J. Elementol. 2009, 14(3): 527–537

THE CONTENT OF MINERAL ELEMENTS IN TWO LAMB GENOTYPES DEPENDENT ON THE SYSTEM OF MAINTENANCE*

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Abstract

The aim of the study was to determine the content of macro- and microelements in the blood serum and in the longissimus dorsi muscle *(Musculus longissimus dorsi – Mld)* of lambs, dependent on the system of maintenance of the lambs with their mothers, the genotype and the year of research. Lambs were reared together with their mothers in two maintenance systems: indoor system in a sheep fold and outdoor system in the open air with unlimited access to pasture. The lambs were of two genotypes: PLS (Polish Lowland sheep Uhruska variety) and BCP (the synthetic prolific meat line sheep). The concentration of elements in the blood serum was estimated in the second and third month of life, as well as in the *Mld*, after slaughter of the lambs at a weight of 25-28 kg.

The results of the study show that the mineral compositions of blood change with the lamb's age and related method of feeding. The system of maintenance had a modifying effect on the calcium, copper and zinc content in the blood serum, especially in the third month of the lambs' life. It was noted that the copper content in the longissimus dorsi muscle in the lambs kept with their mothers in the outdoor system was higher compared to the lambs kept indoors. A similar tendency was observed in the content of mineral elements in the blood serum and in the longissimus dorsi muscle, dependent on the genotype and maintenance system. The concentration of elements (except sodium) in the blood serum in the lambs comprised within the reference values set for adult sheep.

Key words: sheep, maintenance system, lambs, genotype, macroelements, microelements.

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* Scientific study financed by science funds in 2005-2008 under the title of Project No. 2P06Z010029.

ZAWARTOŚĆ SKŁADNIKÓW MINERALNYCH U JAGNIĄT DWÓCH GENOTYPÓW W ZALEŻNOŚCI OD SYSTEMU UTRZYMANIA

Abstrakt

W pracy przedstawiono wyniki badań dotyczących określenia zawartości makroelementów i mikroelementów w surowicy krwi oraz mięśniu najdłuższym grzbietu (*Musculus longissimus dorsi – Mld*) jagniąt w zależności od systemu utrzymania ich przy matkach, genotypu i roku badań. Jagnięta odchowywano z matkami w dwu systemach utrzymania: alkierzowym w owczarni oraz pastwiskowym, na wolnym powietrzu, z nieograniczonym dostępem do pastwiska. Były to jagnięta dwóch genotypów – PLS – polska owca nizinna odmiany uhruskiej i BCP – jagnięta syntetycznej linii plenno-mięsnej. Zawartość pierwiastków w surowicy krwi oceniono w drugim i trzecim miesiącu życia jagniąt, zaś w *Mld* – po uboju tryczków o masie ciała 25-28 kg.

Stwierdzono, że skład mineralny krwi zmienia się wraz z wiekiem jagniąt i związanym z tym sposobem żywienia. System utrzymania wpływał modyfikująco na zawartość wapnia, miedzi i cynku w surowicy krwi jagniąt, zwłaszcza w trzecim miesiącu życia. Stwierdzono wyższą zawartość miedzi w mięśniu najdłuższym grzbietu u jagniąt utrzymywanych z matkami na pastwisku, w porównaniu z jagniętami utrzymywanymi w alkierzu. Zaobserwowano podobną tendencję w zawartości składników mineralnych w surowicy krwi jagniąt a ich zawartością w mięśniu najdłuższym grzbietu (*Mld*) w przypadku genotypu i systemu utrzymania. Stężenie pierwiastków (oprócz sodu) w surowicy krwi jagniąt mieściło się w granicach norm referencyjnych dla owiec dorosłych.

Słowa kluczowe: owce, system utrzymania, jagnięta, genotyp, makroelementy, mikroelementy.

INTRODUCTION

The content of mineral substances in fodder for animals is influenced by many factors. The chemical composition of the soil in which plants are grown has a decisive influence on the mineral content of the plants. The chemical composition of soil largely depends on its geological origin as well as on the level of fertilisation. Obtaining higher and higher crop yields is usually achieved at the expense of decreasing the mineral abundance of soil. One of the possible negative effects of excessive fertilisation is the phenomenon of antagonism between mineral nutrients of soil. Ion antagonism is of great importance in plants taking in mineral nutrients (PRZYBYSZ et al. 2003, HE et al. 2004, GÓRSKI et al. 2005). The content of the mineral elements in plants does not always show the abundance of the soil. Changes in the chemical content can also cause modifications in the botanical content of grasslands. This is particularly common when pasture is intensively fertilised with nitrogen (KOZŁOWSKI et al. 2006), which causes the growth of grass with a concurrent decrease in the share of papilionaceous plants and herbs. Continuous use of pasture by animals changes the composition of the plants as well (BARYŁA, KULIK 2006). The chance that animals in the wild will eat plants in various stages of the development is higher. Hence, deficiencies in the elements are not observed in these animals or they are insignificant (HUMMAN-ZIEHANK et al. 2008).

The level of mineral elements in fodder as well as in sheeps is insignificant, although mineral elements perform an important role in physiological and biochemical processes (CROOKSHANK et al. 1967, ZERVAS et al. 2001). They are also essential for proper metabolic processes in animal organisms, growth and development, as well as the level of productivity (BIS-WENCEL 2001, KHAN et al. 2007, KINCAID 1999, LANE et al. 1968). Mineral elements also affect the level of animal immunity (BOLAND et al. 2005). The interactions that occur between particular elements are of considerable significance for the mineral transformations in animals (MILLER 1985).

Many authors (BARANOWSKI 1992, 2000, FICK et al. 1976, KLATA et al. 2000, KOŁACZ et al. 1994, PEARL et al. 1983) have proved that the concentration of mineral elements in the blood serum does not show their actual demand. The content of mineral elements in tissues (muscle tissue, bone tissue), organs (heart, kidneys, liver) and in milk can be of great significance.

The aim of the present study was to analyse the mineral content in the blood serum and in the *Musculus longissimus dorsi* (*Mld*) in lambs of Polish Lowland Sheep and in the synthetic BCP line kept with their mothers in indoor and outdoor systems.

MATERIAL AND METHODS

The experiment was carried out in the Small Ruminants Research and Experimental Station in Bezek. The station belongs to the Department of Sheep and Goat Breeding at the University of Life Sciences in Lublin. The experiment was carried out twice in 2006 and 2007. Young rams of two genotypes were examined: the Polish Lowland sheep (PLS) and the BCP synthetic line. The sheep of Uhruska variety are kept as a preservative herd of a native breed that was created in this region after World War II. The herd is included in the programme of preservative breeding. The BCP synthetic line was created in Bezek with the participation of the following breeds of sheep: PLS Uhruska variety, prolific breeds (Romanowska, Finnish, Olkuska, Booroola), Berrichone du Cher and Charolaise. The breeding is of a prolific meat specialization.

The lambs with their mothers were bred in two systems:

Indoors – kept year-round in a sheep house. They could make use of a fenced sheep yard. The lambs from this group during the period of rearing were fed with hay and concentrates (crushed oats, and ground grain or bran).

Outdoors – kept year-round in the open air, with permanent access to a roofed shelter. In the summer, pasture was the form of basic nutrition.

For this purpose, approx. 5 ha of pasture was enclosed with a net, and the sheep, at any time of the day, could make use of the pasture's green fodder. The lambs bred by the mothers, in the same way, could also graze on the pasture. The lambs were provided with concentrates in feeders (at first crushed oat, then ground grain or bran). Care was also taken to provide the lambs with hay.

The lambs of both groups were born at the end of April and in May, due to the delayed date of the mothers being mated.

Blood from the lambs was taken from their outer jugular vein twice: when they were two and three months old. Blood sampling was always done in the morning. Each year, the blood was taken from 10 lambs within the same genotype and the maintenance system and from young rams and ewes. Each year, five young rams were slaughtered from each maintenance system and genotype. When slaughtered, the body mass was about 25-28 kg. Samples from the *musculus longissimus dorsi* were taken from the carcass for determination of the mineral content. In the blood serum and in the fresh muscle mass *Mld*, the content of such elements as Na, K, Ca, Mg, Zn, Cu and Fe was established. The ASA method was applied using a Solar 939 UNICAM device. The content of phosphorus in the blood serum was determined using the colorimetric method with Cormay monotests.

The results were elaborated statistically using a multi-factor analysis of variance (SAS 2003) for orthogonal data. Means and standard deviations were put in tables.

RESULTS AND DISCUSSION

The level of calcium in the blood serum in the second month of life was significantly lower in the lambs kept outdoors, compared to the group kept indoors. A similar tendency was observed for potassium (Table 1). Calcium is found mainly in the osseous tissue, as well as in the systemic tissues and fluids. Calcium is crucial for maintaining regular activity of the neural tissue and for ensuring the proper coagulation and work of the heart. An important role in the assimilation of calcium by the body is played by phosphorus and vitamin D. The level of calcium in the blood serum depends on the season of the year and on the physiological condition (KHAN et al. 2007). Its concentration influences the accumulation of heavy metals (PEARL et al. 1983). At the same time, no differences were recorded between the systems of maintenance with regard to the content of microelements.

In the third month of life, the calcium concentration in the blood serum increased. It was especially distinct in the outdoor group, where the level of phosphorus and copper was also higher. The level of sodium, irrespective of age, was below the reference values set for adult sheep. The role of sodium

Table 1

The content of macro- and microelements in the lamb blood serum dependent on the maintenance system

Element		Maintenance system			
		indoor		outdoor	
		mean	standard deviation	mean	standard deviation
Second month of life					
Macroelements ($mmol \cdot dm^{-3}$)	Mg	0.908	0.242	0.979	0.320
	Ca	3.14^{xx}	1.19	2.17^{xx}	0.61
	K	4.89^{x}	0.77	4.37^{x}	0.75
	Na	134.76	24.12	123.73	24.67
	P	2.58	0.36	2.75	0.54
Microelements ($\mu mol \cdot dm^{-3}$)	Cu	10.13	2.21	10.59	3.12
	Zn	14.74	4.84	14.52	3.53
	Fe	48.37	14.69	55.99	22.19
Third month of life					
Macroelements ($mmol \cdot dm^{-3}$)	Mg	1.033	0.378	1.076	0.261
	Ca	3.30^{xx}	0.71	3.87^{xx}	0.68
	K	4.57	0.66	4.41	0.75
	Na	125.92	21.23	127.28	29.51
	P	2.36^{xx}	0.44	2.65^{xx}	0.67
Microelements ($\mu mol \cdot dm^{-3}$)	Cu	10.09^{x}	3.12	11.46^{x}	2.92
	Zn	15.34^{x}	3.56	13.42^{x}	2.79
	Fe	34.65	12.30	31.12	10.93

Statistically significant differences at $^{xx}p < 0.01$, $^{x}p < 0.05$

and potassium is mainly connected with regulating the osmotic pressure of cells and the water metabolism in the body. Potassium is the main mineral element of cell cytoplasm as well as of wool ash. Sodium deficiency in sheep is supplemented by fodder salt. Sheep generally show good tolerance to high doses of salt (KINCAID 1999, SKRZYPCZAK 1983).

The iron content in lambs decreased with age (Tables 1, 2, 3), more clearly in the outdoor system than in the indoor system.

No statistically significant differences were revealed in the mineral composition between the various genotypes of lambs. Only the level of copper proved to be higher in the PLS lambs, compared to the BCP lambs (Table 2).

Table 2

The content of macro- and microelements in the lamb blood serum dependent on the genotype

Element		Genotype			
		Polish Lowland sheep		Synthetic line BCP	
		mean	standard deviation	mean	standard deviation
Second month of life					
Macroelements ($mmol \cdot dm^{-3}$)	Mg	0.975	0.278	0.913	0.290
	Ca	2.57	0.92	2.74	1.19
	K	4.64	0.88	4.63	0.72
	Na	130.57	25.68	127.92	24.30
	P	2.65	0.62	2.68	0.23
Microelements ($\mu mol \cdot dm^{-3}$)	Cu	11.24^{x}	3.03	9.48^{x}	1.99
	Zn	15.23	4.95	14.04	3.25
	Fe	55.29	19.25	49.08	18.64
Third month of life					
Macroelements ($mmol \cdot dm^{-3}$)	Mg	1.014	0.241	1.095	0.389
	Ca	3.70	0.60	3.47	0.86
	K	4.35	0.56	4.63	0.81
	Na	125.24	26.02	127.95	25.33
	P	2.46	0.73	2.54	0.39
Microelements ($\mu mol \cdot dm^{-3}$)	Cu	10.70	2.99	10.85	3.21
	Zn	14.75	3.06	14.01	3.56
	Fe	35.48	12.93	30.29	9.80

Statistically significant differences at $^{x}\, p < 0.05$

A higher concentration of magnesium in the lamb blood serum was recorded in 2006, irrespective of the lambs' age. In the second year, a higher content of calcium, potassium, sodium, phosphorus and copper was recorded in the third month of life (Table 3). Nearly 30% of all the magnesium forms part of the osseous tissue. Hence, magnesium deficiency is manifested in the form of grass tetany, excessive irritability of the nervous system or convulsions and may even cause death (Kania 1998, Khan et al. 2007, Reid et al. 1979). The content of magnesium in the blood serum, in this case, closely correlates to its content in the fodder provided. The absorption of magnesium remains strongly influenced by an adequate concentration of zinc in the feed (Salles et al. 2008).

Table 3

The content of macro- and microelements in the lamb blood serum dependent on the investigations year

Element		Year of investigations			
		2006		2007	
		mean	standard deviation	mean	standard deviation
Second month of life					
Macroelements (mmol · dm^{-3})	Mg	1.133^{xx}	0.220	0.755^{xx}	0.201
	Ca	3.26^{xx}	1.10	2.06^{xx}	0.54
	K	4.59	0.49	4.67	1.03
	Na	135.19	10.32	123.30	32.67
	P	2.60	0.22	2.73	0.61
Microelements (μmol · dm^{-3})	Cu	11.15	2.22	9.57	2.92
	Zn	12.69^{xx}	2.48	16.58^{xx}	4.67
	Fe	46.98^{x}	12.46	57.38^{x}	22.95
Third month of life					
Macroelements (mmol · dm^{-3})	Mg	1.300^{xx}	0.268	0.808^{xx}	0.119
	Ca	3.32^{xx}	0.64	3.85^{xx}	0.76
	K	4.30^{x}	0.75	4.68^{x}	0.61
	Na	109.40^{xx}	19.34	143.79^{xx}	18.20
	P	2.19^{xx}	0.38	2.82^{xx}	0.58
Microelements (μmol · dm^{-3})	Cu	8.37^{xx}	1.95	13.18^{xx}	1.83
	Zn	13.66	3.23	15.10	3.29
	Fe	30.29	11.73	35.49	11.21

Statistically significant differences at $^{xx}p < 0.01$, $^{x}p < 0.05$

Regarding the content of macroelements in the longissimus dorsi muscle, no significant differences were revealed between the lambs from two systems of maintenance. A higher copper content was recorded in the lambs kept outdoors compared to those kept indoors (Table 4). It may be observed that the macro- and microelement content in the longissimus dorsi muscle in the PLS lambs was higher than in the BCP lambs (Table 5). In 2007, as compared to 2006, the content of magnesium, calcium, copper, zinc and iron recorded was higher (Table 6). The mineral element content in the blood serum corresponded to the content in the longissimus dorsi muscle. Similar results were obtained by Baranowski (2000), Fick et al. (1976), and Klata et al. (2000).

Table 4

The content of macro- and microelements in the longissimus dorsi muscle of lambs dependent on the maintenance system

Element		Maintenance system			
		indoor		outdoor	
		mean	standard deviation	mean	standard deviation
Macroelements (mmol·kg^{-1} f. m.)	Mg	12.043	1.251	12.620	2.317
	Ca	1.192	1.029	1.585	1.466
	K	81.11	20.22	77.64	28.67
	Na	27.620	3.896	27.971	5.846
	Cu	10.476^{x}	8.429	16.297^{x}	10.892
Microelements (µmol·kg^{-1} f. m.)	Zn	435.8	60.8	431.1	93.5
	Fe	447.3	178.3	486.6	238.6

Statistically significant differences at $^{x}p< 0.05$

Table 5

The content of macro- and microelements in the longissimus dorsi muscle of lambs dependent on the genotype

Element		Genotype			
		Polish Lowland sheep		Synthetic line BCP	
		mean	standard deviation	mean	standard deviation
Macroelements (mmol·kg^{-1} f. m.)	Mg	12.891^{x}	2.381	11.772^{x}	0.884
	Ca	1.698	1.565	1.080	0.798
	K	82.77	24.93	75.98	24.35
	Na	28.959	4.700	26.632	4.948
	Cu	13.459	10.259	13.314	10.112
Microelements (µmol·kg^{-1} f. m.)	Zn	441.0	97.7	425.9	52.88
	Fe	468.8	179.8	465.2	239.3

Statistically significant differences at $^{x}p< 0.05$

Table 6

The content of macro- and microelements in the longissimus dorsi muscle of lambs dependent on the investigations year

Element		Year of investigations			
		2006		2007	
		mean	standard deviation	mean	standard deviation
Macroelements ($mmol \cdot kg^{-1}$ f. m.)	Mg	11.363^{xx}	0.459	13.300^{xx}	2.219
	Ca	0.828^{xx}	0.588	1.949^{xx}	1.510
	K	91.56^{xx}	4.46	67.20^{xx}	30.11
	Na	29.350^{x}	3.153	26.241^{x}	5.865
	Cu	10.689	8.807	16.083	10.707
Microelements ($\mu mol \cdot kg^{-1}$ f. m.)	Zn	384.3^{xx}	40.4	482.6^{xx}	75.713
	Fe	399.9^{x}	121.4	534.1^{x}	255.6

Statistically significant differences at $^{xx}\,p< 0.01$, $^{x}\,p< 0.05$

CONCLUSIONS

1. Changes were observed in the content of some elements in the blood serum, dependent on the age of the lambs. These changes are especially noticeable in the case of iron.

2. The system of lamb maintenance significantly influenced the concentration of calcium, phosphorus and zinc in the blood serum.

3. The content of macro- and microelements in the longissimus dorsi muscle in the PLS lambs was slightly higher than in the BCP lambs.

4. The content of mineral elements (except sodium) fell within the reference values set for adult ewes, which proves that the lambs' rearing and nutrition were conducted properly, regardless of the maintenance system.

5. The results presented concern young lambs, for which no reference standards have been formulated as regards the content of the macro- and micro- maintenance elements in the blood serum and in the muscles. These results can be used in the future in order to establish such standards.

REFERENCES

BARANOWSKI P. 1992. *Niektóre wskaźniki hematologiczne oraz stężenie składników mineralnych w surowicy krwi i krwinkach czerwonych owiec mieszańców merynos polski x suffolk [Some hematologic indices and concentration of mineral components in blood serum and red cells in Polish Merino x Sufolk cross sheep].* Med. Wet., 48 (3): 138-140. [in Polish]

BARANOWSKI P. 2000. *Wybrane wskaźniki krwi u owiec dorosłych oraz makroelementy w surowicy i tkance kostnej jagniąt w zależności od różnych czynników środowiska [Some blood indices in adult sheep and macroelements in serum and bone tissue of lambs depending on various environmental factors].* Wyd. AR w Szczecinie, ser. Rozprawy, 194. [in Polish]

BARYŁA R., KULIK M. 2006. *Zawartość azotu i podstawowych składników mineralnych w runi pastwiskowej w róznych latach jej użytkowania [Content of nitrogen and basic mineral components in pasture cover in different years of pasture use].* Ann. UMCS, E, 61: 157--164. [in Polish]

BIS-WENCEL H. 2001. *Rozpoznawanie i zapobieganie niedoborom mineralnym u przeżuwaczy w regionie południowo-wschodniej Polski [identification and prevention of mineral deficits in ruminants in south-eastern Poland].* Wyd. AR Lublin, ser. Rozprawy, 243. [in Polish]

BOLAND T.M., KEANE N., NOWAKOWSKI P., BROPHY P.O., CROSBY T.F. 2005. *High mineral and vitamin E intake by pregnant ewes lowers colostral immunoglobulin G absorption by the lamb.* J. Anim. Sci., 83: 871-878.

CROOKSHANK H. R., ROBBINS J. D. , KUNKEL H. O. 1967. *Relationship of dietary mineral intake to serum mineral level and the incidence of urinary calculi in lambs.* J. Anim. Sci., 26: 1179-1185.

FICK K. R., AMMERMAN C. B., MILLER S. M., SIMPSON C. F., LOGGINS P.E. 1976. *Effect of dietary lead on performance, tissue mineral composition and lead absorption in sheep.* J. Anim. Sci., 42 (2): 515-523.

GÓRSKI K., SABA L., BOMBIK T., BOMBIK E. 2005. *Poziom wybranych mikroelementów (Fe, Cu, Zn) w glebie, paszach i surowicy krwi krów w rejonie południowego Podlasia [Level of some micrpnutrients (Fe, Cu, Zn) in soil, feeds and blood serum of cows in South Podlasie].* Rocz. Nauk. PTZ, 1 (2): 309-318. [in Polish]

HE P.P., LV X.Z., WANG G.Y. 2004. *Effects of Se and Zn supplementation on the antagonism against Pb and Cd in vegetables*. Environm. Int., 30: 167-172.

HUMANN-ZIEHANK E. ,GANTER M., HENNIG-PAUKA I , BINDER A. 2008. *Trace mineral status and liver and blood parameters in sheep without mineral supply compared to local roe deer (Capreolus capreolus) populations.* Small Rum. Res., 75: 185-191.

KANIA B.F. 1998: *Znaczenie magnezu dla zwierząt.* Med. Wet., 54 (6:) 378-382.

KHAN Z.I.,. HUSSAIN A, ASHRAF M., ASHRAF M.Y., MCDOWELL L.R. 2007. *Macromineral status of grazing sheep in a semi-arid region of Pakistan.* Small Rum. Res., 68: 279–284.

KINCAID R.L. 1999. *Assessment of trace mineral status of ruminants: A review.* Proc. Am. Soc. Anim. Sci., 1-10.

KLATA W., BARANOWSKI P., BARANOW-BARANOWSKI S. 2000. *Składniki mineralne surowicy krwi i kości kręgów ogonowych jagniąt rasy merynos polski [Mineral components in blood serum and caudal vertebra bones in the Polish Merino lambs].* Med. Wet., 56 (9): 586--588. [in Polish]

KOŁACZ R., DOBRZAŃSKI Z., PATKOWSKA-SOKOŁA B., BODKOWSKI R.1994. *Wpływ przemysłu miedziowego na akumulację metali ciężkich w tkankach i narządach [Influence of the copper industry on accumulation of heavy metals in tissues and organs].* Zesz. Nauk. Prz. Hod. PTZ, 13: 316-317. [in Polish]

KOZŁOWSKI S., GOLIŃSKI P., ZIELEWICZ W., BINIAŚ J. 2006. *Badania nad nawożeniem pastwiska nawozami płynnymi [Studies on fertilization of pastures with liquid fertilizers].* Ann. UMCS, E, 61: 341-352. [in Polish]

LANE A. G., CAMPBELL J. R. , KRAUSE G. F. 1968. *Blood mineral composition in ruminants.* J. Anim Sci., 27: 766-770.

MILLER E.R. 1985. *Mineral disease interactions.* J. Anim. Sci., 60 (6): 1500-1507.

PEARL D. S., AMMERMAN C. B., HENRY P. R., Littell R. C. 1983. *Influence of dietary lead and calcium on tissue lead mineral composition in sheep accumulation and depletion, lead metabolism and tissue* J. Anim. Sci., 56: 1416-1426.

PRZYBYSZ T., BOROWIEC J., KAMIŃSKA A. 2003. *Próba statystycznej interpretacji wyników badań chemizmu siedlisk łąkowych Lubelszczyzny [An attempt at statistical interpretation of the results of studies on the chemism of meadow habitats in the Lublin region].* Ann. UMCS, E, 58: 79-92. [in Polish]

REID R. L., JUNG G. A., WOLF C H. , KOCHER R. E. 1979. *Effects of magnesium fertilization on mineral utilization and nutritional quality of alfalfa for lambs.* J. Anim. Sci., 48: 1191--1201.

SALLES M.S.V, ZANETTI M.A., SALLES F.A. 2008. *Effect of monensin on mineral balance in growing ruminants reared under different environmental temperatures*. Anim. Feed Sci. Tech., 141: 233–245.

SAS Institute Inc. 2003. *User's Guide*, v. 9.1.3, Cary.

SKRZYPCZAK W. 1983. *O znaczeniu elektrolitów Na, K, Cl dla organizmu zwierząt [On the role of electrolytes Na, K, Cl in animal organisms].* Prz. Hod., 10: 12-14. [in Polish]

ZERVAS G., RISSAKI M., DELIGEORGIS S. 2001. *Free-choice consumption of mineral lick blocks by fattening lambs fed ad libitum alfalfa hay and concentrates with different trace mineral content.* Liv. Prod. Sci., 68: 251–258.