite et al., 2012; Yatoo et al., 2013). A decrease in serum Zn concentration produced physiological issues as well as a range of ailments such as anorexia, weight loss, delay growth, skin lesions, eyelid enlargement, loss of wool, and dermatitis (Sloup et al., 2017), joint stiffness and a fall in hematological indicators (Song and Shen, 2020). Reduced serum Cu levels caused sheep to suffer from anemia, poor growth, wool keratinization, and bone disorders (Hefnawy and El-Khaiat 2015; Mandour et al., 2021).

Nutritional deficiency is recognized as one of the most significant problems impacting animal productivity. The most critical aspect of avoiding wasting in sheep and goat herds is nutritional management. Adequate and high-quality feed is necessary for proper mineral, vitamin, and micronutrient intake (Asín et al., 2021). Sheep and goats in Sana'a governorate, Yemen, are grazing animals that obtain most of their nutrients from pasture and local roughage. Due to the differences among the levels of essential elements in grass and pasture plants, they are vulnerable to mineral insufficiencies. To the best of our knowledge, very limited information is available on mineral deficiency disorders in local Yemeni sheep and goats. Therefore, the aim of the current study is to evaluate the mineral deficiency in grazing sheep and goats at Sana’a Governorate, this will provide baseline data for future preventive and control strategies.

MATERIALS AND METHODS

Study area

The current study was conducted from May to August 2024 at Sana'a Governorate, Yemen. Sana'a Governorate is located in a mountainous region of Yemen, situated at a high altitude of over 2,200 meters (7, 392 feet). It has a semi-arid climate with warm summers and cool, dry winters, and experiences significant temperature differences between day and night. The highest daytime temperatures can reach 33°C (91°F) in June, while temperatures can occasionally drop below 0°C (32°F) in winter. Rainfall is sparse, with the wettest months being July and August (Hasan et al., 2025).

Animals and study design

A total of 200 indigenous breed of sheep and goats (one hundred each) of both sexes and different ages (1-4 years) from different areas of Sana'a Governorate were selected and investigated in this study. Animals were sharing same grazing pastures and management conditions. The pastures consist of native shrubs, perennial grasses, and agricultural forage crops.

The animals of each species were assigned into two groups: a control group and a mineral-deficient group. The control group was contained 20 animals (each species) apparently healthy. Prior to the commence the study, each animal’s physiological parameters, rectal temperature (38.1–39.3 ◦C), respiratory rate (18–32 rpm), and heart rate (68–92 bpm) were monitored to evaluate their health status according the techniques described by Radostits et al. (2006). Mineral-deficient group was contained 80 animals (each species) showed clinical signs of mineral insufficiency such as hair/wool loss, color change, decreased body weight, pale mucous membranes, and other related symptoms animals were maintained on a free-grazing diet with unlimited food and water. Blood samples were collected from these animals for the study. The collection was performed under the supervision of animal welfare experts and a pathologist from the University of Sana'a, Yemen**.**

Clinical examination

Clinical examination of animals was carried out according to the techniques described previously by Jackson and Cockcroft (2002); Radostits et al. (2006). A specific questionnaire was created to record the animal owner's bio -information and clinical signs exhibited by animals.

Samples collection

The blood samples were collected according to the techniques described by Ibrahim et al. (2017). In brief, blood samples were collected by puncturing the jugular vein using hypodermic needles after clipping the hair or wool in the area of puncture, followed by disinfection with 70% ethyl alcohol. Two blood samples were collected from each animal of all groups. The first sample (5 ml) was taken in a sterile tube with ethylene diamine tetra acetic acid (EDTA) as an anticoagulant for hematological parameters analysis. The second sample (5 ml) was taken in a sterile tube without anticoagulant for biochemical parameters analysis. The samples were labelled properly and transported in an ice pack to the National Centre of Public Health Laboratories, Sana`a city. The samples (without anticoagulant) were allowed to clot in a slanting position at room temperature for about 2 hours, then stored overnight in the refrigerator at 4°C, then centrifuged at 3000 rpm for 10 minutes. Clear non-hemolyzed serum was obtained and stored in Eppendorf tubes at -20°C until the time of biochemical analysis.

Hematological parameters analysis

The hematological parameters were estimated using Micros ESV 60 hematology Analyzer (Horiba ABX, France) as manufacturer instructions. The parameters estimated include: Total erythrocyte count (RBCs), Packed cell volume (PCV), Hemoglobin concentration (Hb), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and Total leukocyte count (WBCs), as well as Platelets and Red cell distribution width (RDW blood test).

Serum biochemical parameters analysis

Biochemical parameters were analyzed using the blood analyzer atomic absorption spectrophotometer according to method described by Ji and Ren (2002). Serum Ca, P, Mg, Cu, Fe and Zn concentrations were estimated photometrically using commercial kits (Bio-Diagnostic, Giza, Egypt) according to the manufacturers instructions. serum total protein (TP) and albumin concentrations were analyzed using commercial kits (Spectrum Diagnostics, Cairo, Egypt) according to the manufacturer instructions. Serum globulin concentration was calculated mathematically by subtracting the total protein values minus albumin values (Kaneko et al., 2008).

Statistical analysis

The obtained results for blood hematology and biochemical and trace element analyses were recorded using Microsoft Excel. The statistical analyses, including the calculation of standard error and means, were performed using SPSS program version 25 Software, Inc., Chicago Ill., USA, For the comparison between healthy and affected animals' groups, the student's t-test was used. The difference was considered statistically significant when P**<0.05.**

RESULTS

Clinical examination

The clinical examination results revealed that sheep and goats in menial deficient groups showed variety ranges of clinical signs include: easily detached hair/wool (70.0 &45%), alopecia (35.0% & 15.0%), a change in hair/wool color (22.5% & 20.0%), a pale mucous membrane (60.0% & 65.0%), inappetence and emaciation (40.0% & 42.0%), dullness (37.5% &32.5%), and diarrhea (10.0% & 2.5%) respectively for Sheep and goat compared to control groups as presented in Figure 1 & Table 1. Body temperature, respiratory and pulse rates were recorded accordingly. The mean of body temperature was similar in both control and mineral deficiency group. While the means of respiratory and pulse rate were significantly higher in the affected animal group compared to the control (p<0.0) as depicted in Table 2.

Figure 1. Sheep and goats about 1-4 years of age with highly detached hair/wool, alopecia and emaciation.

Table 1. Clinical signs observed on mineral deficient grazing sheep and goats at Sana`a governorate (n= 80 for each species)

Clinical signs	Sheep		Goats	
	Number	%	Number	%
Easily detached hair/wool	56	70.0	36	45.0
Alopecia	28	35.0	12	15.0
Change in hair/wool color	18	22.5	16	20.0
Pale mucous membrane	48	60.0	52	65.0
Inappetence	32	40.0	34	42.5
Emaciation	32	40.0	34	42.5
Dullness	30	37.5	26	32.5
Diarrhea	8.0	10.0	2.0	2.50

Table 2. Mean ± SE of temperature, pulse and respiration in healthy control and mineral-deficient groups of sheep and goats

Parameters	Sheep		Goats	
	Control (n=20)	Mineral-deficient (n=80)	Control (n=20)	Mineral-deficient (n=80)
Body temperature (C°)	38.72±0.20	39.21±0.14	39.30±0.16	39.28±0.10
Pulse rate (beats/min)	79.61±1.75	118.20±2.25*	81.70±0.36	124.55±2.85*
Respiratory rate (breaths/min)	23.07±0.78	39.28±1.59*	26.15±0.67	42.29±2.37*

**Values with an asterisk within the same raw are statistically significant (P<0.05)*

Table 3. Mean ± SE of hematological parameters in control and mineral-deficient groups of sheep and goats

Parameters	Sheep		Goats	
	Control (n=20)	Mineral-deficient (n=80)	Control (n=20)	Mineral-deficient (n=80)
RBC ($x10^6$/ul)	11.67±0.22	7.06±0.27*	11.89±0.10	6.41±0.19*
Hb (g/dl)	9.86±0.67	6.21±0.18*	10.73±0.45	6.24±0.30*
PCV (%)	35.69±0.81	21.42±0.14*	33.72±0.51	20.11±0.21*
MCV (fL)	29.82±0.59	33.62±0.57	29.49±0.18	32.98±0.76
MCH (pg)	9.10±0.83	12.23±1.19	9.75±0.30	12.56±0.28
MCHC (g/dl)	30.12±0.29	33.88±1.41	31.47±0.23	36.78±0.59
RDW	9.1±0.27	15.9±0.87*	10.4±0.42	15.8± 0.83*
Platelet($x10^3$/ul)	298.4±21.9	605.7±48.7*	266.5±33.6	591.5±67.5*
WBC ($x10^3$/ul)	12.34±0.67	6.32±0.43*	12.59±0.29	6.01±0.51*

**Values with an asterisk within the same raw are statistically significant (P<0.05). WBCs (white blood cells), Hb (hemoglobin), RBCs (red blood cells), PCV (hematocrit), MCV (mean corpuscular volume), MCHC (Mean corpuscular hemoglobin concentration), RDW (red cell distribution width).*

Table 4. Mean ± SE of serum minerals concentrations in control and mineral-deficient groups sheep and goats.

Parameters	Sheep		Goats	
	Control (n=20)	Mineral-deficient (n=80)	Control (n=20)	Mineral-deficient (n=80)
Ca (mg/dl)	8.95±0.42	6.42±0.25*	8.98±0.37	6.21±0.28*
P (mg/dl)	5.86±0.39	3.24±0.11*	5.59±0.27	2.99±0.10*
Mg (mg/dl)	3.11±0.07	2.00±0.04*	3.27±0.01	2.01±0.02*
Cu (µg/dl)	119.60±3.21	81.10±1.26*	112.61±4.32	74.31±2.14*
Fe (µg/dl)	113.74±4.57	65.32±1.29*	118.56±3.71	64.29±2.19*
Zn (µg/dl)	98.76±4.62	52.37±1.61*	87.93±3.68	44.71±2.32*

**Values with an asterisk within the same raw are statistically significant (P<0.05). Ca (calcium), P (phosphorus), Mg (magnesium), Zn (zinc), Fe (iron).*

Table 5. Mean ± SE of serum albumin, total protein and globulin concentrations in control and mineral-deficient groups of sheep and goats

Parameters	Sheep		Goats	
	Control (n=20)	Mineral-deficient (n=80)	Control (n=20)	Mineral-deficient (n=80)
Total protein (g/dl)	8.01±0.36	6.86±0.53*	7.89±0.76	6.46±0.19*
Albumin (g/dl)	3.98±0.41	2.29±0.14*	3.87±0.57	2.27±0.13*
Globulin (mg/dl)	4.03±0.32	4.57±0.23	4.02±0.36	4.19±0.29

**Values with an asterisk within the same raw are statistically significant (P<0.05).*

Hematological analysis

The results of hematological parameters analysis revealed that there was significant decrease (P<0.05) in total RBCs, Hb, PCV, and WBCs in mineral-deficient group of sheep and goats compared to the control group. The mean values were (7.06±0.27 & 6.41±0.19), (6.21±0.18 & 6.24±0.30), (21.42±0.14 & 20.11±0.21) and (6.32±0.43 & 6.01±0.51) for RBCs, Hb, PCV, and WBCs in mineral deficient groups of sheep and goats respectively, whereas, the mean values in control groups were (11.67±0.22 and1 1.89±0.10), (9.86±0.67 & 10.73±0.45), (35.69±0.81 & 33.72±0.51) and (12.34±0.67 & 12.59±0.29) for sheep and goats respectively as presented in Table 3. However, there were significant increases (P<0.05) in red cell distribution width (RDW) and platelet counts. The mean value of red cell distribution width was 15.9±0.87 & 15.8±0.83 in the mineral-deficient group sheep and goats, respectively, compared to the control groups (9.1±0.27 & 10.4±0.42, respectively). The mean value of platelets was 605.7±48.7 and 591.5±67.5 in the mineral-deficient group of sheep and goats, respectively, compared to the control groups (298.4±21.9 & 266.5±33.6) respectively. Furthermore, no significant differences (P<0.0) were observed in the mean values of MCV, MCH, and MCHC of mineral-deficient groups compared to the control groups of sheep and goats as illustrated in Table 3.

Biochemical analysis

Biochemical analysis results of serum revealed that there was a significant decrease (P<0.05) in serum levels of Ca, P, Mg, Cu, Fe, and Zn in the mineral-deficient groups of sheep and goats compared to the control groups. As shown, the mean values of serum calcium, phosphorus, magnesium, copper, iron and zinc in deficient groups were (6.42±0.25&6.21±0.28), (3.24±0.11 & 2.99±0.10), (2.00±0.04 & 2.01±0.02), (81.10 ±1.26 & 74.31 ±2.14), (65.32 ±1.29 &64.29 ±2.19) and (52.37 ±1.61 & 44.71 ±2.32) of sheep and goats respectively. While; the mean values in control groups were (8.95 ±0.42 & 8.98 ±0.37), (5.86 ±0.39 & 5.59 ±0.27), (3.11±0.07 & 3.27±0.01), 119.60±3.21 & 112.61±4.32), (113.74 ±4.57 & 118.56 ±3.71) and (98.76 ±4.62 & 87.93 ±3.68) of sheep and goats respectively as presented in Table 4.

Considering the total protein and albumin levels in animals subjected in this study, the results revealed significant decrease (P<0.05) in total protein and albumin in the mineral-deficient sheep and goats compared to the control groups, as shown in Table 5. The mean values of total protein were (6.86±0.53 & 6.46±0.19) in the mineral-deficient of sheep and goats respectively, compared to the control groups (8.01±0.36 & 7.89±0.76). The mean values of albumin were (2.29±0.14 and 2.27±0.13) in the mineral-deficient of sheep and goats respectively compared to the control groups (3.98±0.41 & 3.87±0.57). However, there were no significant differences (P<0.0) in mean values of globulin between the mineral-deficient and control groups of sheep and goats (Table 5).

DISCUSSION

In the current study, animals showed various clinical signs of mineral deficiency in sheep and goats such as change in hair/wool color, readily detached hair/wool, and alopecia in some parts of the body. These results are in consistent with findings reported by (El-khaiat et al., 2012; Constable et al., 2016; Saleh, 2019; Emam et al., 2024). In general, rough hair coat and/or wool abnormalities were linked to copper, zinc, and selenium deficiencies. Copper deficiency causes low tyrosinase activity (Hefnawy and El-Khaiat, 2015), resulting in incomplete sulfhydryl group oxidation in prekeratin and reduced melanogenesis, which clinically manifests in animals as poor wool quality and hypopigmentation (Mauldin and Peters-Kennedy 2015). Zinc deficiency causes wool fibers to lose their crimp, become thin and loose, and the entire fleece to shed, since zinc supports cellular integrity, epidermal cell growth, keratin production, and wound healing. Furthermore, it promotes the growth and differentiation of epidermal keratinocytes (Song and Shen, 2020; Ogawa et al., 2016). Moreover, Pond et al., (2004) suggested that, Primarily, rough hair coat condition and/or wool abnormalities were usually related to deficiency of copper, zinc and cobalt.

Pale mucous membranes, inappetence, emaciation, and diarrhea signs were also observed in mineral deficient animals. These results are in line with findings of Wu et al., (2020); Abo Amer et al., (2020); and Emam et al., (2024). Unthriftiness (emaciation) and paleness of mucous membranes of studied animals could be attributed to deficiency of iron, zinc and copper (Radostits et al., (2000). In addition, Hefnawy & El-khaiat (2015) and Naji (2017) suggested that, the effect of hypoxia reduced RBCs result in pale mucous membrane and the loss of natural light pink color due to anemia related with copper deficiency.

Diarrhea is a common clinical sign in secondary copper insufficiency related with molybdenosis and previous investigation has shown that diarrhea in sheep occurs when Cu, Zn, and cobalt concentrations are dropped to low levels (Kaneko et al., 2008). Diarrhea is usually a major clinical finding in secondary copper deficiency associated with molybdenosis and may also occur due to the atrophy of intestinal villi. The inhibitory role of copper in the regulation of intestinal motility leads to disturbances in the gastrointestinal motility (Kaneko et al., 2008)

The physical examination of studied animals demonstrated that there was no significant difference in body temperature between the mineral-deficient and control groups. This finding is similar to previously findings of Saleh (2019), who observed that mineral deficiency did not cause an increase of body temperature due to the absence of an inflammatory state. However, there was significant increase (P<0.05) in respiratory and pulse rates in mineral-deficient compared to control groups. These findings agreed with those mentioned by Abd El-Raof and Ghanem (2006), Naji (2017), Saleh (2019), Emam et al. (2024). Earlier studies (Kusiluka and Kambarage, 1996) demonstrated that copper or zinc insufficiently causes hypoxia and anaemic conditions, resulting in increased respiratory and pulse rates as a compensatory mechanism.

The hematological examination displayed that, there was significant decrease (P<0.05) in total RBCs, Hb, PCV, and WBCs in mineral-deficient groups compared to the control groups of sheep and goats. These results are in agreement with previous studies by Mohammed et al. (2013), Saleh (2019), Galbat et al. (2021), and Emam et al. (2024). The reduction in total RBC, Hb and PCV might be attributed to many reasons such as disturbance in iron metabolism, as insufficient copper intake impairs iron absorption, the release of iron from bodily stores, and its utilisation in haemoglobin synthesis (Abd El Raof and Ghanem, 2006; Ibrahim et al., 2017). To decrease in the ceruloplasmin enzyme in serum (Hefnawy and El-Khaiat, 2015), which is responsible for moving iron from storage cells in the colon and liver to transferase in plasma. To Transferase enzyme that transports iron to the bone marrow for haemoglobin production. To decrease in iron liberation from typically injured erythrocytes (Sharma et al., 2005; Kaneko et al., 2008). The zinc deficiency, as highlighted by Ibrahim et al. (2016), who stated that low levels of red blood cells, haemoglobin, and white blood cells associated with induced zinc deficiency could lead to impaired cell replication and protein synthesis, ultimately affecting the production of blood cells. Whereas, the reduction count of WBC, might be attributed to the complexity of immune system responses to mineral deficiencies, the presence of confounding factors like age, stress, and parasitic infections, and various study methodologies and regional differences in mineral availability.

The biochemical analysis results of serum displayed that, there was significant decrease ($P<0.05$) of serum Ca, P, Mg, Cu, Fe and Zn levels in the mineral-deficient sheep and goats compared to the control groups. These results are aligning with the findings published by Emam et al. (2024), who reported a significant reduction of serum Ca, P, Mg, Cu, Fe, Zn and Se in diseased sheep compared to the control. Galbat et al. (2021) also reported significant decrease of serum Ca, P, Mg, Cu, Fe and Zn in the mineral-deficient group of sheep at El-Dakhla locality, Egypt. Another study conducted by Saleh (2019), who observed a significant reduction in Ca, P, Mg, Cu and Zn levels in affected sheep. The lower mineral level in studied animals in current and previous studies could be linked to decreased feed intake or eating low-quality feed, as most of the survey was done on sheep and goat flocks that grazed at random without a good feeding management system.

Calcium and phosphorus are physiologically vital minerals that are essential for growth and energy generation (Weaver et al. 2016). Reduction in feed intake and hypoalbuminemia could be the cause of low level of Ca in the present study. About 40-45% of excreted calcium is bounded with albumin mainly (Faez et al., 2013). The significant decline in serum phosphorus concentrations appears to be caused by reduced phosphorus absorption from the gut and tissue phosphorus resorption (Orr et al., 1990). Low P levels are connected with decreased feed intake, bone softness, lameness, and acid-base imbalance.

The development of a low Mg level could be attributed to several factors that affect Mg absorption and utilisation in ruminants, such as parathyroid hormone, which decreases urinary excretion and stimulates bone resorption, thereby releasing Mg into the extracellular fluid. Mg urinary excretion and absorption from the gastrointestinal tract, which may be due to high dietary K, which reduces Mg absorption. Several studies found that sheep fed high-K diets suffered from hypomagnesaemia (Castillo et al., 2016). In contrast, Galbat et al. (2021) ascribed hypomagnesaemia in their study to poor dietary magnesium intake, which was supported by the presence of low soil magnesium levels.

Copper deficiency in sheep can be caused by lower consumption, altered absorption, reduced tissue availability, or elevated excretion due to interactions with dietary molybdenum (Mo) and sulphur in ruminants, resulting in the formation of molybdates and thiomolybdates that bind Cu and decrease its uptake and utilization (El-khaiat et al., 2012; Asín et al., 2021).

Zinc is very important for animal health and production. Zinc is a constituent of numerous meta loenzymes and required for normal protein synthesis and metabolism. Zinc deficiency may be primary due to inadequate levels in the ration or secondary as a result of the presence of a substance interfering with its absorption or metabolism, in spite of the normal diet concentration (Wasilewski et al., 1992; Abd El-Raof. and Ghanem,2006; Ibrahim et al., 2017).

Current study revealed a drop in serum iron levels, which led to a decline in the majority of haematological markers. Iron deficiency in sheep and goat may be due to the adequate content of iron in forages (Yatoo et al., 2011). Low iron levels may also be associated with cu insufficiency, which regulates iron absorption and utilisation from storage cells, as well as its use in haemoglobin production via the action of ceruloplasmin, as stated by Sharma et al. (2005) and Kaneko et al. (2008).

Our study showed significant decreases ($P<0.05$) in total protein and albumin levels in mineral-deficient sheep and goats, compared to control groups. This finding is in consistent with Abd El-Raof and Ghanem (2006), Huo et al. (2020), and Emam et al. (2024), who found that a low level of albumin indicates protein insufficiency in animals, but it could also be due to a decline in albumin production caused by liver illness. On the other hand, this finding contradicts with Jin et al. (2023), who observed that mineral shortage is related with an increase in total protein and albumin and ascribed that damage to hepatocytes in the event of nutritional deficit.

Study Limitations

This study was limited in geographical coverage and a lack of consideration of seasonal variations, which may affect the generalizability of the findings. Variability in feeding practices among flocks and the presence of other health conditions such as parasitic infections may have confounded the clinical signs attributed to mineral deficiency.

CONCLUSIONS

Based on the present findings it could be concluded, naturally grazed sheep in different Sana`a localities, exhibited variable degrees of clinical signs and serum minerals deficiency that led marked deceases in performance and health of animals. Hence, mineral supplementation in the form of mineral mixture or other preparations of these animals is recommended**.** Further studies are also encouraged to explore long-term impacts of mineral supplementation on health, productivity, and reproductive performance in small ruminants in study areas**.**

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CONTRIBUTION OF AUTHORS

AAA author contributed to the study conception, design, written 1st draft and final version of the manuscript. Materials preparation and data collection were performed by AAA, ASA, A.A, SAMAA, HAA, BSA. Data analysis and visualization were performed by A.A. All authors read and approved the final version of manuscript.

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ETHICS STATEMENT

The study protocol was approved by the faculty board, the Faculty of Veterinary Medicine, Sana'a University.

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التقييم السريري والمختبري لنقص المعادن في الأغنام والماعز الرعوية في محافظة صنعاء، اليمن

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الملخص

يُعد نقص المعادن من أبرز التحديات الصحية التي تؤثر سلباً على إنتاجية المجترات الصغيرة. هدفت هذه الدراسة إلى تقييم حالات نقص المعادن في الأغنام والماعز التي تعتمد في غذاءها على الرعي في محافظة صنعاء - اليمن، وعلاقتها بالمعايير الدموية والبيوكيميائية. تم فحص 200 رأس من الأغنام (100) والماعز (100) من سلالات محلية تتراوح أعمارها بين 1–4 سنوات. اعتماد على الفحص السريري. تم اختيار 160 حيواناً (80 من الأغنام و80 من الماعز) تطهر عليها أعراض نقص المعادن واعتبرت حيوانات مصابة، بينما بدا 40 حيواناً (20 من الأغنام و20 من الماعز) بصحة جيدة واعتبرت كمجموعة ضابطة. تم متابعة الحيوانات في الحقل مع تجميع عينات دموية للاختبار الدموية والبيوكيميائية خلال فترة الدراسة. كشفت النتائج ان الحيوانات المصابة بنقص المعادن اظهرت علامات سريرية مثل سهولة انتزاع الشعر أو الصوف وتغير لونه، بقع خالية من الشعر (ثعلبة)، شحوب الاغشية المخاطية، قلة الشهية، الهزال والخمول، مع ارتفاع معنوي ($P<0.05$) في معدل النبض والتنفس مقارنة بالمجموعة الضابطة. كشفت الفحوصات الدموية انخفاضاً معنوياً ($P<0.05$) في تركيز الهيموغلوبين وحجم الخلايا المضغوطة واجمالي عدد كريات الدم الحمراء والبيضاء في حين ارتفع بشكل معنوي ($P<0.05$) عرض توزيع الكريات الحمراء وعدد الصفائح الدموية. كما كشفت الفحوصات البيوكيميائية انخفاضاً معنوياً ($P<0.05$) في مستويات الكالسيوم والفوسفور والمغنيسيوم والنحاس والحديد والزنك، إضافة إلى البروتين الكلي والألبومين في الحيوانات المصابة بنقص المعادن مقارنة بالمجموعات بالضابطة. خلصت الدراسة إلى أن الأغنام والماعز التي ترتعي في المراعي الطبيعية والتقليدية في مختلف مناطق صنعاء، أظهرت درجات متفاوتة من العلامات السريرية ونقص المعادن مما قد أدى إلى خسائر اقتصادية كبيرة مثل الوفاة ونقص اداء الحيوان. توصي الدراسة بإعطاء الحيوانات المصابة مكملات المعادن الضرورية على شكل خليط معدني أو مستحضرات غذائية أخرى، والتشجيع على اجراء المزيد من الدراسات لاستكشاف الآثار طويلة المدى للمكملات المعدنية على الصحة والإنتاجية والأداء الإنجابي في المجترات الصغيرة في مناطق الدراسة.

الكلمات المفتاحية: الفحص السريري، الاغنام، الماعز، نقص المعادن، صنعاء، اليمن

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