

Monitoring of some indicators of lead and cadmium spread along the trophic chain ‘feed – animals – food’ in a region with an increased ecological Clarc

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Abstract

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The aim of the study was to trace the dynamics of transformation of lead and cadmium in food chain „feed – way of processing – lamb’s products“ in an area with increased environmental risk.

The authors found that the processing of lamb carcasses in private yards (in the open) increase the contamination of the elements in edible parts of the carcass. The content of lead in the organs/tissues of lambs slaughtered outdoors is higher – from 40% in liver to 125% in kidneys. The exceedances of cadmium in the same tissues are from 10% to 43%.

Keywords: lead; cadmium; bioaccumulation; lamb carcasses

Introduction

Lead and cadmium are heavy metals that are usually found in ore mining and processing sites and both metals are a potential health risk for a long time after the industrial activity ceased. However, agricultural activity in such areas cannot be stopped. On the other hand, European legislation imposes stricter limits on the content of those elements in food (Commission Directive 2005/87/EC).

Along with the studies on the effect of those metals on laboratory animals (Lovasova et al., 2013; Sajjad et al., 2014; Ali, 2016), as well as the search for protectors, which can block those elements in the organism of different animals (Kravtsov and Vaseruk, 2003; Hannan et al., 2015), investigating the transformation of those elements along the trophic chain and the possibilities of limiting their biotransformation is essential to prevent their accumulation in food products. In this respect, a bioecological monitoring of “feed – environment of realization – animal organs/tissues” chain is more than relevant.

The aim of the present study was to establish eventual change in lead and cadmium levels in the chain “fodder – processing conditions – consumed by humans lamb’s products” in an ecotechnical system of a pastoral type in an area with increased ecological Clarc.

Materials and Methods

The study was carried out in an industrial area with an increased ecological Clarc in the South Central Region of the Republic of Bulgaria. Samples of feed and animal products were collected from a family farm in the period January – May 2016. The total number of sheep and lambs reared during the period was 48. The lambs under control were born in January 2016. A milk sample for analysis was taken once from the mixed milk of all mothers, between the 23rd and the 30th day of their lactation.

Data on the content of the studied metals in the drinking water were kindly provided by the Regional Inspectorate of Environment and Water – Plovdiv.

Samples of alfalfa hay and grain forage (a mixture of 50% barley and 50% wheat) were taken in February from the own stocks of the farm.

Calculations of the average daily amounts of consumed milk, rough and concentrate forages were made on the following basis:

Suckled milk, the lamb rearing system being as follows: until 45th day the animals were in individual boxes together with the mothers, suckling milk *ad libitum*. After that age, the lambs were separated into another premise, staying with their mothers twice a day for half an hour until 60th day and after that – once a day (in the evening) for half an hour. After separating the mothers, they were milked once a day and after 60th day – twice a day. Suckled milk was recalculated by the twice control milking method, 25 ± 3 days after birth, by the method described by Tyankov et al. (1985).

The amount of feed and water consumed per day was calculated according to the equation: total amount of forage (water) consumed for the whole period by all the lambs divided by the sum of the days of life of all the lambs produced.

At the beginning of May, the farmer sold two lambs to a spiritual institution for a religious lunch ritual and he slaughtered a lamb for his own consumption. The three animals were slaughtered outdoors in the yard on a site unprotected from environmental conditions.

Within 5 days, the remaining lambs were brought to a licensed slaughterhouse meeting the regulatory requirements of Regulation EC No. 853/2006. Samples from 3 lambs were taken, their body weight being closest to the animals slaughtered in home conditions.

After the initial processing of all the animals, the weight of the skinned and cleaned carcass was measured together with the edible entrails using balances of 5 g accuracy and the liver and kidney weight was measured with balances of 1 g accuracy.

One average sample of all studied elements of the tro-

phic chain was developed for the analysis. All the samples from forages, muscles, liver and kidneys were tested for the lead and cadmium content, following the method of Jorhem (1993) by I AAS, type Perkin-Elmer 4100.

Results

Table 1 presents the data of the main indicators reported for the experimental lambs. Lambs brought for processing to a meat production factory had about 0.9 kg heavier carcass than those slaughtered outdoors in home conditions, but they were reared about 5 days longer. Consequently, older lambs had consumed more milk, forages and drinking water, but the weight of their liver and kidneys was insignificantly higher compared to the lambs of lower weight.

Table 2 presents the lead and cadmium content in the studied components. Due to the fact, that the consumed amounts of milk, forages and drinking water were produced, harvested and stored under the same conditions, the values of the two metals in a unit of primary trophic components were equal. The differences in the content of the studied metals in the secondary trophic elements were more significant. Lead in lambs slaughtered outdoors was 2.5 times higher in the kidneys, about 60% higher in the liver and about 25% higher in the abdominal muscles. Cadmium amounts in the same organs/tissues were 25%, 10% and 25% higher, respectively.

Table 3 presents two indicators for the spread of lead and cadmium along the trophic chain – Bioaccumulation Factor 2 (FB2) (Baykov et al., 2003), representing the ratio of the chemical element content in the secondary biological product (animal tissues) and an average primary biological product (forages and drinking water), as well as Distribution Clarc (CD) (Baykov et al., 2005, 2006), representing the ratios in the content of the elements between the studied animal organ/tissue and the average total content in all the studied organs/tissues.

Table 1. Main indexes for the lambs, object of the experiment

Indexes	Lambs processed in meat producing company	Lambs processed in the open
Age of realization – days	96,5 ± 1,5	91,6 ± 1,03
Mass of carcass for realization – kg	11,6 ± 1,6	10,73 ± 0,31
Liver's weight – kg	0,228 ± 0,03	0,223 ± 0,002
Left kidney's weight – kg	0,048 ± 0,002	0,045 ± 0,003
Consumed milk, average for the whole life from 1 lamb – kg	75	75
Consumed drinking water, average for the whole life from 1 lamb – kg	289,5 ± 4,5	272,5 ± 2,5
Consumed lucerne hay, average for the whole life from 1 lamb – kg	19,3 ± 0,3	18,15 ± 0,15
Consumed energy fodder, average for the whole life from 1 lamb – kg	19,53 ± 0,3	18,33 ± 0,15

Table 2. Lead and cadmium contents in fodder components and in organs/tissues of the lambs

Fodders/Tissues	Lambs processed in meat producing company		Lambs processed in the open	
	Pb – mg/kg	Cd – mg/kg	Pb – mg/kg	Cd – mg/kg
Sheep's milk	0,025	0,0002	0,025	0,0002
Drinking water	0,002	0,0002	0,002	0,0002
Lucerne hay	2,5	0,22	2,5	0,22
Energy (grain) food – 50% wheat/ 50% barley	0,08	0,025	0,08	0,025
Content in kidney	0,55	1,0	1,32	1,25
Content in liver	0,60	0,20	1,0	0,21
Content in the abdominal muscle	0,15	0,08	0,20	0,14

Table 3. Factor of bioaccumulation (FB2) and Clarc of distribution (CD) in different organs/tissues of tested lambs, processed in company and in the open

Organ/Tissue	Element	Lambs processed in meat producing company		Lambs processed in open	
		FB2	CD	FB2	CD
Abdominal muscle	Pb	0,06	1,40	0,08	1,80
	Cd	0,36	0,10	0,64	0,13
Liver	Pb	0,24	1,50	0,40	1,40
	Cd	0,91	0,20	0,95	0,20
Kidney	Pb	0,22	1,40	0,40	1,70
	Cd	4,55	0,70	5,68	1,12

It can be seen that the bioaccumulation factor (FB2) of lead was higher in the lambs processed outdoors in all the three types of raw animal products obtained. The smallest difference was established in the abdominal muscles, and in kidneys and liver the differences were almost twice higher. FB2 factor for cadmium was also higher in lambs slaughtered outdoors, with the highest value found in the kidneys of both groups, which is normal, provided that this metal accumulates exactly in those organs.

The cadmium content expressed by CD indicated the spread of the element both in the muscles and in the liver and kidneys in both groups of lambs. In terms of lead, however, significant accumulation was observed.

Discussion

The slaughter weight of the lamb carcasses and of kidneys and liver was compatible with the average values for the area. No significant differences in those values were found in both groups of animals.

Regarding the contents of the two metals in the different components at autotrophic and heterotrophic levels, the following features were established: The sheep milk consumed by lambs had high levels of lead, exceeding the Bulgarian Maximal Admission Level (MAL) by 25%. The cadmium content was several times lower than the

MAL adopted in Bulgaria (Ordinance No. 31/29.7.2004 of the Ministry of Health). But we assume that the value of that indicator might have been influenced by hand milking, and that the animals and the premises in which they were reared were not cleaned on the day of collecting the samples.

Drinking water samples contained 2 times more lead than the latest MALs reflected in EU Drinking Water Directive 98/83/EC. Besides the natural content of lead in the water, the old metal pipes in most plumbing installations also contributed to the increased lead concentrations. The cadmium content was about 2.5 times lower than the admission level published in the same Directive.

The content of both elements taken by the animals, were much lower in hay and concentrated forages compared to the MAL adopted in Bulgaria, which are: cadmium – 1 mg/kg⁻¹; lead: in cereal feed – 10 mg/kg⁻¹, in grass forages – 30 mg/kg⁻¹ (Ordinance of the Ministry of Agriculture and Food, No. 10/03.04.2009).

Therefore, consumed milk and drinking water could be considered as the major lead pollutants.

The major source of pollution in the area stopped the lead production as early as 2006 and since 2004 dust filters had been installed over the furnaces for the other production processes. Monitoring data provided by the Regional Inspection of Environment and Water in the recent years

show that the company did not allow excessive pollution with any of the components tested on an annual basis.

In our previous studies (Hristev et al., 2002; Baykov et al., 2003) it was found out that the major contamination of forages, mainly with lead, was due to the fine dust particles. Over a period of more than 10 years, the contents of both elements have decreased significantly. The minimum amounts established in feed were mainly attributed to the dust aerosol adhered to forages during harvesting, drying and transportation.

The bioaccumulation factor (FB2) in all the studied lamb organs/tissues slaughtered outdoors, remained higher than in the case of industrially processed animals, with the differences in the abdominal muscles being the lowest. Provided that the animals took almost identical amounts of the metal with feed and drinking water, the higher concentration in the animals processed outdoors can be explained by the dust particles adhered to the lamb organs from soil, dirty hands, instruments and storage containers. The higher differences in the kidneys and liver could be explained by the fact that those organs were subject to additional hand manipulations and remained outdoors in the containers for a longer time.

The same tendency was observed for the FB2 of cadmium. The differences between the two groups of lambs were lower, which is probably due to the fact, that the dust particles in the soil and atmosphere contain much less cadmium, confirmed in our previous studies (Baykov et al., 2003).

In conclusion, it could be summarized that despite excluding the Non-Ferrous Metal Works as the major environmental pollutant with heavy metals, they continue to be found in the fine dust fractions in the region. Traditional slaughtering of the animals outdoor, as well as the inadequate personal hygiene of people, of the pots and tools used, pose a risk of further contamination with lead and cadmium of the products processed outdoors.

Conclusions

The amounts of milk and drinking water consumed by the experimental lambs contained 25 to 100% more lead and less cadmium than the MALs adopted in Bulgaria. Plant forages consumed by animals do not pose a risk of contamination with both elements.

The content of both elements was higher in the organs/tissues of lambs slaughtered outdoors, lead content exceeding 40% in liver, 125% in kidneys and 25% in the abdominal muscles, respectively. The exceedances of cadmium in the same tissues are 10%, 25% and 43%, respectively.

The bioaccumulation factor (FB2) of lead and cadmium from primary to secondary link of the trophic chain was higher in the three studied organs/tissues of the lambs slaughtered outdoors, the differences ranging from 20 (FB2 – lead – abdominal muscles) to 90% (FB2 – lead – liver).

The cadmium distribution Clarc (CD) showed the spread of the element both in muscles, on the one hand, and, liver and kidneys, on the other, in both groups of lambs and referring to lead, a significant accumulation was reported.

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