ORIGINAL RESEARCH

HEAVY METAL CONCENTRATIONS AND THEIR CORRELATIONS WITH PHYSICAL MEAT QUALITY ATTRIBUTES IN ABO-DELEEK SHEEP OF EGYPT UNDER INTENSIVE AND SEMI-INTENSIVE MANAGEMENT SYSTEMS

Mohamed Ali Zayed*

ABSTRACT

Animal proteins are important for human nutrition, particularly meat that provides essential amino acids and other bioactive ingredients. Some heavy metal pollutants, e.g., cadmium (Cd), lead (Pb), chromium (Cr), arsenic (As), nickel (Ni) and mercury (Hg); get into animal rations and food chains, and induce toxic effects in animals and might extend it to humans through consumption of foods of animal origin, particularly meat. Rise in environmental pollution due to high rate of industrialization are responsible for increased concentration of heavy metals (Pb, Cd, Fe, Zn etc.) in the environment that are largely air-borne and could be deposited along with dust into the soils, water, and plants that ruminants graze. Abo-Deleek sheep reared in Halaieb – Shalateen - Abouramad triangle region, south of Egypt, are raised primarily for lamb meat production, and are reared under extensive system. But commercial meat production can be boosted with indoor feeding (intensive system) or with provision of supplemental feed (semi-intensive system) besides grazing. However, there is no elaborate study regarding heavy metal concentration of meat under intensive and semi-intensive feeding management systems. This study elaborates heavy metals (Pb, Zn, Cd, Co, Ni, Fe, Cr, Mn, Cu and Hg) concentrations of fresh meat muscle *(Longsimus dorsi)* and liver obtained from fourteen male lambs of Abo-Deleek breed at one year of age after rearing for six months under intensive and semi-intensive management systems in Halaieb-Shalateen-Abouramad triangle of Egypt. The study revealed that there was no difference ($P>0.05$) between intensive and semi-intensive feeding systems in respect of heavy metal concentrations in *LD* muscle and liver of the lambs. The correlations between Cu & Co (0.88), Cr & Shear force (0.72), Cooking loss & Cr (0.58), Shear force & Cooking loss (0.54), and pH & yellowness coloration of meat (0.60) were positive and significant ($P<0.05$), while the correlations between Cr & redness coloration of meat was negative (-0.68) and significant ($P<0.05$). It is concluded that heavy metal concentrations of meat and liver of Abo-Deleek lambsof Halaieb – Shalateen - Abouramad triangle region both under intensive and semi-intensive feeding systems are quite low and are not a threat to human health. It is also a reflection of insignificant heavy metal contamination of the fodder crops, pasture, water, and the ambient environment in this region. Moreover, the concentrations of some of the heavy metals can be judged by producer/consumer from the color configuration of meat.

KEY WORDS

Abo-Deleek sheep, Heavy metals, Liver, Male lambs, Meat quality

Author attribution: *Researcher, Division of Animal and Poultry Production, Desert Research Center, Cairo, Egypt. Corresponding author (E-mail: mazf205@yahoo,com). Receipt: 25-Jun-2020, Acceptance: 20-July-2020. pp. 31-47.

INTRODUCTION

Meat is considered to be a complete *source of protein* because they contain all of the essential amino acids that the body needs to function effectively. Besides, it contains vitamins and minerals such as iron, selenium and zinc. Vitamins and minerals are micronutrients. Macronutrients, e.g., protein, fat, and carbohydrates provide energy. Micronutrients help release energy from these macronutrients, while also performing myriad of functions like healing wounds, bolstering the immune system, and repairing cellular damage etc. (Ahmad et al., 2018).

Beef and lamb meat, which is mainly produced in extensive pasture-based systems in South America contains highly valuable nutrients such as iron, zinc, selenium, fatty acids, and vitamins. Meat is a unique and crucial food for the human in order to secure a long and healthy life, compensating the nutritional deficiencies. Beef and lamb production systems based on temperate or tropical grasslands show interesting and, in some cases, a differential content of minerals, fatty acids and vitamins (Cabrera and Saadoun, 2014).

Metals in general can be classified as toxic, e.g., cadmium, and mercury and essential, e.g., cobalt, copper, zinc, and iron (Munoz-Olives et al., 2001). A toxic metal is defined as the metal that displays severe toxic symptoms even at low levels, which is neither essential nor has beneficial effect (Jaishankar et al., 2014). With increasing industrialization, more metals are entering into the environmental system (Anyanwu et al., 2018). These metals stay permanently because they cannot be easily degraded in the environment (Singh et al., 2011). Metals enter into the food material and from there they ultimately make their passage into the tissues in animals.

Some metal pollutants, e.g., cadmium (Cd), lead (Pb), chromium (Cr), arsenic (As), nickel (Ni) and mercury (Hg); spread out into animal rations and food chains, and increase thereby the possibility of toxic effects in humans and animals (Farmer and Farmer, 2000; Javed et al., 2009). Commonly, meat is very rich in Zn and Cu followed by Cr, Ni, and Co, which are generally considered as micronutrients (Akan et al., 2010). The levels of Pb, Cd and Hg are known to have no biochemical functions in animals and are toxic even at minute levels (Akoto et al., 2014).

Environmental pollution worldwide is on the rise with considerable threats to animals and humans (Yabeet al., 2011; Ihedioha et al., 2013). High rate of industrialization can be held responsible in the widespread of many toxic elements such as lead and cadmium (Okorafor et al., 2015) that are largely air-borne and could be deposited with dust into the soils, the water, and even the plants that ruminants graze on (Bala et al., 2013).

In addition, cows, sheep and horses have been used as excellent indicators of pollution on vegetation due to their indiscriminate eating habits especially in starvation periods (Bala et al., 2013). Contamination with toxic metals is considered as a critical health hazard due to their toxicity, bioaccumulation and magnification in the food chain (Nkansah et al., 2014).

The risk associated with the exposure to heavy metals present in food product has aroused widespread concern to human health (FAO, 1995). Ingestion of these contaminants by animals causes deposition of residues in internal organs and meat (Orisakwe et al., 2017). Toxic elements can be very harmful even at low concentration when ingested over a long time period due to their ability to accumulate in human and animal body (Rays et al., 1994).

The common local sheep breeds in the Shalateen-Abou-Ramad-Halaib triangle region are El Kanzy, Abo-Deleek, and El Manaeet breeds, which are well adapted to local harsh environmental conditions (El-Shaer & El-Khouly, 2016). The range vegetation is considered as the basic source of ruminants feed in this region (El-Hakeem, 2017).

The main nutritional problems of animals on range lands are erratic and short duration of precipitation that lead to long drought periods, resulting in shortage of forage production, seasonal starvation of animals, unavailability of feed concentrates which are brought from the Nile valley, unavailability of drinking water for animals during the dry season and improper economic inter-relationship between animal productivity and potential utilization of range plants (El-Shaer et al., 1997).

The aim of this study was to explore the effects of heavy metals present in the range land pastures of Halaieb-Shalateen-Abouramad triangle region in Abo-Deleek sheep, environmental condition, i.e., comparison between intensive and semi-intensive management systems on the physical properties and the quality of Abo-Deleek lamb meat.

MATERIAL AND METHODS

The experiment was conducted at Ras Hederba Valley region (Haleeb and Shalateen Research Station, Desert Research Center), Ministry of Agriculture and Land Reclamation, which is located 1200 km south of Egypt.

Study area description: Wadi Hederbah is located at the southeast corner of Halaib City, Red Sea Governorate, about 1200 km south eastern from Cairo, the capital of Egypt with latitude 22, 00, 720 N and longitude 36, 48, 955 E (Figure 1).

The average ambient temperatures of the study area was 35°C and 22°C while that of humidity was 37 % and 43%, for summer (dry) and winter (wet) seasons, respectively with erratic rainfall (Askar, et al., 2013). This Wadi has the richest rangeland resources and the greatest potential for improvement of all the Wadis in the Shalateen-Halaib region (El-Hakeem, 2017).

The study area is a part of Wadi Hederbah and it was mapped and delineated according to the terrain and the livestock grazing distribution and movement at the area. Even though mesquites (*Prosopis Juliflora*) have invaded large areas in southeastern Egypt, it isn't found in the study area.

The livestock types in the area included mainly sheep and goats, in addition to few numbers of camels. Livestock owned by the Livestock Research Station of the Desert Research Center and some families who live in the area are the primary animals in the grazing zone. Moreover, number of wild donkeys also live and graze in the study area.

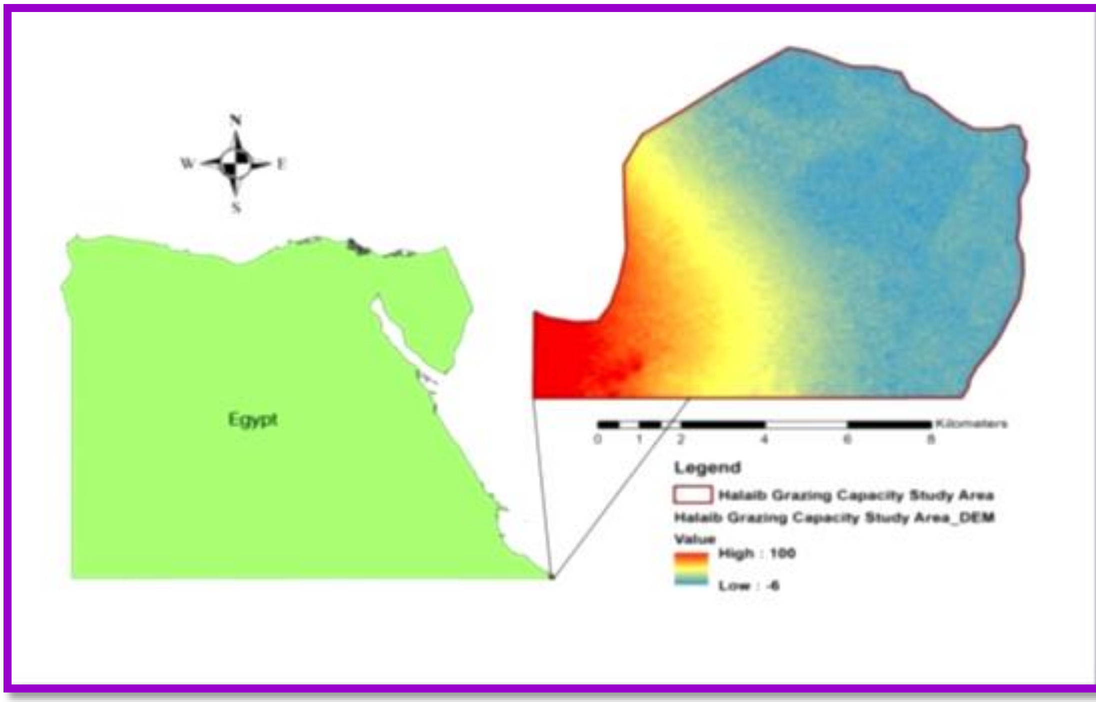

Fig. 1: Location of the study area at Wadi Hederbah, Halaib in southeastern Egypt (Ahmed H. Mohamed et al., 2019)

Animals and management systems: Sixteen Abo-Deleek male lambs, aged six months with an average live body weight of 22.2±0.75 kg were used in the present study. Experimental lambs were divided according to body weight into two similar groups (eight each) and then randomly allocated two different management systems:, viz., intensive management system (G1) with an average body weight of 22.31±1.39kg and semi-intensive management system (G2) with an average body weight of 22.34±0.70kg.

The lambs of G1 group were kept in intensive management system. These animals were not provided any area for their grazing activity in the farm. Lambs were fed a certain amounts of commercial concentrate mixture (12% crude protein) plus alfalfa (berseem) hay (*Trifolium alexandrinum*), offered *ad libitum*. But, lambs of G2 group were put under semi intensive management system. They had free access to grazing on natural vegetations. The grazing time extended from morning till afternoon. Then, they moved back to the barns.

They were offered commercial concentrate mixture (12 % crude protein) in the barn. However, the amounts of concentrates feed mixture (CFM) for G1 and G2 groups were bi-weekly adjusted (according to the live body weight changes) and water was given as per their body requirement. Lambs were fed as per standard schedule (NRC, 1985) to cover their nutritional requirements.

At the end of the experiment (after180 days), fourteen lambs were slaughtered following the stranded protocol (Frild et al., 1963), without significant ($P<0.05$) difference in average pre slaughter weight between G1 (37.63 ± 1.05 kg) and G2 (36.88±1.36 kg) groups, respectively. There was also non-significant difference ($P>0.05$) in hot carcasses weight between G1 (16.90±0.64 kg) and G2 (17.91±0.86 kg) groups.

Sample collection: Samples of natural pasture plants in the grazing area of the experimental lambs as were collected as per the prevailing protocol (El-Shesheny et al., 2014).and samples of commercial feed concentrates (12% crude protein), hay, soil and water were also collected according to standard method (AOAC, 2005).

Physical parameters of meat: Physical properties of meat, viz., colour, expressible fluid (%), cooking loss (%), water-holding capacity (W.H.C), plasticity and shear force were determined.

Meat color was measured using Croma meter (Konica Minolta, model CR 410, Japan) calibrated with a white plate and light trap supplied by the manufacturer. Color was expressed using the CIE *L**, *a**, and *b** color system (CIE, 1976). A total of three spectral readings were taken for each sample on different locations of the muscle. area of the cross section of *Longsimus dorsi* (*L.D*) muscle, and was measured by tracing the exact area of the exposed muscles on acetate paper between 11^{th} and 12^{th} rib using polar plane meter.

Expressible fluid percentage was measured by weighing about 0.3 g of meat (W1) in filter paper (Whatman No .1) and subjected to pressure of 1000 g for 10 minutes. After that it was weighed again (W2). The expressible fluid was estimated as the percentage of the difference between the two weights from the initial weight:

Expressible fluid % = [(W1-W2)/W1] x 100.

Cooking loss was determined on about 100 grams of *L.D* muscle samples (W1) which were boiled in water for 45 minutes, left to be cooled at room temperature and weighed again (W2) to calculate cooking loss percentage as per the standard protocol (Bouton and Harris, 1989).

Cooking loss (%) = (W1-W2) / W1x100.

The (WHC) and plasticity of meat were estimated using the following equation (Wierbicki and Deatharage, 1968):

$$WHC = A_2 - A_1$$

Where,

A_1 = Inner area of plasticity (area of meat after pressing, cm^2)

A_2 = Outer area (area of meat plus area of free water after pressing, cm^2)

Both areas were determined using a plane meter.

The cooked samples were used for determining the Shear force (kg). Samples were kept in refrigerator (4-5 ºC) for about 12 h, before estimating shear force using Instron Universal Testing Machine (Model 2519-105, USA). Cores from each sample were taken using cylinder of 0.5 inch in diameter. Cores were removed parallel to the longitudinal orientation of muscle fibers.

The Shear force machine was adjusted at crosshead speed of 200 mm/min as per the prevailing protocol (Shackelford et al., 2004).

Heavy metals analysis: Advanced Microwave Digestion System, located at Cairo University Research Park (CURP), Faculty of Agriculture, Giza, Egypt, was used for digestion of samples.

The concentrations of Pb, Zn, Cd, Co, Ni, Fe, Cr, Mn, Cu and Hg in all the investigating samples were determined by using Inductively Coupled Plasma-Atomic Emission Spectroscopy (Thermo Scientific iCAP-AES 6000, Thermo Fisher Scientific, UK). Argon gas was used for excitation of the element atom. The blank values for each element were deduced from the sample values.

Methodology of heavy metals determinations: Acid digestion of the fresh meat, soil, commercial feed and dried pasture plants were done in a closed vessel device using temperature control microwave heating to be further used for analysis by spectroscopic methods.

a. **Microwave equipment:** Milestone ETHOS lab station (Milestone Ethos Microwave Extraction System) with easy wave or easy control software HPR1000/10S high pressure segmented rotor.
b. **Sample amount:** The amounts of investigated samples were 1.5 g fresh meat or liver, 0.25 g soil and 0.5 g feed or dried pasture plant.
c. **Reagents:** The reagents used were:

(I) 7 ml of HNO_3 (65%), 1 ml of H_2O_2 (30%) were used for analysis of feed, dried postural plant, meat and liver.

(II) 4 ml of HNO_3 (65%), 1 ml of H_2O_2 (30%) and 3 ml of HF (40%) were used for soil analysis.

Procedure of heavy metals determinations: Place a TFM (Teflon Microwave Digestion Vessel) vessel on the balance plate, tare it and weigh the sample, introduce the TFM vessel into the HTC safety shield, add the acids; if part of the sample stays on the inner wall of the TFM vessel, wet it by adding acids drop by drop, then gently swirl the solution to homogenize the sample with the acids, close the vessel and introduce it into the rotor segment, then tighten by using the torque wrench, insert the segment into the microwave cavity and connect the temperature sensor, run the microwave program to completion, cool the rotor by air or by water until the solution reaches room temperature. Finally, open the vessel and transfer the solution to a marked flask.

STATISTICAL ANALYSIS

The data was subjected to one way analysis of variance (ANOVA) using a general linear model (GLM) of Statistics 22.0 software (SPSS, Inc., Somers, NY, USA). With type of management system as the main effect as follows:

$$Y_{ij} = \mu + d\,i + e_{ij}$$

Where,

Y_{ij} = the observations,

μ = the overall mean,

d_j = the effect due to i^{th} type of management system, i = 1,2 ,

e_{ij} = random error associated with the $_{ij}{}^{th}$ observation.

The significant differences between Means were tested according to Duncan's new multiple ranges test (Duncan, 1955). Pearson's correlation coefficient relationship between heavy metals and meat quality traits was done using SPSS at **α** = 0.05.

RESULTS AND DISCUSSION

Heavy metal concentrations of pasture plants, feed concentrate, hay, soil and water: The mean values along with SE of heavy metal concentrations in some pasture plants, feed concentrate, hay, soil and water are presented in Table 1.

Table 1: Heavy metal concentrations (mg kg^{-1}) in feed concentrate, hay, soil, drinking water and some pasture plants, used for feeding Abo-Deleek lambs

HEAVY METAL / SOURCE									
Pb	Zn	Cd	Co	Ni	Fe	Cr	Mn	Cu	Hg
Drinking water									
ND	0.02 ±0.00	ND	ND	0.05 ± 0.00	ND	ND	ND	0.03 ±0.00	ND
Pasture soil									
159.04 ±0.01	8.71 ±0.06	0.37 ±0.01	7.75 ±0.00	19.86 ±0.00	10862.7 ±0.00	37.36 ±0.00	264.28 ±0.00	58.61 ±0.00	ND
Hay									
ND	9.58 ±0.01	0.13 ±0.01	0.62 ±0.01	1.50 ±0.00	118.11 ±0.01	0.07 ±0.00	14.13 ±0.00	18.48 ±0.01	ND
Feed concentrate									
ND	17.73 ±0.01	0.07 ±0.00	1.27 ±0.01	3.28 ±0.01	260.89 ±0.06	0.26 ±0.01	20.98 ±0.01	24.00 ±0.00	ND
Aizoon canariense L									
13.50 ±0.06	15.16 ±0.01	ND	ND	7.52 ±0.01	3613.8 ±0.06	ND	104.11 ±0.06	3.02 ±0.01	ND
Astragaalus eremophilus Boiss									
10.68 ±0.01	16.02 ±0.01	ND	ND	3.52 0.06	1309.41 ± 0.06	ND	34.44 ±0.06	1.34 ±0.01	ND
Heliotropium aegyptiacum lehm									
18.19 ±0.02	19.17 ±0.03	ND	ND	5.22 ±0.01	4061.08 ±17.34	7.35 ±0.06	57.63 ±0.06	8.62 ±0.01	ND
Reseda pruinosa Delile									
5.88 ±0.06	17.26 ±0.01	ND	ND	4.17 ±0.01	803.93 ±0.01	ND	36.21 ±0.01	3.49 ±0.06	ND
ND = Not Detected									

The determined values for heavy metals were relatively within the normal safe limit (FAO/WHO, 2000). The overall means of the heavy metal concentrations (mg kg^{-1}) of the samples, pooled over both systems in drinking water were 0.02±0.00, 0.05±0.00, and 0.03±0.00 for Zn, Mn, and Cu, respectively, while the concentrations (mg kg^{-1}) of Pb, Zn, Cd, Co, Ni, Fe, Cr, Mn, and Cu on pasture soil were 59.04±0.01, 8.71±0.06, 0.37±0.01, 7.75±0.00, 19.86±0.00, 10862.68±0.00, 37.36±0.00, 264.28±0.00, and 58.61±0.00, respectively.

Heavy metals of meat: Maximum, minimum and mean values of the heavy metal concentrations (mg kg^{-1}) in *Longsimus dorsi (L.D)* muscle of Abo-Deleek lambs under intensive and semi-intensive management systems are presented in Table 2.

No significant differences (P>0.05) were observed between both management systems in respect of Pb, Zn, Cd, Co, Ni, Fe, Cr, Mn, Cu and Hg. Levels of Ni in all the meat samples analyzed from *Longsimus dorsi (L.D)* muscle of Abo-Deleek lambs under intensive and semi-intensive management systems were almost similar, the slight differences in their concentration were not statistically significant (P>0.5). The mean level of Cu in the meat samples studied was 0.28±0.19 µg kg^{-1} while that of Fe was 53.22±3.34 µg kg^{-1}. Mn concentration in all the samples studied ranged from 0.15 to 0.29 µg kg^{-1} and higher concentration of Mn was detected in the intensive system of management. The mean concentration of Zn in the meat samples analyzed ranged from 22.46 to 20.05 µg kg^{-1}.

The overall mean concentrations of Pb (2.91±0.30 kg^{-1}) and Cr (0.071±0.04 mg kg^{-1}) were lower than that reported by Masoumeh Ariyaee et al. (2015), who reported mean value of 9.2 and 242; and Odoh et al. (2016), who reported mean values of 26 and 2 mg kg^{-1} in the industrial area for Pb and Cr, respectively. The variation in the results in comparison with the cited studies could be due to the location or environmental pollution status. Overall mean of Zn, Cd, Ni, Fe, Mn and Cu concentrations were 21.26±1.01, none detected, 0.38±0.07, 53.22±3.34, 0.22±0.06 and 0.28±0.19 mg kg^{-1} thus is lower than that reported by Odoh et al. (2016), who reported means of 1500, 1, 1, 151, 157 and 30 mg kg^{-1}, respectively in the industrial area for the same elements.

Toxicity due to lead exposure is mostly related to the gastrointestinal tract and central nervous system in children and adults (Markowitz, 2000).The maximum limit of 0.02 µg g^{-1} Cd in plant and 5.0 µg g^{-1} of Pb in plant was prescribed by FAO/WHO (2000). Chromium is considered non-essential for plants, but an essential element for animals (Pechova & Pavlata, 2007). Cr toxicity in man has been limited to hemorrhage, respiratory impairment and liver lesions. However, low exposure to chromium can irritate the skin and cause ulceration, while long term exposure can cause kidney and liver damage (Shekhawat et al., 2015). Moreover, it can also cause damage to circulatory and nerve tissues (Engwa et al., 2019).

In this work, Cr was found to range between non-detectable level and 0.539µg kg^{-1} with an average of 0.071±0.004µg kg^{-1}. This value is less than 150,000µg kg^{-1} safe limits, given by EU commission regulation (Baykov et al., 1996). Cr concentration in this study is lower than 100 µg kg^{-1} maximum limit set by FAO/WHO (2000). The mean Ni concentration in the sample products was 0.38±0.07µg kg^{-1}. it is important to note that Ni concentrations in all the meat samples investigated were lower than what was obtained by other researchers in similar studies (Lo'pez-Alonso et al., 2002; Masoumeh Ariyaee et al., 2015).

Table 2: Heavy metal concentrations (mg kg^{-1}) in *Longissimus dorsi* muscle of Abo-Deleek lambs under intensive and semi-intensive management systems.

Parameter	Pb (1)	Zn (2)	Cd (3)	Cr (4)	Ni (5)
μ ± SE	2.91±0.30	21.26±1.01	ND	0.01±0.01	0.38±0.07
Maxim	4.49	26.46	ND	0.156	0.831
Minim	0.99	15.75	ND	ND	ND
Intensive					
Mean± SE	3.04±0.46	22.46±1.68	ND	ND	0.46±0.11
Maxim	4.49	26.46	ND	0.02	0.83
Minim	1.34	16.06	ND	ND	0.00
Semi-intensive					
Mean± SE	2.77±0.42	20.05±1.07	ND	0.02±0.02	0.30±0.09
Maxim	4.11	24.50	ND	0.16	0.71
Minim	0.99	15.75	ND	ND	ND
Parameter	Fe (6)	Cr (7)	Mn (8)	Cu (9)	Hg (10)
μ ± SE	53.22±3.34	0.07±0.04	0.22±0.06	0.28±0.19	ND
Maxim	75.995	0.539	0.857	2.31	ND
Minim	28.56	ND	ND	ND	ND
Intensive					
Mean± SE	49.21±4.82	0.08±0.077	0.15±0.07	0.22±0.22	ND
Maxim	63.71	0.54	0.47	1.55	ND
Minim	28.56	ND	ND	ND	ND
Semi-intensive					
μ ± SE	57.23±4.44	0.06±0.05	0.29±0.11	0.33±0.33	ND
Maxim	76.00	0.34	0.86	2.31	ND
Minim	40.29	ND	ND	ND	ND
ND = Not Detected					

Cu and Fe form the essential group of metals required for some metabolic activities in organisms (Engwa et al., 2019). Toxicological effects of large amounts of copper can cause anaemia, liver and kidney damage, along with stomach and intestinal irritation. People with Wilson's disease are at greater risk for health effects from over exposure to copper.

The mean and range values of Cu, Fe and Mn in all the meat samples studied revealed that the levels of these metals were lower than the regulatory limit for World Health Organization (FAO/WHO, 2000). Manganese is known to block calcium channels and with chronic exposure results in central nervous system dopamine depletion (O'Neal et al., 2015). In the present study, the highest amount of Zn found in the samples is much lower than the permissible level of 250 µg kg^{-1} (FAO/WHO, 2000; Marino and Hardission, 2006). Very high levels of zinc can damage the pancreas and disturb the protein metabolism, and cause arteriosclerosis (Cunningham and Saigo, 1997).

Heavy metals of liver: The heavy metals concentration (mg kg^{-1}) in liver of Abo-Deleek lambs under intensive and semi-intensive management systems are displayed in Table 3.

Table 3: Heavy metal concentrations (mg kg^{-1}) in liver of Abo-Deleek lambs under intensive and semi-intensive management systems.

Parameter	Pb (1)	Zn (2)	Cd (3)	Cr (4)	Ni (5)
µ ± SE	ND	26.10± 1.93	ND	0.06± 0.06	1.03± 0.46
Maxim	ND	32.60	ND	0.37	3.11
Minim	ND	20.73	ND	ND	0.20
Intensive					
Mean± SE	ND	24.00±2.05	ND	ND	0.75±0.37
Maxim	ND	27.77	ND	ND	1.49
Minim	ND	20.73	ND	ND	0.33
Semi-intensive					
Mean± SE	ND	28.20±3.17	ND	0.12±0.12	1.30±0.91
Maxim	ND	32.60	ND	0.37	3.11
Minim	ND	22.05	ND	ND	0.20
Parameter	Fe (6)	Cr (7)	Mn (8)	Cu (9)	Hg (10)
µ ± SE	94.83± 6.33	ND	3.55± 0.46	7.07± 2.67	ND
Maxim	115.37	ND	5.19	16.12	ND
Minim	70.03	ND	2.19	ND	ND
Intensive					
Mean± SE	106.17±5.05	ND	3.39±0.54	7.56±4.68	ND
Maxim	115.37	ND	4.03	16.12	ND
Minim	97.96	ND	2.33	ND	ND
Semi-intensive					
µ ± SE	83.49±6.77	ND	3.70±0.87	6.58±3.68	ND
Maxim	91.51	ND	5.19	12.75	ND
Minim	70.03	ND	2.19	ND	ND
ND = Not Detected					

The overall mean of Pb concentration in meat samples was 2.91±0.30 mg kg^{-1}, however, Pb in liver was failed to be detected. On the other hand Ni and Fe were high in liver on top of the levels of Mn and Cu, which were obviously had a higher levels (P>0.05) in liver for intensive and semi-intensive management systems

However, this result is in contradistinction with the report (Akoto et al., 2014) which noted that mean concentration of Pb in the liver of Obuasi sheep was 0.2±0.2 mg kg^{-1} in fresh samples of liver of sheep reared in Obuasi, and were collected from Obuasi slaughter house, Ghana. On the other hand, Ni and Fe were high in liver. On top of that, the levels of Mn and Cu were obviously had higher levels in liver for intensive and semi-intensive management systems (Table 3).

Furthermore, mean Cu concentrations as observed in the liver was 7.07±2.67 mg kg^{-1} while Akoto et al. (2014) found that Cu was 106.63±111.24 mg kg^{-1}. Additionally, Hg was not detected in the liver, which was close to the result of Akoto et al. (2014) who showed very low mean concentration (0.03±0.03 mg kg^{-1}).

Physical properties of meat: Results revealed no significant (P>0.05) differences between intensive and semi-intensive management systems between the mean values of cooking loss percentages and color parameters (Table 4).

Table 4: Physical properties of meat of *Longissimus dorsi* muscle and pH value for Abo-Deleek lambs under intensive and semi-intensive management

Parameters	Over all	Intensive System	Semi-intensive System
	Mean ± SE	Mean ± SE	Mean ± SE
Physical properties			
Cooking loss %	44.03±1.26	44.74^{a}±2.43	43.32 ^{a}±0.91
Expressible fluid %	48.94 ±4.85	52.02^{a} ±6.27	45.86 ^{a}±7.71
W.H.C (cm^2)*	13.61±0.88	15.53^{a}±1.28	11.69^{b}±0.69
Plasticity (cm^2)	1.99±0.16	1.81^{a}±0.20	2.17^{a}±0.25
Shear force (kg)	5.00 ±0.49	4.90^{a} ±0.78	5.11^{a} ±0.66
Color parameters & Other characteristics			
L (lightness)	41.30 ±0.46	40.88^{a}±0.59	41.72 ^{a} ±0.71
a (redness)	16.41 ±0.22	16.57 ^{a} ±0.33	16.24 ^{a} ±0.30
b (yellowness)	4.36 ±0.30	4.08 ^{a} ±0.22	4.63 ^{a} ±0.55
pH	6.24 ± 0.06	6.19 ^{a} ± 0.06	6.30 ^{a} ± 0.11
Caracas Temp (C°)	40.78± 0.31	40.50^{a} ± 0.44	41.07^{a} ± 0.46

Means followed by different superscript letters within the same row are significantly different at P<0.05.

Same results were obtained for color parameters of meat between lambs under intensive management system and lambs under semi- intensive management system (P>0.05). Keeping experimental animals under both intensive and semi-intensive management systems did not significantly (P>0.05) alter the pH values of meat.

Results revealed that there was no significant differences (P>0.05) in the mean values of cooking loss percentages and color parameters between the lambs under intensive and semi-intensive management systems. In the present study, the lightness (*L*), the redness (*a*) and yellowness (*b*) of lamb's meat were similar and conformed with previous reports (Vicente et al.,2003; ÅdnØyet al., 2006; Majdoub-Mathlouthi et al.,2013).

Keeping experimental animals under both intensive and semi-intensive management systems did not significantly (P>0.05) alter the pH values of their meat. In other words, no significant difference (P>0.05) between the two groups was found in respect pH. In-spite of these results, the pH of meat of lambs kept under semi-intensive management system was higher by 1.78%. This may be owing to the differences between individuals, time-consumed in grazing the grasses as compared with those under the intensive management system. These results are in accordance with the reported results for lambs reared in lowland and mountain pastures (ÅdnØy et al., 2006).

The pH values of Abo Delek lambs meat (6.24) was within the range (5.6 to 6.4) reported for lamb meat (Majdoub-Mathlouthi et al., 2013). The results obtained here are comparable to the report (Almitiairy et al., 2011) which mentioned that pH of meat and color components did not differ among dietary groups. The pH value of meat is the result of combination of many factors including pre-slaughter handling, post-mortem treatment and muscle physiology (Thompson, 2002).

Correlation between heavy metal concentration and physical properties of meat quality: Pearson's correlation coefficient (r) for concentration of heavy metals in *LD* muscle with physical properties of meat quality of Abo-Deleek lambs (Table 5) demonstrated significant positive correlations (P<0.05) between Cu & Co (r = 0.88) and Cr & shear force (r = 0.72), Cr & Cooking loss (r = 0.58), shear force & cooking loss (r = 0.54), and yellowness of meat color & pH (r = 0.60), while significant (P<0.05) negative correlations were observed between Cr & redness of meat color (r = -0.68), lightness of meat color & Expressible fluid (r = - 0.60), lightness of meat color & Pb (r = - 0.56) and plasticity & shear force (r = - 0.62).

It is reported that five latent factors explained 69% of mineral co-variation in beef. The most important, "Mineral quantity" factor is correlated with age at slaughter and with the beef color traits. Two latent factors ("Na + Fe + Cu" and "Fe + Mn") are correlated with performance and beef color traits. Two other factors ("K-B-Pb" and "Zn") are correlated with beef chemical composition and the latter also with carcass weight and daily gain, and beef color traits. Beef cooking losses are correlated with "K-B-Pb". Beef shear force was not related to any latent factor nor any individual mineral in the beef. Therefore, these hidden factors simplify the picture of the relationships between the minerals and meat quality traits, helping the understanding and interpretation of the role minerals. Moreover, the concentrations of some of the heavy metals can be judged from the colour configuration of meat (Nageshvar Patel et al., 2019).

Table 5: Pearson correlation coefficients (r_s) between heavy metal concentrations and meat quality characteristics in *LD* muscle of Abo-Deleek lambs

M/Q	Pb	Zn	Co	Ni	Fe	Cr	Mn	Cu	PH	C°
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Zn	0.401	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Co	0.344	0.289	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Ni	0.229	0.131	-0.038	xxx	xxx	xxx	xxx	xxx	xxx	xxx
Fe	- 0.023	-0.433	0.201	-0.478	xxx	xxx	xxx	xxx	xxx	xxx
Cr	- 0.229	0.049	-0.139	-0.512	0.278	xxx	xxx	xxx	xxx	xxx
Mn	- 0.059	-0.016	0.263	-0.028	-0.011	-0.296	xxx	xxx	xxx	xxx
Cu	0.431	0.413	0.881**	-0.085	0.107	-0.178	0.365	xxx	xxx	xxx
PH	- 0.233	-0.113	0.056	0.024	0.153	0.199	-0.089	0.018	xxx	xxx
C°	- 0.202	-0.393	0.062	-0.356	0.299	0.180	0.367	0.020	0.392	xxx
CL %	0.041	0.195	-0.206	-0.437	0.173	0.575*	0.010	-0.093	0.283	xxx
E.F %	0.144	-0.351	0.043	0.113	0.488	0.153	0.286	0.139	0.087	0.123
Sh. F	0.182	0.187	-0.047	-0.083	0.154	0.720**	-0.013	-0.124	0.217	0.312
WHC	0.432	0.325	-0.265	0.065	-0.027	0.430	-0.403	-0.233	-0.156	0.256
Plasti	-0.149	-0.127	0.158	-0.365	0.337	-0.266	0.068	0.182	-0.218	-0.230
L	–0.560*	0.018	-0.034	-0.346	-0.217	0.281	-0.293	-0.056	0.035	-0.406
a	0.104	-0.265	-0.230	0.400	-0.149	-0.684**	0.044	-0.333	-0.086	-0.282
b	–0.135	-0.201	-0.022	0.298	-0.152	-0.259	-0.212	-0.041	0.596*	-0.242
CONTINUED										
M/Q	CL%	E.F%	Sh. F	WHC	Plasti	L	a	b	---	---
(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	---	---
CL %	XXX	XXX	XXX	XXX	XXX	XXX	XXX	XXX	---	---
E.F %	0.183	XXX	XXX	XXX	XXX	XXX	XXX	XXX	---	---
Sh. F	0.539*	0.294	XXX	XXX	XXX	XXX	XXX	XXX	---	---
WHC	0.573*	0.259	0.497	XXX	XXX	XXX	XXX	XXX	---	---
Plasti	-0.090	-0.214	-0.624*	-0.321	XXX	XXX	XXX	XXX	---	---
L	-0.052	-0.601*	-0.216	-0.378	0.300	XXX	XXX	XXX	---	---
a	-0.190	-0.064	-0.469	0.050	0.120	-0.468	XXX	XXX	---	---
b	-0.076	-0.241	-0.293	-0.326	0.213	0.319	0.197	XXX	---	---

Abbreviations: M (Heavy metal conc.), Q (Meat quality), CL (Cooking loss %), E.F (Expressible fluid %), Sh. F (Shear force), WHC (Water Holding Capacity, cm^2), Plasti (Plasticity). *Significant at P<0.05, ** Significant at P<0.01

CONCLUSIONS

Since animal protein is more important for human nutrition, particularly meat that provides essential amino acids and other bioactive ingredients, it should be free from toxic substances such as heavy metals. This study takes care of the quality of lamb meat reared in triangle region, south of Egypt, where the environmental conditions are totally different than in urban area. Heavy metals in meat of Abo-Deleek sheep breed under different management systems indicated low levels of Cd, Cr, Cu, Fe, Mn, Pb and Zn in the muscles and livers samples of Abo-Deleek lambs. This could be considered as indicative of low contamination of the water, meat and the environment there. Thus, the low level of these metals in the Abo-Deleek lamb's meat does not impair the meat quality traits obtained from them. It could be concluded that, the levels of heavy metals in lamb meat are very low and safe for consumption in Halaieb – Shalateen - Abouramad triangle region. On the basis of the present work, it is suggested that this region should adopt silvopasture to increase fodder harvest for commercial production of lambs for meat.

REFERENCES

ÅdnØy, T et al. 2006. Grazing on mountain pastures - Does it affect meat quality in lambs? Livestock Production Science, 94, 25–31.

Ahmed, H et al.2019. Estimating Grazing Capacity for Desert Rangelands of Wadi Hederbah in Southeastern Egypt. Advances in Environmental Biology, 13 (10), 22-31.

Ahmad, RS et al. 2018. Nutritional composition of meat. In: Meat Science and Nutrition, edited by: Arshad, M. S., IntechOpen, London, UK, 61–77, https://doi.org/10.5772/intechopen.77045.

Akan, J et al. 2010. Distribution of heavy metals in the liver, kidney and meat of beef, mutton, caprine and chicken from Kasuwan Shanu market in Maiduguri Metropolis, Borno State, Nigeria. Research Journal of Applied Sciences, Engineering and Technology, 2(8), 743-748.

Akoto, O et al. 2014.Distribution of Heavy Metals in Organs of Sheep and Goat Reared in Obuasi : A Gold Mining Town in Ghana, International Journal of Environmental Science and Toxicology Research, 2(4), 81–89.

Almitairy, AN et al. 2011. Effects of Feeding Discarded Dates on Growth Performance and Meat Quality Traits of Najdi Lambs. Journal of Animal and Veterinary Advances, 10 (17), 2221-2224.

Anyanwu, BO et al. 2018. Heavy Metal Mixture Exposure and Effects in Developing Nations: An Update. Toxics, 6 (4), 65. Published 2018 Nov 2. doi: 10.3390/toxics6040065

AOAC. 2005. Association of Official Analytical Chemists: Official Methods of Analysis of AOAC International, 18^{th} ed. AOAC, Gaithersburg, MD, USA.

Askar, AR et al. 2013. Feasibility of internal markers to estimate arid-areas rangelands intake and digestibility in sheep: effect of season and supplementary feeding. Egyptian Journal of Nutrition and Feeds, 16 (3), 389-403.

Bala, A et al. 2013. Determination of lead (Pb) residue in kidney, liver and muscle of slaughtered cattle in Jos Central Abattoir, Plateau State, Nigeria. IOSR Journal of Environmental Science, Toxicology and Food Technology (ISOR-JESTFT), 7 (6), 48-51.

Baykov, BD et al. 1996. Cadmium and lead bioaccumulation in male chickens for high food concentrations. Toxicological and Environmental Chemistry, 54, 155-159.

Bhasin, G et al. 2002. Iron augments stage-I and stage-II tumor promotion in murine skin. Cancer Letter, 183 (2),113-122.

Bouton, P.E.; Harris, P.V. 1989. Change in the tenderness of meat cooked at 50-600 C . Journal of Food Science, 46: 283-287.

Cabrera, M.C.; Saadoun, A. 2014. An overview of the nutritional value of beef and lamb meat from South America. Meat Science, 98 (3), 435-444.

Cañeque, V et al. 2003. Use of whole barley with a protein supplement to fatten lambs under different management systems and its effect on meat and carcass quality. Animal Science, 52 (3), 271–285.

CIE. 1976. Commission International de l'E´ clairage (CIE) Official recommendations on uniform color spaces. Color difference equations and metric color terms, Suppl. No. 2. Colorimetry. Paris. CIE Publication, No: 15.

Cunningham, W.P.; Saigo, B.W. 1997. Environmental Science a Global Concern. 4th Edn., WMC Brown Publisher, New York, p. 389. DOI: 10.22587/aeb.2019.13.10.3

Duncan, D.B.1955. Multiple range and multiple F tests. Biometrics, 11,1-42.

El-Hakeem, M.S. 2017. Sustainable development of the Egyptian Rangelands to combat desertification. Desert Research Center, Cairo, Egypt, P 68.

El-Shaer, H.M.; El-Khouly, A.A. 2016. Natural resources of saline habitats in South East of Egypt. Desert Research Center and Academy of Scientific Research and Technology. Cairo, Egypt, P. 172.

El-Shesheny, MA et al. 2014. Assessment of productivity, botanical composition and nutritive value of some plant communities at Sidi-Barrani in North Western Coast of Egypt. Annals of Agricultural Science, 59 (2), 155–163.

Engwa, GA et al. 2019. Mechanism and Health Effects of Heavy Metal Toxicity in Humans, Poisoning in the Modern World - New Tricks for an Old Dog? DOI: 10.5772/ intechopen.82511. https://www.intechopen.com/

FAO.1995. General standard for contaminants and toxins in food and feed (Codex stan. 193). Food and Agriculture Organization of the United Nations (World Health Organization).

FAO/WHO. 2000. Report of the 32nd Session of the Codex Committee of the Food Additives Contaminants. Beijing People's Republic of China, 20-24 March, 2000.

Farmer A.A.; Farmer, A.M. 2000. Concentrations of cadmium, lead and zinc in livestock feed and organs around a metal production center in eastern Kazhakstan. The Science of the Total Environment, 257 (1), 53-60.

Frild, RA et al.1963. Indices for lamb carcass composition. Journal of Animal Science, 22 (1), 218-221.

Hozan Jalil Hamasalim, Hemin Nuradden Mohammed. 2013. Determination of heavy metals in exposed corned beef and chicken luncheon that sold in Sulaymaniah markets. African Journal of Food Science, 7 (7), 178-182. DOI: 10.5897/AJFS2013.0988 ISSN 1996-0794 ©2013 Academic Journals http://www.academicjournals.org/AJFS

Ihedioha, J.N.; Okoye, C.O.B. 2013. Dietary intake and health risk assessment of lead and cadmium via consumption of cow meat for an urban population in Enugu State, Nigeria. Ecotoxicology and environmental safety, 93, 101-106.

Jaishankar, M et al. 2014. Toxicity, mechanism and health effects of some heavy metals. Interdisciplinary Toxicology, 7 (2), 60–72. doi: 10.2478/intox-2014-0009

Javed, I et al. 2009. Heavy metal residues in the milk of cattle and goats during winter season. Bulletin of Environmental Contamination and Toxicology, 82, 616-620.

Khan MZ et al. 2015. Concentrations of heavy metals in liver, meat and blood of poultry chicken gallus domesticus in three selected cities of Pakistan. Canadian Journal of Pure and Applied Sciences, 9 (1), 3313–3324.

Lo'pez-Alonso, M et al. 2002. Cattle as biomonitors of soil arsenic, copper and zinc concentrations in Galicia (NW Spain). Archives of Environmental Contamination and Toxicology, 43, 103-108.

Mahmoud, H.S. 2005. Nutritional studies on camels grazing the natural ranges of Halaib-Shalateen triangle region. Ph.D. dissertation, Cairo University, Cairo, Egypt.

Majdoub-Mathlouthi, L et al. 2013. Effect of concentrate level and slaughter body weight on growth performances, carcass traits and meat quality of Barbarine lambs fed oat hay based diet. Meat Science, 93, 557–563.

Marino, M.; Hardission, A. 2006. Lead and cadmium in meat and meat products consumed by the population in Tenerife Islans, Spain. Food Additives and Contaminants, 23, 757-763.

Markowitz, M. 2000. Lead poisoning. Pediatrics in Review, 21 (10), 327-335

Munoz–Olives, R et al. (Eds). 2001. Trace element speciation for environment food and health. The Royal Society of Chemistry, 331-353.

Nageshvar Patel et al. 2019. Relationships of a Detailed Mineral Profile of Meat with Animal Performance and Beef Quality. Animals, 9, 1073. doi:10.3390/ani9121073.

Nkansah, M.A.; Ansah, J.K. 2014.Determination of Cd, Hg, As, Cr and Pb levels in meat from the Kumasi Central Abattoir. International Journal of Scientific and Research Publications, 4 (8), 1-4.

Odoh, R et al. 2016. Determination of some heavy metal profiles in meat of domesticated animals in the vicinity of Kaduna south industrial area, Nigeria. FUW Trends in Science & Technology Journal, 1 (2), 337-343.

Okorafor, K.A.; Amadiali, P. 2015. Concentrations of some metals in kidneys and liver of goats slaughtered at Atakpa Abattoir, Calabar South, Cross Rivers State, Nigeria. Biosciences Research in Today's World, 1 (1), 90-96.

O'Neal, S.; Zheng, W. 2015. Manganese toxicity upon overexposure: A decade in review. Current Environmental Health Reports, 2 (3), 315-328.

Orisakwe, OE et al. 2017. Horizontal and Vertical Distribution of Heavy Metals in Farm Produce and Livestock around Lead-Contaminated Goldmine in Dareta and Abare, Zamfara State, Northern Nigeria. Journal of Environmental and Public Health, 6, 1-12.

Pechova, A.; Pavlata, L. 2007. Chromium as an essential nutrient: A review. Veterinarni Medicina, 52, (1), 1–18.

Rays, S.; Kiceniuk, J.W. 994. Cadmium. In: Analysis of contaminants in edible aquatic resources - General considerations: metals, organometallics, tainting and organics. VCH Publishers, USA, 91-115.

Shackelford, SD et al. 2004. Evaluation of sampling, cookery, and shear force protocols for objective evaluation of lamb longissimus tenderness. Journal of Animal Science, 82 (3), 802-807.

SPSS. 2013. Statistical Package of The Social Sciences, Relkease 22, SPSS Inc. Chicago, USA.

Thompson, J. 2002. Managing meat tenderness. Meat Science, 62 (3), 295-308.

Wierbicki, E.; Deatharage, F.E. 1968. Determination of water holding capacity of fresh meat Journal of Agriculture and Food Chemistry, 6 (5), 387-392.

Yabe, J et al. 2011. Uptake of lead, cadmium, and other metals in the liver and kidneys of cattle near a lead-zinc mine in Kabwe, Zambia. Environmental Toxicology and Chemistry, 30 (8), 1892-1897.

UNDERTAKING

It is certified that the research paper **HEAVY METAL CONCENTRATIONS AND THEIR CORRELATIONS WITH PHYSICAL MEAT QUALITY ATTRIBUTES IN ABO-DELEEK SHEEP OF EGYPT UNDER INTENSIVE AND SEMI-INTENSIVE MANAGEMENT SYSTEMS** is an original research work carried out by the author in Animal and Poultry Production Division of Desert Research Center, El-Mataria, Cairo, Egypt. It has neither been published nor contemplated for publication elsewhere.

Dr. M. A. Zayed

(Dr. Mohamed Ali Zayed)

CORRESPONDING AUTHOR