Veterinaria Italiana, 2011, **47** (3), 351-361

Heavy metal residues in beef carcasses in Beni-Suef abattoir, Egypt

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Summary

A total of 300 samples were collected from cattle slaughtered in the Beni-Suef abattoir in Egypt. Samples included muscle, liver and kidney. Animals were randomly selected from the slaughter line. The age of the slaughtered cattle was less than three years (18-30 months). Samples were packed separately in plastic bags, identified and stored at –18°C until analysis which was performed at the Max Rubner Institute in Kulmbach, Germany, for the following heavy metals residues: lead, cadmium, mercury, arsenic, chromium and nickel in beef muscle, liver and kidney samples. The results revealed that the overall mean residual levels of lead were 8.77 µg/kg, 42.70 µg/kg and 109.42 µg/kg fresh weight in muscle, liver and kidney samples, respectively, while the mean residual levels of cadmium were 1.40 µg/kg, 14.16 µg/kg and 62.56 µg/kg fresh weight, respectively, and the mean arsenic residual levels were 5.06 µg/kg, 4.64 µg/kg and 14.92 µg/kg fresh weight, respectively. The mean residual levels of mercury were 3.91 µg/kg, 5.81 µg/kg and 10.14 µg/kg fresh weight, respectively, and the residual levels of chromium were 11.20 µg/kg, 21.85 µg/kg and 25.49 µg/kg fresh weight, respectively. Finally, the mean residual levels of nickel were 21.17 µg/kg, 14.59 µg/kg and 34.95 µg/kg fresh weight, respectively. The mean values of all heavy metals examined were low and did not exceed the permissible limits adopted by different organisations. Most heavy metals accumulated in higher concentrations in the kidney in comparison to the liver and muscle.

Keywords

Arsenic, Beef, Cadmium, Egypt, Heavy metal, Kidney, Lead, Liver, Mercury, Nickel.

Residui di metalli pesanti in carcasse di bovino nel mattatoio di Beni-Suef in Egitto

Riassunto

Sono stati prelevati 300 campioni da animali macellati nel mattatoio di Beni-Suef in Egitto. Sono stati prelevati campioni di tessuto muscolare, epatico e renale. Gli animali macellati sono risultati di età inferiore a 3 anni (18-30 mesi). I campioni sono stati riposti in sacchetti di plastica distinti, identificati e conservati alla temperatura di –18°C fino al momento dell'analisi, eseguita all'Istituto Max Rubbner di Kulmbach, Germania. La ricerca ha avuto l'obiettivo di verificare la presenza di residui dei seguenti metalli pesanti: piombo, cadmio, arsenico, mercurio, cromo e nickel. Rispetto al peso fresco dei campioni, i risultati hanno evidenziato i seguenti livelli residuali medi relativi: piombo 8,77 µg/kg, 42,70 µg/kg e 109,42 µg/kg, cadmio 1,40 µg/kg, 14,16 µg/kg e 62,56 µg/kg arsenico 5,06 µg/kg, 4,64 µg/kg e 14,92 µg/kg, mercurio 3,91 µg/kg, 5,81 µg/kg e 10,14 µg/kg, cromo 11,20 µg/kg, 21,85 µg/kg e 25,49 µg/kg, nickel 21,17 µg/kg, 14,59 µg/kg e 34,95 µg/kg. Tutti i metalli pesanti ricercati sono risultati presenti in concentrazioni medie basse, inferiori ai limiti accettabili previsti da diverse organizzazioni. La

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maggior parte di essi è risultata presente in concentrazioni più elevate nel rene rispetto a fegato e tessuto muscolare.

Parole chiave
Arsenico, Bovini, Cadmio, Cromo, Egitto, Fegato, Mercurio, Metalli pesanti, Nickel, Piombo, Rene.

Introduction

Meat and meat products form an important part of the human diet as well as an important source of a wide range of nutrients, but they may also carry certain toxic substances.

Although the level of these toxic substances in muscle is generally low, offal, such as liver and kidney, showed higher concentrations of toxic substances than most other foods.

One of the most important aspects of environmental pollution for humans is the intake of toxic substances in the diet. Since this should be limited to an unavoidable minimum, great attention is paid to the presence of these substances in food. Monitoring programmes have been conducted in many countries with the purpose of avoiding foodstuffs that could pose a risk to human health if consumed (34).

In last few decades, advances in analytical techniques have opened a new window in the understanding of the role of a large number of toxic substances in the biological processes that occur in the human body. Human exposure to these substances mainly takes place through the diet (4). It is well known that the intake of food contaminated with chemicals can lead to episodes of intoxication that can be described as acute or, when the disease appears after a latent period of time, a long-term intoxication. Chemicals that produce the latter tend to accumulate in the body over extended periods of time, producing illness when the levels reach critical values in certain tissues (9).

Toxic substances in beef tissues can be caused by a variety of sources, including animal drugs, pesticides, feed and other agricultural or industrial chemicals (42).

All heavy metals are toxic at certain levels of intake. However, in contrast to elements such as chromium and nickel that have useful biological functions, lead, mercury, cadmium and arsenic as far as we know play no useful role and pose a risk for both animal and human health. This is because they are transferred through the food chain and tend to accumulate in animal tissues, mainly in the liver and kidney (37).

The major sources of heavy metal pollution are processes, such as smelting of non-ferrous ores, waste incineration and the disposal of sewage sludge onto land that releases toxic metals into the environment resulting in enhanced levels of lead, mercury, cadmium and arsenic (5). Therefore, the aim of this study was the determination of certain chemical contaminants in meat, liver, kidney and fat from slaughtered carcasses of native cattle in the Beni-Suef Governorate. These contaminants included heavy metals, such as lead, cadmium, mercury, arsenic, chromium and nickel in meat, liver and kidney samples.

Materials and methods

Sample collection

A total of 300 samples were collected from cattle slaughtered at the Beni-Suef abattoir. The samples included muscle, liver and kidney. Animals were selected randomly from the slaughter line. The age of the slaughtered cattle was generally less than three years (18-30 months). Samples were packed separately in plastic bags, identified and stored at –18°C until analysis.

Estimation of heavy metals

Sample preparation

Homogenisation

The collected samples were homogenised using a laboratory mixer (Büchi, model B-400, Flawil) as described below.

Visible fat was removed from the samples. Samples were homogenised separately for about 20 sec. The mixer was originally equipped with a stainless-steel blade which implies the possibility of contamination of samples with chromium and nickel. Therefore, a special blade of pure titanium was constructed and used to grind the samples.

Wet digestion (microwave digestion method)

The use of microwave heating to solubilise samples, combined with multi-element analysis by inductively coupled plasma-mass spectroscopy (ICP-MS) enabled rapid sample throughput with a minimum risk of sample contamination and elevated blanks. Diluted nitric acid is very compatible with ICP-MS, giving rise to little interference from other acids and has no detrimental effect on glassware and sampling. The procedure of wet digestion was applied according to the technique recommended by the *Agence française de normalisation* (AFNOR) (1) as follows: samples were digested (wet digestion) with nitric acid (HNO_3 65%) under pressure in a closed vessel heated by microwave (Perkin Elmer/Paar Physica Multiwave 2 900W) and each sample analysed was heated according to the digestion programme (milk tetrafluorine methoxil [TFM]). After completion of microwave digestion, sample solutions were cooled to room temperature at maximum cooling capacity and made up to 25 ml with double deionised water after which a blank digest was performed in the same way. The diluted digests were directly measured by ICP-MS.

Analytical procedures

The residual levels of examined metals were determined using the ICP-MS (Agilent 7500 C, ICP-MS, Octopole Reaction System, Tokyo) as recommended by AFNOR (1). A multi-element internal calibration graph was based on the use of multiple reference standards, prepared at levels ranging from 10 µg/l to 50 µg/l, according to element relative sensitivity factors. The instrumental conditions used for the measurement of heavy metals were as follows:

The ICP-MS operating conditions were as follows:

- radiofrequency power: 1 590 W
- sample depth: 8.0 mm
- carrier gas:1.181/min
- nebuliser pump: 0.1 rps
- extract lens: 3.6V.

The isotopes monitored as internal standards were as follows:

- chromium (Cr52)
- nickel (Ni60)
- arsenic (As75)
- cadmium (Cd111)
- mercury (Hg202)
- lead (Pb206,208)
- indium (In115)
- gallium(Ga72).

For multi-element determinations, multi-element standards were prepared, covering the range of concentrations expected for each analyte (additional standard).

On account of the mass interference of Cr52 with Ar40 and C12, the collision cell technique was used for Cr with typical parameters, as follows:

- cell entrance: 19V
- cell exit: 18V
- quadrupole bias: 10V
- octopole bias: 11.6V
- plate bias: 44V:44V
- He gas flow: 5.5 ml/min.

Metal concentrations were calculated in the test sample in accordance with the following formula:

$$C = \frac{(a-b)df \times 25}{m}$$

where:

- C = concentration in the test sample (µg/kg)
- a = concentration in the test solutions (µg/l)
- b = mean concentration in the blank solutions (µg/l)
- df = dilution factor
- m = weight of the test portion (g).

Results and discussion

Lead

The data obtained in Table I shows that none of the muscle samples examined exceeded the limit set by the Egyptian Organisation for Standardisation (EOS) (12) which stipulates that the permissible limit of lead should not exceed 0.1 mg/kg (ppm) in beef muscle. Similar values were detected by Jorhem *et al.* (26), Jorhem and Sundstrom (27), Jorhem *et al.* (28), Miranda *et al.* (37), Niemi *et al.* (40) and Tahvonen and Kumpulainen (48).

Table I
Residual level of lead (µg/kg fresh weight) in muscle, liver and kidney of slaughtered cattle

Tissue	No. of samples	No. of samples <LOD	Minimum	Maximum	Mean	± SE
Muscle	100	7	ND	35.60	8.77	0.76
Liver	100	2	ND	196.65	42.70	4.39
Kidney	100	1	ND	464.80	109.42	10.68

LOD limit of detection
SE standard error
ND non detected equal to LOD

Elevated levels were recorded by Amodio-Cocchieri and Fiore (2), Falandysz (16), Iwegbue (24), Doganoc (11) and Mariam *et al.* (36). None of liver and kidney samples examined exceeded the permissible limit (0.5 ppm) set by the EOS (12). These results were similar to those recorded by Jorhem *et al.* (26) and Stabel-Taucher *et al.* (47). The residual level of lead in kidney samples was significantly (p<0.01) higher (109.42 µg/kg fresh weight) than in liver (42.70 µg/kg fresh weight) and muscle (8.77 µg/kg fresh weight) samples (Table II). Therefore, the kidney is considered to be the target organ for lead accumulation. Lead is frequently the cause of accidental poisoning in domestic animals, especially cattle. Absorbed lead is stored mainly in the liver and kidneys and, like arsenic and cadmium, accumulates in tissues of animals (6).

Lead is a widespread environmental contaminant that is caused by largely airborne sources, such as industrial emissions and the combustion of fuel containing lead additives. The fallout from these sources is a particular problem for grazing animals (22). The low lead findings in the present study are possibly due to the remarkable reduction in national as well as international lead emission from automobiles. This confirms the report by Erivo *et al.* (14). However, Jorhem *et al.* (28) stated that lead levels in meat tissues had been considerably reduced (several orders of magnitude) in recent decades. This reduction can be probably attributed to some degree to the increased awareness of lead as a health problem and, consequently, for example, the gradually reduction of use of leaded fuel in many countries. However, the main reason for this radical decrease is most likely a result of an improvement in the methodology (instrumentation) and, above all, the introduction of quality assurance measures, such as the use of certified reference materials (CRMs). Moreover, the European Commission (15) suspected that the reduction in lead levels in animal tissues over the past decade can be attributed to improvements in chemical analysis quality assurance measures.

From the data collected in our study, it was concluded that the mean and maximum

Table II
Comparison between means of residual levels (µg/kg fresh weight) of heavy metals in muscle, liver and kidney samples examined

Criteria	Muscle	Liver	Kidney
Lead	$8.77 \pm 0.76^{(z)}$	$42.70 \pm 4.39^{(y)}$	$109.42 \pm 10.68^{(x)}$
Cadmium	$1.40 \pm 0.22^{(z)}$	$14.16 \pm 0.72^{(y)}$	$62.56 \pm 4.28^{(x)}$
Arsenic	$5.06 \pm 0.46^{(y)}$	$4.64 \pm 0.40^{(y)}$	$14.92 \pm 1.70^{(x)}$
Mercury	$3.91 \pm 1.07^{(y)}$	$5.81 \pm 0.68^{(y)}$	$10.14 \pm 0.58^{(x)}$
Nickel	$21.17 \pm 1.78^{(b)}$	$14.59 \pm 1.16^{(c)}$	$34.95 \pm 2.96^{(a)}$
Chromium	$11.20 \pm 0.76^{(b)}$	$21.85 \pm 2.24^{(a)}$	$25.49 \pm 2.51^{(a)}$

a, b, c superscripts within rows indicate significant difference at p<0.05
x, y, z superscripts within rows indicate significant difference at p<0.01

concentrations of lead found in bovine muscles and organs could be considered to be low from a public health point of view.

Cadmium

The results given in Table III illustrate that the residual level of cadmium in muscle samples ranged from a non-detectable level to 17.78 µg/kg fresh weight with a mean value of 1.40±0.22. None of the muscle samples examined exceeded the permissible limit (0.5 ppm) recommended by the Food and Agriculture Organization (FAO)/World Health Organization (WHO) (20). Similar findings were detected by Jorhem *et al.* (26), Kramer *et al.* (32), López-Alonso *et al.* (35), Niemi *et al.* (40) and Vos *et al.* (51).

The residual levels of cadmium in liver samples ranged from 4.46 µg/kg to 41.85 µg/kg fresh weight with a mean value of 14.16 ± 0.72 (Table III). None of the liver samples examined exceeded the permissible limit (0.5 ppm) recommended by the FAO/WHO (20). High levels have been recorded by Antoniou *et al.* (3), Jorhem *et al.* (26), Kramer *et al.* (32), López-Alonso *et al.* (34, 35) and Niemi *et al.* (40).

It can be concluded from the data presented in Table III that the residual level of cadmium in kidney samples ranged from 16.92 µg/kg to 280.75 µg/kg fresh weight, with a mean value of 62.56 µg/kg fresh weight. None of the kidney samples examined exceeded the permissible limit (1.0 ppm) recommended by the FAO/WHO (20).

Cadmium is recognised as being one of the most toxic elements to humans and animals. It predominantly accumulates in the kidney, bound to metallothionein, and has a biological half-life of over 10 years. Excessive long-term cadmium exposure may produce irreversible adverse renal effects as reported by the WHO (53, 54, 55).

Cadmium is used in, and is a waste by-product of, many industrial processes; it is also a contaminant in sulphur-phosphate fertilizers. This widespread distribution, combined with industrial fallout, has resulted in feedstuffs being a major source of cadmium for domestic animals. This view is clearly explained by Kostial (30).

In this respect, Ryan *et al.* (44) stated that considerable amounts of cadmium are deposited on agricultural lands and gardens each year through the application of phosphate fertilizers and sewage sludge.

Low cadmium levels in the samples examined may be due to lower cadmium concentrations in fertilizers as well as an improvement in public waste management and manufacturing which may have resulted in a reduction of cadmium emission into the environment, as described by Niemi *et al.* (40).

On the other hand, Fitzgerald *et al.* (17) reported that cattle allowed to graze on pastures treated with anaerobically digested sludge did not demonstrate any health problems. However, feeding on such forage could lead to high cadmium levels in the liver and kidneys which would make these organs unsuitable for human consumption.

The high residual level of cadmium in kidney tissue may be caused by the detoxification function of the organ in which this metal accumulates, thus confirming the hypothesis reported by Antoniou *et al.* (3). However, Husain *et al.* (23) stated that high concentrations of cadmium in the kidney was

Table III
Residual level of cadmium (µg/kg fresh weight) in muscle, liver and kidney of slaughtered cattle

Tissue	No. of samples	No. of samples <LOD	Minimum	Maximum	Mean	± SE
Muscle	100	9	ND	17.78	1.40	0.22
Liver	100	0	4.46	41.85	14.16	0.72
Kidney	100	0	16.92	280.75	62.56	4.28

LOD limit of detection
SE standard error
ND non detected equal to LOD

largely due to the result of binding of cadmium to sulfhydryl groups in the protein metallothionein the kidneys and liver.

In this respect, Hecht (21) suggested that the cadmium content of the kidney increased with the increasing age of the animal and in relation to the concentrations of cadmium in feed. In regard to cadmium concentrations in muscle samples, Kreuzer *et al.* (33) stated that muscle tissue contained only small amounts of cadmium, whereas kidneys accommodated 4-5 times more.

From the data we collected, it was concluded that the residual levels of cadmium in muscle, liver and kidney samples were low from a public health point of view.

Arsenic

The results obtained in Table IV show that the residual level of arsenic in muscle samples ranged from 1.85 µg/kg to 26.77 µg/kg fresh weight with a mean value of 5.06 µg/kg fresh weight.

Similar results were recorded by, López-Alonso *et al.* (34, 35), Miranda *et al.* (37) and Vos *et al.* (51). High arsenic levels were recorded by Jorhem *et al.* (26), Kramer *et al.* (32) and Mariam *et al.* (36). In addition, data showed that the residual level of arsenic in liver samples ranged from 1.20 µg/kg to 26.36 µg/kg fresh weight, with a mean value of 4.64 µg/kg fresh weight.

High figures were recorded by Vos *et al.* (51). The arsenic residual level in the kidney samples examined ranged from a non-detectable level to 113.00 µg/kg fresh weight with a mean value of 14.92 µg/kg fresh weight. Similar results were detected by Jorhem *et al.* (26) and Kludge-Berge *et al.* (29). None of the muscle, liver and kidney samples examined exceeded the permissible limit (1 ppm) (38). The results given in Table II show that the residual level of arsenic in kidney samples (14.92 µg/kg fresh weight) was significantly (p<0.01) high in comparison to the level recorded in liver (4.64 µg/kg fresh weight) and muscle (5.06 µg/kg fresh weight) samples. The principal sources of arsenic compounds are the arsenical pesticides, smelters and coal-fired power plants. Smelting of non-ferrous metals and the production of energy from fossil fuel are the two major industrial processes that lead to arsenic contamination of the air, water and soil (8). Arsenic accumulation in meat is very low and the principal tissues involved in accumulation were the kidneys and liver as confirmed by Miranda *et al.* (37).

In this respect, Vreman *et al.* (52) reported that arsenic is an accumulative poison which is mainly stored in the kidney, liver, skin and hair. Arsenic concentrations in animal tissues are usually related to the arsenic level in the diet. High residual levels of arsenic in liver, kidney and lean meat are indicative of arsenic pollution in the environment which may be due to copper smelting, coal combustion, burning of firewood and cow dung (7).

From our data, it was concluded that the residual levels of arsenic in all samples examined remained within the permissible levels; this may be attributed to the fact that these samples were collected from unaffected animals reared in unpolluted areas.

Mercury

It can be observed from Table V that residual levels of mercury in muscle samples ranged from a non-detected level to 80.80 µg/kg fresh weight, with a mean value of 3.91 µg/kg fresh weight. Similar results were reported by

Table IV
Residual level of arsenic (µg/kg fresh weight) in muscle, liver and kidney of slaughtered cattle

Tissue	No. of samples	No. of samples <LOD	Minimum	Maximum	Mean	± SE
Muscle	100	0	1.85	26.77	5.06	0.46
Liver	100	0	1.20	26.36	4.64	0.40
Kidney	100	3	ND	113.00	14.92	1.70

LOD limit of detection
SE standard error
ND non detected equal to LOD

Table V
Residual level of mercury (µg/kg fresh weight) in muscle, liver and kidney of slaughtered cattle

Tissue	No. of samples	No. of samples <LOD	Minimum	Maximum	Mean	± SE
Muscle	100	1	ND	80.80	3.91	1.07
Liver	100	0	0.67	45.72	5.81	0.68
Kidney	100	0	2.51	26.29	10.14	0.58

LOD limit of detection
SE standard error
ND non detected equal to LOD

Jorhem *et al.* (26) and Kottferova and Korenekova (31).

High figures were obtained by Kramer *et al.* (32) and Niemi *et al.* (40), whilst Miranda *et al.* (37) and Vos *et al.* (51) observed low levels.

Table V shows that the residual level of mercury in liver samples ranged from 0.67 µg/kg to 45.72 µg/kg fresh weight with a mean value of 5.81 µg/kg fresh weight. Similar results were recorded by Falandysz (16), Jorhem *et al.* (26) and Vos *et al.* (51). Elevated figures were recorded by Kramer *et al.* (32), Niemi *et al.* (40) and Salisbury *et al.* (45), whereas Miranda *et al.* (37) observed low levels.

Furthermore, the residual level of mercury in kidney samples ranged from 2.51 µg/kg to 26.29 µg/kg fresh weight with a mean value of 10.14 µg/kg fresh weight. Almost similar results were recorded by Vos *et al.* (51). Elevated levels were recorded by Niemi *et al.* (40). A significantly (p<0.01) higher level of residual mercury was detected in kidney samples (10.14 µg/kg fresh weight) than in liver (5.8 µg/kg fresh weight) and muscle (3.91 µg/kg fresh weight) samples (Table II).

High levels of mercury in kidney samples may be attributed to the fact that mercury preferentially accumulates in kidneys while the accumulation in liver and muscle was lower. This may be because mercury does not induct metallothionein in the liver and consequently there is no appreciable bioaccumulation in this organ, as reported by Kludge-Berge *et al.* (29).

The major agricultural sources of mercury for domestic animals are organo-mercurial fungicides, treated seed grains and fish meal used in feed (43). Mariam *et al.* (36) concluded that the major sources of mercury were geothermal steam used for power production, the paper, chemical and paint industries, pesticides and fungicides. From the present data, residual levels of mercury were considered low in all samples examined.

This result may be attributed to the strict controls of the use of organo-mercurials in agriculture which has reduced the possibility of exposure of food-producing animals to mercury. This concurs with the observations of Salisbury *et al.* (45).

Nickel

The results presented in Table VI reveal that the residual level of nickel in muscle samples examined ranged from 1.35 µg/kg to 90.27 µg/kg fresh weight with a mean value of 21.17 µg/kg fresh weight.

Similar results were reported by Flyvholm *et al.* in muscle samples (19). Elevated levels were recorded by Smart and Sherlock (46) and Onianwa *et al.* (41), while low levels were observed by Jorhem *et al.* (25). The residual level of nickel in liver samples ranged from non-detectable to 42.46 µg/kg fresh weight, with a mean value of 14.59 µg/kg fresh weight (Table VI).

Elevated levels were recorded in liver samples by Flanjak and Lee (18), Iwegbue (24), Flyvholm *et al.* (19), Onianwa *et al.* (41) and Smart and Sherlock (46), while low results were reported by Jorhem *et al.* (25).

The results presented in Table VI indicate that the nickel residual levels in kidney samples ranged from the non-detected level to 143.85 µg/kg fresh weight, with a mean value

Table VI
Residual level of nickel (µg/kg fresh weight) in muscle, liver and kidney of slaughtered cattle

Tissue	No. of samples	No. of samples <LOD	Minimum	Maximum	Mean	± SE
Muscle	100	0	1.35	90.27	21.17	1.78
Liver	100	2	ND	42.46	14.59	1.16
Kidney	100	4	ND	143.85	34.95	2.96

LOD limit of detection
SE standard error
ND non detected equal to LOD

of 34.95 µg/kg fresh weight. High levels were obtained by Flanjak and Lee (18), Iwegbue (24) Flyvholm *et al.* (19), Onianwa *et al.* (41) and Smart and Sherlock (46) To the contrary, low levels were reported by Jorhem and Sundstrom (27) and Jorhem *et al.* (25).

A low residual level ($p<0.05$) of nickel was obtained in muscle (21.17 µg/kg fresh weight) and liver (14.59 µg/kg fresh weight) samples in comparison to kidney (34.95 µg/kg fresh weight) samples as illustrated in Table II.

Nickel is possibly an essential metal for experimental animals. In addition, it may be beneficial as an activator for some enzyme systems. This agrees with the report by Underwood (50). On the other hand, the EOS has stated that high levels of dietary nickel may contribute to outbreaks of nickel allergy (13). Moreover, nickel accumulates in the lungs and may cause bronchial haemorrhage or collapse. This supports the view recorded by Nielsen (39).

From the present results, it was concluded that, in general, the level of nickel in all examined samples were extremely low. This confirmed the results of Ellen *et al.* (13) who stated that exposure to nickel by consumption of animal organs appears to be only marginal in comparison with other foods.

Chromium

Table VII shows that the residual level of chromium in the muscle samples examined ranged from 1.05 µg/kg to 47.95 µg/kg fresh weight with a mean value of 11.20 µg/kg fresh weight. Similar results were recorded by Jorhem and Sundstrom (27) and Jorhem *et al.* (25). High levels were recorded by Kreuzer *et al.* (37), whereas low levels were obtained by Jorhem *et al.* (28).

The chromium residual levels in the liver samples examined ranged from 1.96 µg/kg to 112.85 µg/kg fresh weight with a mean value of 21.85 µg/kg fresh weight (Table VII).

High results were reported by Flanjak and Lee (18), Iwegbue (24) and Kreuzer *et al.* (37), while low results were recorded by Jorhem and Sundstrom (27), Jorhem *et al.* (25) and Kramer *et al.* (32).

From the data obtained (Table VII), it was found that the chromium residual level in kidney samples ranged from 2.60 µg/kg to 143.62 µg/kg fresh weight with a mean value of 25.49 µg/kg fresh weight. High levels were recorded by Flanjak and Lee (18); Iwegbue (24) and Kreuzer *et al.* (37). On the contrary, low levels were obtained by Ellen *et al.* (13) Jorhem and Sundstrom (27) and Jorhem *et al.* (25).

Table VII
Residual level of chromium (µg/kg fresh weight) in muscle, liver and kidney of slaughtered cattle

Tissue	No. of samples	No. of samples <LOD	Minimum	Maximum	Mean	± SE
Muscle	100	0	1.05	47.95	11.20	0.76
Liver	100	0	1.96	112.85	21.85	2.24
Kidney	100	0	2.60	143.62	25.49	2.51

LOD limit of detection
SE standard error

The results presented in Table II conclude that muscle samples have a significantly (p<0.05) lower (11.20 µg/kg fresh weight) residual level of chromium than liver (21.85 µg/kg fresh weight) and kidney (25.49 µg/kg fresh weight) samples.

Chromium is an essential mineral for humans and has been related to carbohydrate, lipid and protein metabolism as explained by Tuzen and Soylak (49). In this respect, Demirezen and Urue (10) stated that chromium (III) is an essential element that helps the body to use sugar, protein and fat.

The chromium results obtained indicated that muscle, liver and kidney samples examined contained extremely low concentrations of chromium, thus confirming the view of very low environmental and feed pollution.

From the data we obtained, it was concluded that chromium is an essential metal, as it possesses constituents of enzymes and other important proteins involved in key metabolic pathways. Hence, a deficient supply of those metals will result in a shortage of enzymes which could lead to metabolic dysfunction causing disease. Chromium is fairly evenly distributed throughout various foods, with the highest concentrations found in meat.

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