ISSN 1644-0714
ISSN 2300-6145 (online)
www.asp.zut.edu.pl

Acta Sci. Pol. Zootechnica 14(2) 2015, 175–182

SHORT COMMUNICATION

THE MOLYBDENUM CONTENT IN THE MUSCLES OF RED DEER (*CERVUS ELAPHUS*)

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Abstract. The aim of the study was to evaluate the molybdenum concentrations in the muscles of red deer hunted in north-eastern Poland. Samples for analysis were collected from 27 females, and metal concentrations were determined using ICP-MS. The resulting data were analyzed for both benefits and potential risks in terms of consumer health. The average concentration of Mo in the muscles was 0.042 $\pm$0.007 mg $\cdot$ kg^{-1} wet weight. The results obtained were similar to those observed in other species of free-living ruminants and much lower than those found in farmed ruminants. Based on the results of the study, it can be stated that meat of the red deer is not a good source of molybdenum in terms of human nutritional demands. However, it can be treated as an additional source of this micronutrient.

Key words: red deer (*Cervus elaphus*), muscles, molybdenum

INTRODUCTION

The red deer (*Cervus elaphus*) is a game animal present in most of Europe. It is one of the largest members of Cervidae family and, as a free-living ruminant (*ruminantia*), the red deer belongs to animals most tightly bound with their habitat. The mineral composition of red deer tissues can be treated as an indicator of bioavailability of selected metals [Frank et al. 1994, Frank and Galagan 1997,

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Gasparik et al. 2004, Falandysz et al. 2005, Pilarczyk et al. 2009, Wieczorek-Dąbrowska et al. 2013, Skibniewski et al. 2015]. The literature on environmental biomonitoring highlights the fact that bioavailability should be measured in the tissues of the animals that are at the end of a relatively long trophic chain [Frank et al. 2004]. In the Scandinavian countries the moose (*Alces alces* L.), the most common undomesticated ruminant in the region [Aupperle et al. 2001], fully meets this criterion. Since the population of red deer in Poland is very large, the species serves here as the proper model for analysis. According to the data published by the Central Statistical Office [GUS 2012, 2014], a constant growth in the red deer population has been observed over the last decade. In the hunting season of 2002/2003, the red deer population in Poland was estimated to 123 thousand individuals, whereas in 2013, as many as 217 thousand red deer were reported.

Due to the nature and specific functioning of the ruminant digestive system, tissue content of molybdenum is particularly interesting, since the element is essential for numerous metabolic processes. However, in excess it may also be toxic [Anke et al. 2010]. Molybdenum enters into complex interactions with copper and sulphates; however, the mechanism of these reactions is not fully understood [WHO 2011]. In small quantities, molybdenum is present in all the fluids and tissues of the body, as a constituent of numerous enzymes [Kośla 1999]. Monogastric animals are exposed to its toxic effects if copper deficiency occurs. In ruminants, molybdenum poisoning can occur even at the adequate level of copper in tissues. The disorder is refered to as molybdenosis. An important factor contributing to the occurrence of the disease are sulphates in the diet. A level of dietary molybdenum reaching 10 mg $\cdot$ kg^{-1} body weight results in depletion of tissue copper reserves, which is additionally magnified by sulphates [Huber et al. 1971, Suttle 1974, 1980, Campbell et al. 1976, Kośla 1999, WHO 1993, 2011].

Analysis of the mineral composition of skeletal muscles of an animal enables us to evaluate the impact that meat can have on the consumer's health, especially as venison is widely regarded as a valuable meat, free of any additives that are used during an intensive farm production. Venison is widely available in retail chains as either raw meat or a processed product. In the hunting season of 2013/2014, a total of 77 thousand red deer carcasses were harvested and reached either the national or foreign markets [GUS 2012, 2014]. Food market analysts predict for developed countries that game may soon partly replace the meat of livestock animals produced by large-scale industrial farms.

The aim of the study was to evaluate molybdenum concentration in the skeletal muscle of red deer coming from north-eastern Poland and to compare the results to those measured in other species of free-living and domesticated ruminants. The study also aimed to determine the effect of venison on the health of the consumer in terms of human demand for molybdenum.

MATERIAL AND METHODS

The material consisted of muscle samples obtained from 27 red deer (*Cervus elaphus*) from north-eastern Poland (Warmia and Mazury region). This poorly industrialized area is a refuge for many species of the deer family.

The material was collected in 2008 and 2009 in a game processing factory. The animals have been hunted within the official hunting limits during the season open from 1 October 2008 to 15 January 2009. The samples were approx. 10-g sections of the *m. masseter* obtained from the carcasses of mature females. The samples were stored at –20°C until analyzed.

Mineralization of the samples was carried out in a mixture of 5 ml concentrated nitric acid and 1 ml of 30% hydrogen peroxide (Merck, Germany). We used the Milestone (MSL 1200) microwave digestion system. The analysis of the molybdenum content in the collected samples was carried out using inductively coupled plasma mass spectrometry (ICP-MS, Elan DRC II Perkin Elmer, USA). The accuracy of the method was verified using the certified reference material NCS ZC 71001beef liver. The assays were performed in triplicate. The results are presented as the means of the measurements expressed in mg · kg^{-1} wet weight of the analyzed tissue. Statistical analysis was carried out using the Statistica v. 10.0 package (StatSoft Inc.).

RESULTS AND DISCUSSION

The available literature brings just a few reports on muscle content of molybdenum in ruminants. Most authors deal with its concentration in the liver and kidneys. Jarzyńska and Falandysz [2011], who studied red deer tissue from the Warmia and Mazury region, reported the average skeletal muscle molybdenum concentration 0.15 mg · kg^{-1} dry weight, which is – if we correct it by the muscle water content – about 0.049 mg · kg^{-1} wet tissue weight. This is similar to our results (Table 1). In both cases the results are characterized by low variability, which in our study ranged between 0.04 and 0.07 mg · kg^{-1} wet weight. These values are much lower compared to data concerning other species of ruminants (Table 2). The observed differences result from the common practice of supplementing the diet of livestock animals with mineral supplements that include molybdenum. Pott et al. [1999], who analyzed the effects of various molybdenum compounds on its tissue concentration in the skeletal muscles of sheep, observed an average molybdenum content of 0.03 mg · kg^{-1} wet weight of the control animals. In those fed with sodium molybdate at a dose 15 mg · kg^{-1} dry weight of feed, the concentration of molybdenum in the muscles averaged 0.08 mg · kg^{-1} wet weight. An increase in dietary molybdenum resulted in its increased concentration in the

muscles. The animals that received a three times higher dose of sodium molybdate (45 mg · kg^{-1} feed dry weight) demonstrated a skeletal muscle molybdenum concentration at a level of 0.19 mg · kg^{-1} wet weight of muscle tissue. Much lower values are observed in free-living ruminants. Gamberg et al. [2005] reported an average molybdenum concentration at a level 0.01 mg · kg^{-1} wet tissue in the Canadian moose.

Table 1. The molybdenum content in the muscles of examined animals, mg · kg^{-1} wet weight

Tabela 1. Zawartość molibdenu w mięśniach badanych zwierząt, mg · kg^{-1} ś.m.

Species Gatunek	n	Median Mediana	Arithmetic mean (w.w./d.m.) Średnia (ś.m./s.m)	SD	Minimum	Maximum Maksimum
Red deer Jeleń	27	0.05	0.042/0.144	0.007	0.04	0.07

Table 2. The molybdenum content in the muscles of free living and domesticated ruminants, mg · kg^{-1} wet weight/dry mass

Tabela 2. Zawartość molibdenu w mięśniach przeżuwaczy wolno żyjących i udomowionych, mg · kg^{-1} ś.m./s.m.

Species Gatunki		n	Mean (wet m./ d.m) Średnia (ś.m. /s.m)	Country Kraj	References Piśmiennictwo
Free living ruminants Wolnożyjące przeżuwacze	red deer jelenie	20	0.049/0.17	Poland Polska	Jarzyńska and Falandysz [2011] Jarzyńska i Falandysz [2011]
	elk łosie	37	0.01/0.03	Canada Kanada	Gamberg et al. [2005] Gamberg i in. [2005]
Domestic ruminants Udomowione przeżuwacze	cattle bydło	120	0.09/0.33	Espain Hiszpania	López Alonso et al. [2004] López Alonso i in. [2004]
	goats kozy	13	0.157/0.54	Germany Niemcy	Frank et al. [2000a] Frank i in. [2000a]
	sheep owce	10	0.03/0.11	USA	Pott et al. [1999] Pott i in. [1999]

Molybdenum, as a component of metalloenzymes such as xanthine oxidase, aldehyde oxidase, and sulfite oxidase, is essential for the metabolic processes in mammals [Kośla 1999, Anke et al. 2010]. Its absorption depends on the valency of molybdenum in various compounds. Hexavalent molybdenum – in contrast to trivalent molybdenum – is efficiently absorbed into the blood following oral administration, and then distributed to all the tissues of the body. Higher levels of the metal are found in the liver, kidneys and bones [WHO 2011]. There are fundamental differences between monogastric animals and ruminants in molybdenum absorption efficiency and elimination pathways. The amount of molybdenum absorbed in non-ruminants is higher than that in ruminants. Monogastric animals excrete the element primarily in the urine; in addition, homeostatic mechanisms in non-ruminants more effectively maintain the balance between absorption and

excretion of molybdenum. Accordingly, the symptoms of molybdenum toxic properties in the body of a monogastric animal are observable particularly at copper deficiencies [Anke et al. 2010]. Ruminants are more often poisoned with molybdenum, despite the fact of its excretion with both urine and faeces, which results mainly from the complex reactions involving copper and dietary sulphates. In the environment of the forestomach, especially the rumen, thiomolybdates are formed which effectively reduce both the absorption of copper and its concentration in various body tissues [Gould and Kendall 2011]. This characteristic of thiomolybdates found its medical application in the treatment of humans suffering from Wilson's disease, which consists in elimination of copper from the liver and the central nervous system [Medici et al. 2007, Rodríguez-Flores et al. 2011].

The effect of molybdenum on the health of free-living ruminants came into focus in the 1980s, after the outbreak of the so-called "mysterious" moose disease that affected the animals in south-western Sweden. The number of deaths among the moose resulting from the disease was about 150 animals per year, which represented about 3% of the entire population in the region [Frank 1998]. Research showed that the most likely reason was molybdenosis and copper deficiency [Frank 1998, Frank et al. 2000b, Frank et al. 2002, Frank 2004, Frank et al. 2004]. This supports our reasoning that it is of importance to analyze the tissue concentration of molybdenum in free-living deer inhabiting north-eastern Poland.

The meat of free-living ruminants has been gaining in popularity in the recent years. Venison is considered a valuable food, free of additives that are used in an intensive animal production. The scientific literature on the topic brings relatively little information on wild ruminants, including the red deer, whose meat represents a nutritious and desirable component of the human diet [Jarzyńska and Falandysz 2011]. The muscular tissue of these animals, is considered to be of particular culinary value. Increasing consumption of venison in Poland raises questions about its potential impact on the consumer's health. The World Health Organization estimated the daily requirement for molybdenum of an adult at the level of 0.1–0.3 mg [Rose et al. 2010]. Skeletal muscles – as compared to liver or kidneys – are a relatively poor source of molybdenum. An amount of 100 g of venison provides as little as 0.004 to 0.007 mg of molybdenum. It has been estimated that an adult human body absorbs 30 to 70% of molybdenum contained in the diet [WHO 2011]. Therefore it can be concluded that the meat of the red deer, similar to the muscle tissue of other animal species, is poor in molybdenum, and can only be treated as an additional source of this micronutrient in the human daily requirement.

CONCLUSIONS

The molybdenum content in the muscles of the red deer from the Warmia and Mazury region of Poland is of a similar level compared to those observed in other species of free-living ruminants. The observed values are much lower compared to farm ruminants.The results allow concluding that venison, widely regarded as a high-quality food rich in many macro- and microelements, contains small amounts of molybdenum, which only marginally cover the nutritional requirements of the human organism.

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ZAWARTOŚĆ MOLIBDENU W MIĘŚNIACH JELENIA SZLACHETNEGO (*CERVUS ELAPHUS*)

Streszczenie. Celem pracy była ocena zawartości molibdenu w mięśniach szkieletowych jeleni szlachetnych z północno-wschodniej Polski. Próby pobrano od 27 osobników. Zawartość molibdenu określono za pomocą ICP-MS. Zawartość molibdenu w mięśniach analizowano w kontekście korzystnego wpływu, jak też potencjalnego ryzyka dla zdrowia konsumentów. Średnie wartości Mo w mięśniach były na poziomie 0,042 $\pm$0,007 mg $\cdot$ kg^{-1} świeżej masy. Uzyskane wyniki były podobne do wartości obserwowanych u innych gatunków wolno żyjących przeżuwaczy i znacznie niższe w odniesieniu do przeżuwaczy udomowionych. Na podstawie uzyskanych wyników, można stwierdzić, że mięso jelenia szlachetnego nie jest dobrym źródłem molibdenu pokrywając zapotrzebowanie żywieniowe człowieka zaledwie w nieznacznym stopniu. Może być ono traktowane jako dodatkowe źródło tego mikroelementu.

Słowa kluczowe: jeleń szlachetny, (*Cervus elaphus*), mięśnie, molibden

Accepted for print: 11.05.2015

For citation: Skibniewski, M., Skibniewska, E.M., Kośla, T., Kołnierzak, M. (2015). The molybdenum content in the muscles of red deer (*Cervus elaphus*) . Acta Sci. Pol. Zootechnica, 14(2), 175–182.