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RESEARCH ARTICLE

LEAD, CADMIUM AND MERCURY RESIDUES IN THE EDIBLE OFFAL OF SHEEP AND GOAT WITH A SPECIAL REFERENCE TO THEIR PUBLIC HEALTH IMPLICATIONS

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Abstract

The contamination of the environment with heavy metals is a serious problem worldwide, particularly in Egypt. Heavy metals get their way into human body mainly through ingestion of contaminated food. Animals, especially small ruminants are exposed during their lifetime to a vast array of heavy metals such as lead, cadmium and mercury. The objective of this study was to estimate heavy metal (lead, cadmium and mercury) residues in the edible offal (liver, kidney, lung, tongue and masseter muscle) of sheep and goat collected from butcher shops at Zagazig city, Egypt. The public health implications of the tested metals were also discussed. In addition, a trial for reduction of the metal load in the livers of the sheep was done using immersion in acetic acid 2% and heat treatments. The obtained results declared that sheep samples had significantly higher metal concentrations than goat. Liver and kidney had the highest residual concentrations compared with other examined offal. Concentrations of lead and cadmium in the liver and kidney exceeded the maximum residual limits of these metals set by WHO. Thus, it is advisable to reduce our daily intake of the offal of these animals. Furthermore, a combination of immersing the liver samples in acetic acid 2% for 15 min followed by either boiling or frying is effective for reduction of the metal load especially in the case of mercury.

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Introduction:-

Meat and edible offal are considered major sources of animal-derived protein, vitamins, essential trace elements and fatty acids. However, meat consumption had been identified as the major pathway of human exposure to pollutants, accounting for 90% compared to other ways of exposure such as inhalation and dermal contact (Zheng et al., 2007).

Environmental pollution is considered to be one of the most dangerous hazards affecting the majority of world countries like Egypt. Heavy metal pollution has increased in Egypt due to the increased population, agricultural projects, industrial and other anthropogenic activities (Darwish et al., 2015). Accumulation of heavy metals in meat is of key concern due to food safety issues and potential health risks because heavy metals are toxic even at relatively low concentrations in nature (Akan et al., 2010; Akoto et al., 2014). Lead, cadmium and mercury are

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considered potential carcinogens and are associated with etiology of a number of diseases, especially cardiovascular, kidney, nervous system, blood as well as bone diseases (Jarup, 2003).

Lead (Pb) may enter the atmosphere during mining, smelting, refining, manufacturing processes and by the use of lead containing products. Lead intake occurs from the consumption of food stored in lead lined containers, cosmetics, cigarettes and motor vehicle exhaust. Excess lead can cause serious damage to the brain, kidneys, nervous system and red blood cells (Darwish et al., 2013).

The use of cadmium (Cd) in industries had resulted in contamination of environment and food chain, as well as, its effect on animals and man. It is used mainly in compounds such as nickel cadmium batteries & anticorrosive coating metals pigments and stabilizers for plants so significant amount of cadmium is released from these industries. Animal and man absorb cadmium by means of air, water, direct consumption of contaminated livers and kidneys, as well as, contaminated vegetables. Cadmium is considered one of the most toxic metals. In addition, it is implicated in high blood pressure, prostate cancers, mutations and fetal death (Pitot and Dragan, 1995).

Mercury (Hg) pollution in most parts of the world is caused by the mining activities, the release into the environment of metallic mercury used in the recovery of gold by the crude method of amalgamation and using of mercury in the agrochemicals like herbicides and fungicides. Mercury can get entry into the animal tissues through contaminated drinking water or dietary substances (FAO/WHO, 2002).

Sheep and goat are domesticated and live under the same environment with human, thus they are considered as ideal biomarkers for human exposure to heavy metals, and furthermore their meat and offal are frequently consumed by the Egyptian population (Darwish et al., 2015).

Edible offal such as liver, kidneys, lungs, tongue and masseter muscle are sold and consumed as a valuable food source: however, such organs might significantly contribute to human exposure to heavy metals. Therefore, evaluating heavy-metal levels in such organs is important for safety and health purposes (Yabe et al., 2010). Therefore, the present study aimed to evaluate levels of the heavy metals Pb, Cd and Hg in sheep and goat edible offal (liver, kidney, lung, tongue and masseter muscle) marketed at Zagazig city, Egypt. Additionally, a human health risk assessment was conducted on the consumption of meat from these animals. Moreover, a trial to reduce the heavy metal load in the liver was done by either immersion in acetic acid 2% for 15 min, boiling for 15 min, frying in oil, or a combination between immersion in acetic acid 2% and either boiling or frying.

Materials and Methods:-

Collection of Samples:-

A total of 100 random samples collected equally from sheep and goat edible offal including liver, kidneys, lungs, tongue and masseter muscle (10 of each). Samples were collected from butcher shops at Zagazig city, Egypt during the period of July to December 2016. Sampled tissues for analysis were stored in plastic falcon tubes and placed in a cooler box. Samples in the box were stored at -20°C during transfer to the laboratory until sample preparation and analyses.

Sample preparation and extraction:-

Heavy-metal levels in examined tissues were measured according to the method described by (Finerty et al., 1990). In summary, 1 g of each sample was mixed with 10 mL 3:2 HNO₃ (65%v/v): HClO₄ (70%v/v). The mixture was allowed to digest overnight in the cold and later heated for 3 h in a water bath at 70°C with swirling at 30 min intervals to ensure complete digestion. After cooling, the digest was transferred into 20 mL standard flasks, rinsing with de-ionized water and made up to the mark. Prepared sample solutions were kept in acid-leached polyethylene bottles at room temperature until metal analyses.

Measurement of lead and cadmium concentrations:-

All reagents used were analytical grade and standard solutions of lead and cadmium were purchased from Merck, Darmstadt, Germany. Metals concentrations were measured using an atomic absorption spectrophotometer (PerkinElmer 2380), using hollow cathode lamps, equipped with air-acetylene flame, the level of lead (Pb) was measured at 217 nm, while that of cadmium (Cd) was measured at 228.8 nm. The accuracy of the analysis was checked by measuring IAEA-142/TM from IAEA's certified reference materials, Vienna, Austria (muscle homogenate). Mean recoveries ranged from 97 to 104 %. Recovered concentrations of the certified samples were

within 5 % of the certified values. The detection limits of Pb and Cd were 0.05 and 0.02 µg/g respectively. Samples were analyzed in triplicates.

Measurement of total mercury concentrations:-

Total mercury was measured directly by thermal decomposition, gold amalgamation, and atomic absorption spectrophotometry (Mercury Analyzer, MA-3000, Nippon Instruments Corporation, Tokyo, Japan) according to the method described by (Yabe et al., 2010). Analytical quality control was performed using the DOLT-4 (Dogfish liver, National Research Council of Canada, Ottawa, Canada) certified reference material and certified mercury standard solutions. Recovery rate (%) was acceptable as it recorded (92–103%), The detection limit of Hg was 2.0 pg of total Hg. Concentrations of Hg were expressed as ppm/wet weight.

Estimated daily intake (EDI):-

The EDI was calculated based on integration of data from analysis of heavy metals, meat consumption rates, and body weight of Egyptian adults.

EDI (µg/kg/day) for both lead and cadmium was obtained using the following equation described by the Human Health Evaluation Manual (US Environmental Protection Agency, EPA) (USEPA 2010):

$$EDI = \frac{C_m \times F_{IR}}{BW}$$

Where C_m is the concentration of the metal in the sample (mg/kg wet weight); F_{IR} is the food (meat) ingestion rate in Sharkia, Egypt, which was estimated at 89.4 g/day (FAO 2003); BW is the body weight of Egyptian adults, which was estimated at 70 kg.

Health risk Assessment:-

The (US EPA, 1989) quantitatively assesses human health risks in terms of non-cancer and cancer risks. This study aimed to quantify the non-cancer risk imposed on Sharkia, Egypt, by consumption of metal-contaminated offal. The risk assessment followed the guidelines recommended by the (US EPA, 2010). For non-carcinogenic effects, the EDI was compared with the recommended reference doses (RfD) (0.001 mg/kg/day for Cd and 0.004 mg/kg/day for Pb, 0.0005 mg/kg/day for Hg) (US EPA, 2010), as stated in the following equation:

$$\text{Hazard Ratio (HR)} = \frac{EDI}{RfD} \times 10^{-3}$$

The hazard ratios (HRs) can be summed to generate a hazard index (HI) to estimate the risk of mixed contaminants. HI was generated by using the following equation:

$$HI = \sum HR_i$$

Where i represent each metal

A HR and/or HI of >1 indicates that there is potential risk to human health, whereas a result of ≤1 indicates no risk of adverse health effects.

Reduction trial for heavy metal load in the livers:-

An experimental trial to reduce the heavy metal load in the sheep liver samples was performed. In this trial, from the same sheep liver, 6 pieces were divided each weighted 50 g, one sample was measured for heavy metal residual concentration without any further treatment and set as a control sample. The second piece was immersed in acetic acid 2% locally produced for 15 min, and then metal concentrations were measured. The third piece was boiled in hot water 100°C for 15 min, and then sample was left to cool and measured for residual heavy metal concentrations. The fourth sample was deep-fried in corn oil until well-done appearance (brown color, approximately 5 min), and then sample was left to cool and measured for residual heavy metal concentrations. The fifth sample was immersed in acetic acid 2% for 15 min, then was boiled in hot water 100°C for 15 min, then sample was left to cool, and then metal concentrations were measured. The sixth sample was immersed in acetic acid 2% for 15 min, and then was deep-fried in corn oil until well-done appearance, and then sample was left to cool and measured for residual heavy metal concentrations. This trial was repeated 5 times at different days and the results were recorded as mean ± SD percentage of metal load in treated samples and in the control samples, the percentage was set to be 100%.

Statistical Analysis:-

Statistical significance was evaluated using Tukey–Kramer honestly significant difference tests, with $p < 0.05$ considered as significant, in case of reduction experiments, statistical significance with the control was done using Dunnett's test (JMP program, SAS Institute, Cary, NC, USA).

Results and Discussion:-

Exposure of humans to heavy metals is very common worldwide either via ingestion of contaminated foods drinks or inhalation in heavy metal polluted areas (Darwish et al., 2016). In this study, we screened the residual concentrations of three toxic heavy metals (Pb, Cd and Hg) in the edible offal of sheep and goats. Estimation of health risk assessment was performed and a trial to reduce the concentrations of these metals was tested.

Residual concentrations of the tested heavy metals:-**Lead (Pb):-**

The results achieved in this study showed a clear contamination of the examined samples with lead. Liver had significantly the highest mean residual concentration of Pb (0.61 ± 0.06 ppm/wet weight) followed by kidney (0.49 ± 0.05 ppm/wet weight), tongue (0.34 ± 0.04 ppm/wet weight), lung (0.17 ± 0.03 ppm/wet weight) and finally masseter muscle (0.05 ± 0.005 ppm/wet weight) in the examined sheep samples (Figure 1). The recorded Pb residual concentrations in the goat offal was corresponding to that estimated in the sheep samples. As liver also had significantly the highest mean residual concentration of Pb (0.33 ± 0.06 ppm/wet weight). Kidney came second to the liver (0.20 ± 0.04 ppm/wet weight), followed by tongue (0.14 ± 0.01 ppm/wet weight), lung (0.07 ± 0.008 ppm/wet weight) and finally masseter muscle (0.03 ± 0.003 ppm/wet weight) in the examined goat samples (Figure 1). It notes worthy that sheep samples had significantly higher Pb residues compared with the goat (Figure 1). Levels of Pb in edible offal of sheep and goat from our study were corresponding to those reported by (Husain et al., 1996) from Kuwait and (Akoto et al., 2014) from Ghana. However, (Liu, 2003) reported higher Pb concentrations in the edible offal of the sheep, the residual concentrations of Pb in liver; kidney, lung, and muscle were 0.72, 0.96, 1.45 and 0.86 ppm, respectively. Furthermore, (Caggiano et al., 2005) recorded strongly higher concentrations of Pb from Italy (1.5, 2.0 and 1.6 ppm in liver, kidney and muscle of sheep). Additionally, (Swaileh et al., 2009) detected higher concentrations of Pb in the edible offal of sheep and goat collected from the West Bank, Palestinian authority (liver, 2.42 and 2.17; kidney, 3.02 and 3.49; lung 1.06 and 1.15; muscle 0.25 and 0.37 ppm in sheep and goat respectively).

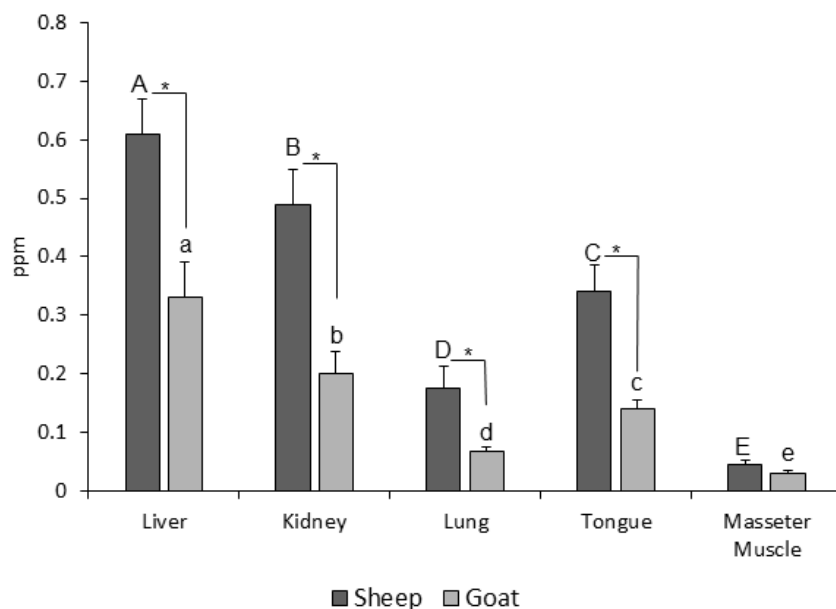


Figure 1:- Lead residual concentrations in the edible offal of the sheep and goat

The results were recorded as mean \pm SD (ppm/wet weight) of lead concentrations in offal samples ($n=10$ each from each species). Means carrying star marks are statistically significant between sheep and goat. Means carrying different large letter are statistically significant among edible offal of the sheep. Means carrying different small letter are statistically significant among edible offal of the goat. P value was set to be less than 0.05.

Cadmium (Cd):-

The results recorded in figure 2 showed the mean residual concentrations of Cd in the edible offal of sheep and goat. In sheep offal, kidney and liver had significantly the highest mean concentrations of Cd (0.14 ± 0.06 and 0.11 ± 0.01 ppm/wet weight, respectively), followed by lung and tongue (0.02 ± 0.009 and 0.01 ± 0.018 ppm/wet weight, respectively). Masseter muscle had the lowest mean residual concentrations of Cd (0.009 ± 0.001 ppm/wet weight) (Figure 2). Regarding Cd residues in goat offal, liver and kidney had significantly the highest mean concentrations of Cd (0.054 ± 0.004 and 0.057 ± 0.005 ppm/wet weight for both of them, respectively), followed by tongue, lung and finally masseter muscle, with mean residual concentrations of 0.018 ± 0.002 , 0.009 ± 0.001 and 0.001 ± 0.0002 ppm/wet weight, respectively (Figure 2). Results of (Liu, 2003) for Cd levels in the organs of sheep sampled from sites in China are clearly higher than those found in our study. The mean concentrations of Cd in liver in this study was low when compared to 0.33 ppm reported in Lahore (Mariam et al., 2004). Cd concentrations reported in our study were in agreement with that recorded in the liver, kidney and lung of sheep and goat reared in Ghana (Akoto et al., 2014); but higher than concentrations (0.009 and 0.006 mg/kg) in liver and kidney respectively of sheep from Kenya (Oyaro et al., 2007). Additionally, (Swaileh et al., 2009) recorded higher concentrations of Cd in the edible offal of sheep and goat collected from the West Bank, Palestinian authority.

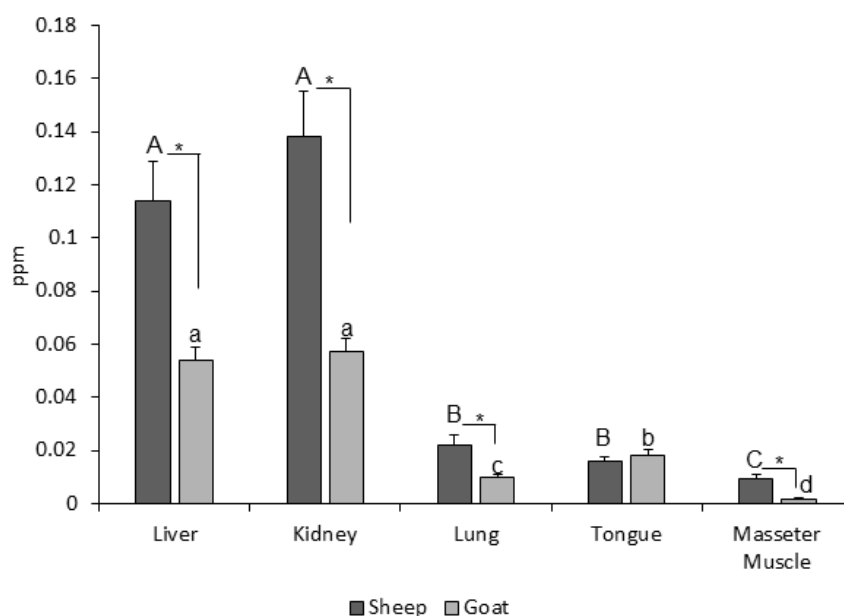


Figure 2:- Cadmium residual concentrations in the edible offal of the sheep and goat

The results were recorded as mean \pm SD (ppm/wet weight) of cadmium concentrations in offal samples ($n=10$ each from each species). Means carrying star marks are statistically significant between sheep and goat. Means carrying different large letter are statistically significant among edible offal of the sheep. Means carrying different small letter are statistically significant among edible offal of the goat. P value was set to be less than 0.05.

Mercury (Hg):-

Total mercury was analyzed in this study and the results were recorded in figure 3. In the examined sheep offal, liver and kidney had significantly the highest mean concentrations of Hg with mean concentrations of 0.077 ± 0.006 and 0.064 ± 0.007 ppm/wet weight, respectively, followed by lung and tongue with mean concentrations of 0.044 ± 0.003 and 0.031 ± 0.005 ppm/wet weight, respectively. Masseter muscle had the lowest residual concentration of Hg (0.007 ± 0.001 ppm/wet weight) (Figure 3). Total mercury residual concentrations in the goat offal had the same trend as that of the sheep as clear in figure 3. The recorded Hg residual concentrations in the goat liver, kidney, lung, tongue and masseter muscle were 0.069 ± 0.005 , 0.065 ± 0.007 , 0.043 ± 0.005 , 0.036 ± 0.003 and 0.020 ± 0.003 ppm/wet weight, respectively (Figure 3). Mercury concentrations in our study were corresponding to that recorded in free ranging sheep and goat in Ghana (Akoto et al., 2014).

Examined edible offal was ranked according to their capacity to concentrate different metals by calculating the total rank score (TRS) for each organ (Swaileh, 2009). The liver of both species were ranked the richest in metals, while masseter muscle was the least in their ability to concentrate metals in the two animal groups investigated (Figure 4).

According to the TRS, metal concentrations in the organs followed the order: liver > kidney > tongue > lung > masseter muscle. The liver and kidneys are target tissues for monitoring metal contamination in animals because both organs function in detoxification and excretion of toxic metals from the body and therefore end up accumulating them (Abou-Arab, 2001; Darwish et al., 2015).

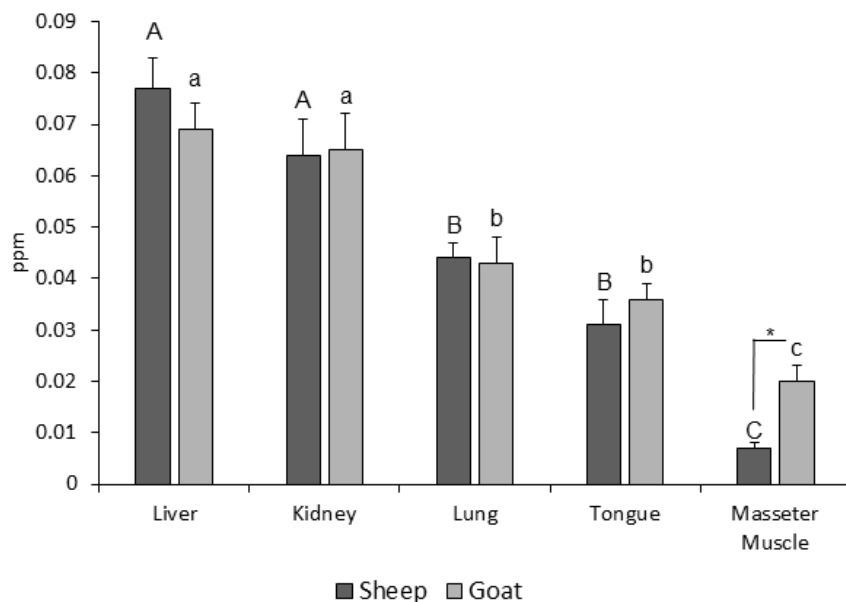


Figure 3:- Mercury residual concentrations in the edible offal of the sheep and goat.

The results were recorded as mean \pm SD (ppm/wet weight) of mercury concentrations in offal samples ($n=10$ each from each species). Means carrying star marks are statistically significant between sheep and goat. Means carrying different large letter are statistically significant among edible offal of the sheep. Means carrying different small letter are statistically significant among edible offal of the goat. P value was set to be less than 0.05.

Health risk assessment:-

One major task of food hygienist is to investigate the public health safety of meat and offal prior to introduction to consumers. Thus, health risk assessment for the examined metals in the edible offal was performed via comparison of the metal content in the offal with WHO/FAO maximum permissible limits (MPL), estimating estimated daily intake (EDI), hazard index (HI) and hazard ratio (HR).

The results reported in table 1 showed percentage of examined samples exceeding (FAO/WHO 2002) MPL, which were 0.1ppm in Pb, 0.05 ppm in Cd and 0.05 ppm in Hg. Pb content exceeded MPL in all examined liver and kidney samples; 90% of tongue and 40% of lung samples of the sheep. Regarding goat examined samples, 80%, 50%, 0% and 40% exceeded MPL in liver, kidney, lung and tongue samples respectively. All examined samples of liver and kidney of the sheep exceeded Cd MPL, but 40% and 50% of these samples exceeded MPL in the goat. None of the examined lung and tongue exceeded Cd MPL in both species under investigation. Regarding Hg concentrations, 90%, 50%, 10%, 10% of the examined sheep liver, kidney, lung and tongue samples exceeded WHO/FAO MPL. However, these percentages were 60%, 50%, 30% and 10% in goat liver, kidney, lung and tongue, respectively. None of the examined masseter muscle samples in either sheep or goat exceeded MPL of Pb, Cd and Hg (Table 1).

The recorded results in table 2 showed the EDI ($\mu\text{g}/\text{Kg Bwt}/\text{day}$) of the examined toxic metals due to consumption of sheep and goat offal. EDI values of Pb in sheep samples ranged from 0.058 to 2.120; 0.012 to 0.383 in cadmium, whereas EDI values for Hg ranged from 0.009 to 0.197. In case of goat samples, EDI values of Pb ranged from 0.039 to 0.979; 0.002 to 0.176 in cadmium, whereas EDI values for Hg ranged from 0.025 to 0.296 (Table 2).

Pb is encountered in many poisoning cases especially in children in many locations such as in Bagega community, Zamfara, Nigeria (Ajumobi et al., 2014); in Kabwe, Zambia (Yabe et al., 2014) and in Changchun, Jilin Province,

China (Xu et al., 2014). In our study, mean intakes of lead for both sheep and goat offal samples were within the tolerable levels established by (WHO, 2003) on the daily intake (3.6 µg/kg bw per day).

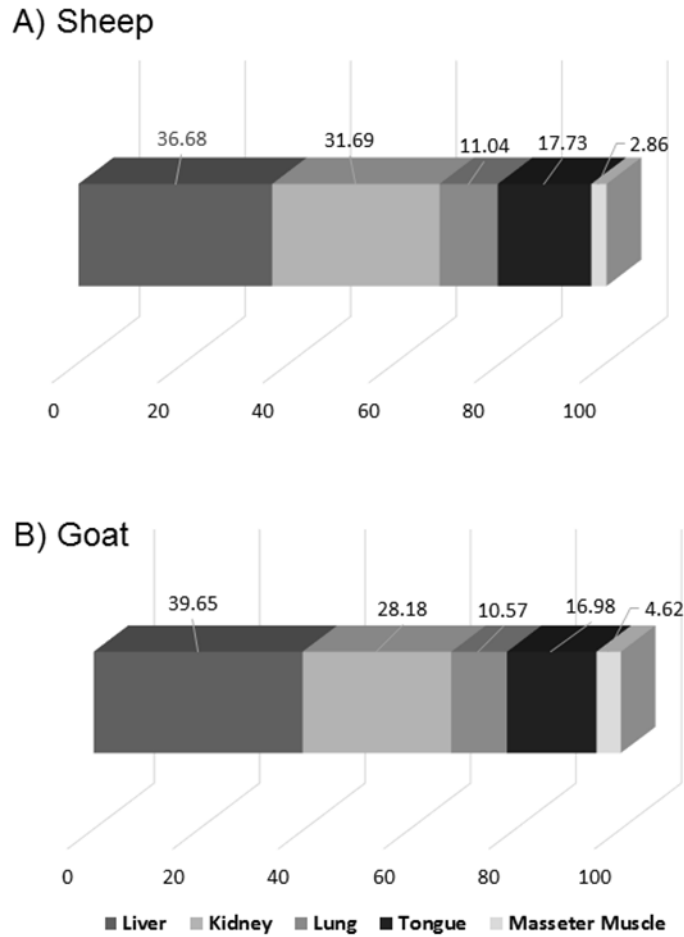


Figure 4:- Total Rank Score (TRS) of total heavy metal load in the different organs of sheep and goat

Table 1:- Percentage of sheep and goat samples exceeding maximum permissible limits of Pb, Cd and Hg set by WHO/FAO

	Pb (0.1ppm)		Cd (0.05ppm)		Hg (0.05ppm)	
	Sheep	Goat	Sheep	Goat	Sheep	Goat
Liver	100	80	100	40	90	60
Kidney	100	50	100	50	50	50
Lung	40	0	0	0	10	30
Tongue	90	40	0	0	10	10
Masseter Muscle	0	0	0	0	0	0

In 2009, the European Food Safety Authority (EFSA, 2009) published its scientific perspective on cadmium in food, and established a revised TWI for cadmium of 2.5 µg/kg bw (equivalent to 0.36 µg/kg bw per day). Our results showed that the estimated daily intakes of Cd due to consumption of one or even all examined offal in either sheep or goat were within the TWI determined by EFSA. The mean dietary exposure across European countries was estimated to be 2.3 µg/kg bw per week, with high-level exposure estimated to be 3.0 µg/kg bw per week. Although

adverse effects on kidney function are unlikely to occur at exposures twofold greater than the TWI, the EFSA concluded that exposure to cadmium at the population level should be reduced. Consideration of the recent TWI values for Cd clearly indicates that the excessive consumption of offal may pose a public health risk.

Mercury and its compounds are highly toxic. Acute health effects reported include kidney failure following exposure to high concentrations of inorganic mercury. Allergic skin reactions were also reported following contact with mercury. Mercury vapor causes erosive bronchitis and bronchiolitis with interstitial pneumonia. These symptoms may be combined with signs caused by effects on the CNS, such as tremor or increased excitability. Workers acutely exposed to mercury exhibited chest pain, dyspnea, cough, haemoptysis and evidence of interstitial pneumonitis (FAO/WHO, 2002). At the request of the European Commission, EFSA's Scientific Panel on Contaminants in the Food Chain (CONTAM Panel) considered new scientific information regarding the toxicity of inorganic form of the mercury and evaluated provisional TWIs established in 2003 and 2010 by the Joint FAO/WHO Expert Committee on Food Additives (JECFA). In its opinion, the CONTAM Panel has established a TWI for inorganic mercury of 4 µg/kg body weight (bw) which is in line with JECFA (EFSA, 2012). It is clear from our results reported in table 2, that EDI of mercury due to consumption of the edible offal of sheep and goat lies within the recommended levels by (EFSA, 2012).

Table 2:- Estimated Daily intake (µg/kg Bwt/day) of Pb, Cd and Hg due to consumption of edible offal of sheep and goats

	Pb		Cd		Hg	
	Sheep	Goat	Sheep	Goat	Sheep	Goat
Liver	0.779	0.421	0.146	0.068	0.098	0.088
Kidney	0.626	0.255	0.176	0.071	0.081	0.083
Lung	0.223	0.086	0.028	0.012	0.004	0.054
Tongue	0.434	0.178	0.021	0.023	0.005	0.046
Masseter Muscle	0.058	0.039	0.012	0.002	0.009	0.025
Sum	2.12	0.979	0.383	0.176	0.197	0.296

HR and HI values did not exceed 1 for Pb, Cd and Hg in all examined offal (Table 3). The HR values recorded in our study were lower than (Min *et al.*, 2012), who recorded a hazard ratio for lead as 1.24 and for cadmium as 1.27 and suggested that high blood lead and cadmium levels in human body may be associated with balance and vestibular dysfunction in a general sample of U. S. adults. Unlikely, lower values were reported by (Yu *et al.*, 2014), who recorded 0.58 and 0.28 as HI for children and adults exposed to the toxic metals (arsenic, cadmium, copper, chromium and lead) in the urban street dust of Tianjin, China.

The HR and HI for mean levels of Pb, Cd and Hg were <1; however, the consumption of high levels of these toxic metals may pose a public health hazard. These findings imply that some consumers in Zagazig city, Egypt may be exposed to high concentrations of these toxic metals in offal of backyard sheep and goat, which are allowed to roam and scavenge for food to reduce the cost of production and provide an inexpensive source of protein.

Table 3:- Hazard ratio (HR) and hazard index (HI) of Pb, Cd and Hg due to consumption of edible offal of sheep and goats

	Sheep				Goat			
	Pb	HR	Hg	HI	Pb	HR	Hg	HI
		Cd				Cd		
Liver	0.195	0.146	0.197	0.538	0.105	0.068	0.176	0.349
Kidney	0.156	0.176	0.112	0.444	0.064	0.073	0.166	0.303
Lung	0.056	0.028	0.019	0.103	0.022	0.013	0.109	0.144
Tongue	0.109	0.02	0.163	0.292	0.045	0.022	0.092	0.159
Masseter Muscle	0.015	0.012	0.04	0.067	0.009	0.002	0.051	0.062
HI	0.531	0.382	0.531	1.444	0.245	0.178	0.594	1.017

A trial to investigate the effect of some cooking methods or acetic acid immersion on reduction of the toxic metal load was performed. The achieved results recorded in figure 5 showed that a combination of either boiling or frying with immersion in acetic acid 2% achieved significant reductions in the metal load in the liver samples compared

with immersion in the acid only. In particular, a clear reduction in Hg concentrations especially after immersion in acetic acid 2% followed by frying and boiling achieving reduction percentages of 90% and 75% respectively. In parallel, Pb concentrations were significantly reduced using the same treatments achieving 50% and 45% reduction, while Cd was the least in the reduction with 43% and 40% after immersion in acetic acid 2% followed by frying and boiling respectively (Figure 5). It notes worthy that the reduction percentages achieved in this study were corresponding to (Atta et al., 1997) who found that copper, lead, cadmium and zinc residual concentrations were significantly reduced in *Tilapia nilotica* on baking and steaming. Furthermore, (Ersoy et al., 2006) observed a clear reduction in the Pb residual concentration after microwaving of sea bass filets. Additionally, (Perello et al., 2008) found that Hg and Pb concentrations were lower in the raw meat samples compared with the cooked ones. The reduction was dependent on cooking conditions like time, temperature and method of cooking. In conclusion, we highly recommend reduction of our daily consumption of offal and advice consumers with immersion of offal in acetic acid 2% followed by efficient cooking in order to reduce the metal load in the offal.

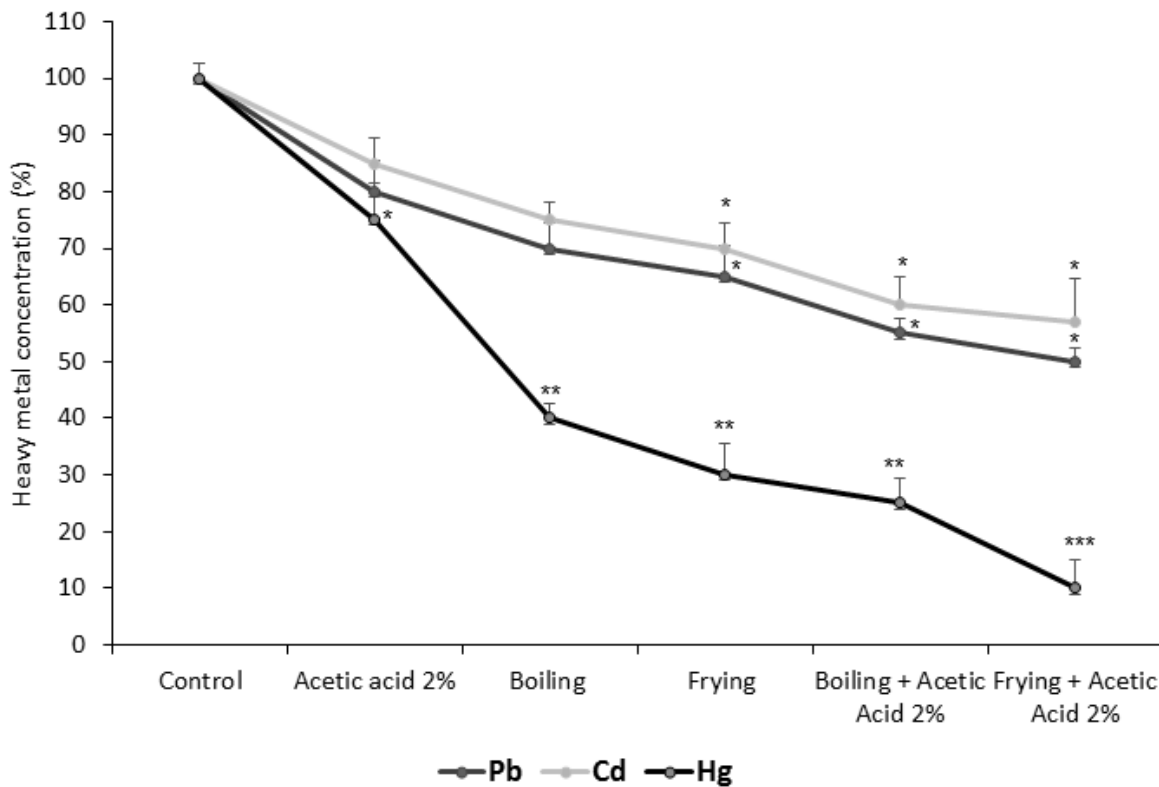


Figure 5:- Reduction of heavy metal concentration in the liver of the sheep using acetic acid 2% and heat treatments

The reduction trials were repeated 5 times at different days and the results were recorded as mean \pm SD percentage of metal load in treated samples and in the control samples, the percentage was set to be 100%. Means carrying star marks are statistically significant with the control at $P < 0.05$.

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The authors financially supported this study

Conflict of interest:

The authors declare that there is no conflict of interest

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