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A STUDY ON BIOACCUMULATION OF SELECTED METALS IN MEAT AND INTERNAL ORGANS OF INTENSTIVELY FED KID GOATS

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Abstract

Owing to its wholesomeness and good taste, meat of goats and lambs is an increasingly more important in human nutrition. It is characterized by excellent nutritive value and high digestibility. It is also relatively rich in mineral compounds. The aim of this study has been to determine the content of some elements in muscles, liver and kidneys of male and felame kid goats, fattened to 150 day of life. The animals received full-ration mixture containing 169 g total protein and 6.0 MJ net energy. The mixture was given ad libitum and supplemented with meadow hay as bulk feed. During the whole period of fattening, the animals were kept under the conventional housing system. Samples for analysis were taken from *adductor femoris* muscles, liver and kidneys.

The muscle tissue of the analysed male goats contained less Cd (0.002 mg kg^{-1} ± 0.004) than that of the female goats (0.003 mg kg^{-1} ± 0.001). In turn, the level Pb was lower in the female goats (0.019 mg kg^{-1} versus 0.026 mg kg^{-1} in male goats), although the difference was statistically non-significant. In the internal organs, more Cd occurred in kidneys than in the liver, unlike Pb. The concentration Pb was higher in kidneys of the male than female goats (0.073 mg kg^{-1} ± 0.02), whereas the level of this element the liver was identical in both groups (0.084 mg kg^{-1}). In the muscule tissue, the sex differentiated the content of Fe ($p = 0.01$) as well as Mg and Zn ($p = 0.05$). The liver accumulated not only Pb and Cd, but also Cu and Zn. The concentration Cu in the liver of female goats was higher (146.79 mg kg^{-1} at $p = 0.01$) than in male goats by about 50 mg kg^{-1}. High disproportions between the sexes in the content of Fe in the liver were observed: 36.30 mg kg^{-1} for female goats and 21.99 mg kg^{-1} for male goats ($p = 0,01$). In kidneys, however, the concentration of Ca was very high, particularly for female goats particularly (81.01 ± 26.55 mg kg^{-1}).

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Key words: goat kids, meat, liver, kidneys, bioaccumulation, elements.

BADANIA BIOAKUMULACJI WYBRANYCH METALI W MIĘSIE I NARZĄDACH WEWNĘTRZNYCH KOŹLĄT ŻYWIONYCH INTENSYWNIE

Abstrakt

Ze względu na walory zdrowotne i smakowe mięso kozie i jagnięce nabiera coraz większego znaczenia w żywieniu człowieka. Charakteryzuje się doskonałymi właściwościami pod względem wartości odżywczej i wysoką strawnością. Jest stosunkowo bogate w związki mineralne. Celem badań było określenie zawartości wybranych pierwiastków w mięśniach, wątrobie i nerkach koziołków i kózek żywionych do 150. dnia życia. Materiał doświadczalny stanowiły koziołki i kózki rasy białej uszlachetnionej oraz tuczone do 150. dnia życia. Zwierzęta żywiono pełnoporcjową mieszanką o wartości pokarmowej 168 g białka ogólnego i 6,0 MJ energii netto. Mieszankę podawano *ad libitum* i uzupełnioano dodatkiem strukturalnym siana łąkowego. Przez cały okres tuczu zwierzęta utrzymywano w chowie alkierzowym, w pomieszczeniach zamkniętych. Próby do analizy pobrano z mięśnia przywodziciela uda (*m. adductor*), wątroby i nerek.

W tkance mięśniowej analizowanych koziołków doświadczalnych stwierdzono niższą zawartość Cd (0,002 mg $kg^{-1} \pm 0$, 0,004) niż u kózek (0,003 mg $kg^{-1} \pm 0,001$). Natomiast poziom Pb był niższy w grupie kózek i wyniósł 0,019 mg kg^{-1} wobec 0,026 mg kg^{-1} – różnice okazały się nieistotne statystycznie. W narządach wewnętrznych wyższy poziom Cd stwierdzono w nerkach niż w wątrobie, a w przypadku Pb odwrotnie. Stężenie Pb było wyższe w nerkach koziołków i wyniosło 0,073 mg $kg^{-1} \pm 0,02$. W wątrobach poziom tego pierwiastka był na tym samym poziomie (0,084 mg kg^{-1}). Płeć różnicowała istotnie zawartość Fe i Ca w tkance mięśniowej ($p \leq 0,01$) oraz Mg i Zn ($p \leq 0,05$). Wątroba była narządem koncentracji nie tylko Pb i Cd, ale Cu i Zn. Stwierdzono, że stężenie Cu w wątrobie kózek było wyższe ($p \leq 0,01$, 146,79 mg kg^{-1}) w porównaniu z koziołkami o ok. 50 mg kg^{-1}. Zaobserwowano wysokie dysproporcje w zawartości Fe w wątrobie, ponieważ u kózek stwierdzono 36,30 mg kg^{-1}, a u koziołków 21,99 mg kg^{-1} ($p \leq 0,01$). W nerkach wykazano zdecydowanie większe stężenie Ca, szczególnie u kózek (81,01 ± 26,55 mg kg^{-1}).

Słowa kluczowe: koźlęta, mięso, wątroba, nerki, bioakumulacja, pierwiastki.

INTRODUCTION

Human economic activity leads to increased levels of heavy metals in environment, which directly influence the ability of plants and animals to function properly. As a result, occurrence of increased contents of certain metals in edible parts of slaughter animals is an alarming phenomenon (Krełowska-Kułas 1989, Węglarz 2007).

Heavy metals are found most often and are the most dangerous contaminants to human health. In particular, lead, cadmium and mercury are distinguished by high accumulation due to their faster absorption from the digestive tract and easy transfer through the organism's biological barriers (Park 1990, Lidwin-Kazimierkiewicz et al. 2006, Niedziółka et al. 2006, Oleszkiewicz 2007, Węglarz 2007).

Numerous studies, for example by KRUPA and KOGUT (2000), PIENIAK-LENDZION et al. (2006), NIEDZIÓŁKA et al. (2007), have shown that kidneys, livers, and muscle tissues of small ruminants from the Podlasie region as well as south-eastern Poland have low heavy metal content, which does not exceed the permissible levels. The present study was undertaken with the aim to determine contents of selected elements in the muscle tissue, livers and kidneys of kid goats offered concentrate rations of feed produced in the Podlasie region

MATERIALS AND METHODS

Experimental animals were 20 kid goats of the Polish White Improved breed. They remained with the mothers kept under standard conditions up to 55 days of age. Next, they were weaned and fattened up to 150 days of age in two feeding groups: group I – males, and group II – females. The grouping was to examine the impact of sex on the accumulation of elements when the same feeding regime was applied in both groups.

Throughout the whole period of the experiment, the animals were kept indoors. Following the fattening, the animals were slaughtered and their carcasses were chilled for 24 hours at 4ºC.

Samples of *adductor femoris* muscles, livers and kidneys were examined. Weighed samples were dried at 110ºC and then burned in an oven at 450ºC. Lead, cadmium, iron, copper and zinc contents were determined by atomic adsorption spectroscopy (AAS). Lead and cadmium contents were determined by means of the extraction method using 2% APDC (nickel pyrrolidine-dithiocarbamate) as an extraction agent. Methylisobutyl ketone saturated with deionised water was the organic phase. Iron, copper and zinc contents were determined directly from the mineralised material applying suitable dilutions. The determination was performed on an AAS-1 atomic adsorption spectrometer produced by Carl Zeiss Jena.

Statistical analysis included the ANOVA procedure, and was carried out using Stat. 6.0 PL (Statistica 2002).

RESULTS AND DISCUSSION

Excessively high doses of some elements, e.g. copper, may induce haemolysis and cause liver and kidney damages. Table 1 presents contents of the elements in the muscle tissues of male and female kid goats. Lead content was by 0.006 mg kg^{-1} higher in male muscles than in female meat, and amounted to 0.025 mg kg^{-1}. In contrast, female kid goat meat was charac-

Table 1

Concentration of elements in the muscle tissue of male and female kids

Elements	Male kids, N=10		Female kids, N=10	
	mg kg^{-1} of fresh tissue			
	$\overline{x}$	SD	$\overline{x}$	SD
Pb	0.025	0.01	0.019	0.01
Cd	0.002	0.001	0.003	0.001
Mn	0.24	0.04	0.35	0.16
Fe	16.70**	0.81	18.66**	3.69
Zn	28.41*	1.56	27.89*	0.72
Cu	0.94	0.39	1.23	0.44
Ca	20.76**	1.44	19.11**	2.65
Mg	156.55*	6.31	164.59*	10.47

The values are means ($\overline{x}$), standard deviation (SD);
*row mean value significant at $p \leq 0.05$;
**row mean value significant at $p \leq 0.01$.

terised by a higher cadmium concentration (by 0.003 mg kg^{-1}). The differences for both lead and cadmium were statistically insignificant. Higher cadmium and lead concentrations in the meat of kid goats and lambs were recorded for animals from central-eastern Poland slaughtered at 180 days of age (Niedziółka et al. 2007) as well as adult goats and sheep reared in the Rzeszów region (Krupa and Kogut 2000).

The Minister of Health regulation (Journal of Law 2001) states that cadmium and lead contents in muscle tissue can reach up to 0.05 and 0.20 mg kg^{-1}, respectively. It is worth noting that in 2003 the Minister of Health introduced a detailed norm (Journal of Law 2003), which set a lower permissible lead content in muscle tissue, i.e. 0.10 mg kg^{-1} fresh tissue.

It was found that male kid goat meat had a significantly ($p = 0.01$) lower iron and magnesium content (respectively, 16.70 and 156.55 mg kg^{-1}). By contrast, female kid goat meat was characterised by less calcium and zinc (respectively, 19.11 ($p = 0.01$) and 27.89 mg kg^{-1} ($p = 0.05$)). The Polish norm of 2000 specified that the maximum Zn content could not exceed 80 mg kg^{-1} fresh muscle tissue. From 2000 to 2003 there were no limits for copper and zinc content in food like eggs and meat (Journal of Law 2001, 2003). In other studies (Johnson et al. 1995) the muscle tissue of young kid goats contained an average of 28.1 mg 100 g^{-1} calcium, 92.3 mg 100 g^{-1} zinc and 4.4 mg 100 g^{-1} copper. Excess of lead and magnesium deficiency is typical of and common among different age groups of Poles. Thus, magensium supplementation or a diet including magnesium have a positive effect on the population and on children in particular (Dunicz-Sokołowska et al. 2006, Oleszkiewicz 2007).

No significant differences in the lead content in the liver were found between the sex groups (0.084 mg kg^{-1} fresh tissue, Table 2). Only a slightly lower cadmium level was found in female livers, that is 0.020 mg kg^{-1} versus 0.021 mg kg^{-1} for males. The values were about 20-fold lower than the level accepted by the Minister of Health regulation of 2003 (Journal of Law 2003). Lead and cadmium contents in mammalian livers should not exceed

Table 2

Concentration of elements in the liver of male and female kids

Elements	Male kids, N=10		Female kids, N=10	
	mg kg^{-1} of fresh tissue			
	$\bar{x}$	SD	$\bar{x}$	SD
Pb	0.084	0.01	0.084	0.06
Cd	0.021	0.01	0.020	0.01
Mn	3.54*	0.33	3.86*	1.31
Fe	21.99**	7.79	36.30**	14.74
Zn	30.34	1.41	31.99	2.01
Cu	96.23**	11.97	149.79**	23.11
Ca	35.59*	7.26	33.01*	8.61
Mg	127.57**	9.40	134.98**	14.16

The values are means ($\bar{x}$), standard deviation (SD);
*row mean value significant at $p \leq 0.05$;
**row mean value significant at $p \leq 0.01$.

0.50 mg kg^{-1}. The concentration of both lead and cadmium was also much lower compared with other studies (Krupa and Kogut 2000, Niedziółka et al. 2007). Copper was mainly accumulated in the liver irrespective of the sex. Significant ($p = 0.01$) differences were found in copper content. The copper level, higher by 52.56 mg kg^{-1}, was recorded for females (149.79 mg kg^{-1}) as compared to males. The results were lower (21.99 mg kg^{-1}), and the variation in the accumulation according to the analysed tissues confirmed the results of earlier studies (Niedziółka et al. 2006). The maximum permissible zinc content in liver, according to the Minister of Health norm of 2000 (Journal of Law 2001), was set at 80 mg kg^{-1} fresh tissue but since 2003 all such limits have been abandoned (Journal of Law 2003). It is estimated that in most countries, including the wealthiest ones, the daily zinc intake is less than 10 mg whereas the adult person's demand is 12-20 mg (Węglarz 2007). In the present work, the zinc level in the liver was similar in males and females, reaching 31.99 and 30.34 mg kg^{-1}, respectively.

Lead and cadmium levels in the kidneys of examined animals (Table 3) were 0.073 mg kg^{-1} and 0.038 mg kg^{-1}, respectively. Significant differences ($p \leq 0.05$) were found in iron content in the kidneys of investigated animals,

Table 3

Concentration of elements in the kidneys of male and female kids

Elements	Male kids, N=10		Female kids, N=10	
	mg kg^{-1} of fresh tissue			
	$\overline{x}$	SD	$\overline{x}$	SD
Pb	0.073	0.02	0.057	0.01
Cd	0.031	0.01	0.038	0.01
Mn	1.53	0.46	1.32	0.15
Fe	49.88*	10.28	45.36*	8.80
Zn	20.80	4.23	20,68	1.71
Cu	3.49	0.36	3.99	0.35
Ca	75.86**	18.44	81.07**	26.55
Mg	135.58**	7.74	127.30**	7.59

The values are means ($\overline{x}$), standard deviation (SD);
*row mean value significant at $p \leq 0.05$;
**row mean value significant at $p \leq 0.01$.

similarly to calcium and magnesium ($p \leq 0.01$), all the results being similar to the findings of previous studies (Niedziółka et al. 2006). Krupa and Kogut (2000) concluded that kidneys of kid goats reared in the Rzeszów region were not suitable for consumption because lead and cadmium contents were higher than the norms. The results of a study by Zięba (2003) showed an evidently higher cadmium content in flesh organs, several-fold higher level in livers and more than ten-fold higher concentration in kidneys than in muscles. In turn, lead content varied, reaching up to 0.06 in muscles, and to 0.092 and 0.061 mg kg^{-1} in livers and kidneys, respectively. Analysis of individual tissues showed that the highest was the level of calcium in kidneys, and in females it was significantly ($p = 0.01$) and by 5.21 mg kg^{-1} higher, reaching 81.07 mg kg^{-1}.

SUMMARY

The results of the present study indicate a higher accumulation of toxic metals in flesh organs. It was found that lead and cadmium concentrations were similar in both sex groups. The bulk of copper and zinc accumulated in livers of both males and females. Irrespective of the sex, the highest and the lowest magnesium levels were found in muscle tissue and livers, respectively, and the differences reached between ten and twenty per cent. In turn, in kidneys the highest was the accumulation of iron: from 45.36 mg kg^{-1} (in females) to 49.88 mg kg^{-1}(in males), whereas in muscle tissue the greatest was the concentration of magnesium.

The values of all the elements, including toxic ones, did not exceed the upper levels of the Polish norms for meat tissue and internal organs, which indicates that the meat was fully suitable for human consumption.

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