ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume LX 9 Number 6, 2012

TRACE ELEMENT CONTENT IN MARKET EGGS IN BOHEMIA

H. Dušová, J. Trávníček, Z. Peksa, D. Falta, V. Pálka

Received: July 17, 2012

Abstract

DUŠOVÁ, H., TRÁVNÍČEK, J., PEKSA, Z., FALTA, D., PÁLKA, V.: *Trace element content in market eggs in Bohemia.* Acta univ. agric. et silvic. Mendel. Brun., 2012, LX, No. 6, pp. 75–80

The aim of this study was to analytically determine the content of iodine, copper, zinc and manganese in the yolk of consumer eggs in Bohemia in 2007 and 2008. Investigated eggs originated from six so called intensive farms with large flocks (118 eggs) and twelve backyard farms or small-flock establishments (136 eggs) from three administrative regions in Czech Republic. Eggs from intensive farms were obtained directly from the establishments, while eggs from backyard farms were purchased from private farmers. Spectrophotometric Sandell-Kolthoff method was used for determination of iodine content in egg yolk, while Cu, Zn and Mn levels were determined by the flame absorption spectrophotometric method (AAS). The average content in fresh egg yolk from intensive farms was determined to 0.9 ± 0.2 for iodine, 8.4 ± 2.1 of copper, 29.8 ± 6.9 of zinc and 1.2 ± 0.3 of manganese, all in $mg \cdot kg^{-1}$, as compared to yolk content from backyard farms with 0.4 ± 0.04 $mg \cdot kg^{-1}$ of iodine, 10.8 ± 2.9 of copper, 32.5 ± 6.9 of zinc and 1.5 ± 0.3 of manganese. Average content of copper, zinc and manganese was lower in egg yolks from intensive farms ($P < 0.01$) as compared to the egg yolks from backyard farms, while iodine content on the other hand was lower in eggs from backyard farms ($P < 0.01$).

egg yolk, iodine, copper, zinc, manganese

For the past ten years several authors have dealt with the essential trace elements in hen eggs in relation to given feed (Balevi and Coskun, 2004; Haldimann *et al.*, 2005; Skřivan *et al.*, 2005, 2006; Trávníček *et al.*, 2005, 2006), with focus on the effects of both the elements deficiency and surplus.

Eggs belong to easily digestible food with balanced content of nutrients. Among significant components in eggs dominate proteins that are furthermore biologically more valuable than meat proteins. The content of vitamins, minerals and trace elements is also considerable, and can be influenced by the composition of hen feed.

The deficiency of trace elements in hens contributes to several problems, such as enlarged endocrinal glands, slow growth and increase of fat reserves in case of iodine (Zelenka and Zeman, 2006), lower egg production and feed intake, worsened quality of eggshells and increased embryonic mortality in case of copper (Wolf *et al.*, 1998), zinc (Zamani *et al.*, 2005) and manganese (Hossain and Bertechini, 1998). Many authors have discussed the influence of trace element supplementation to hens on their egg production. For instance, Yalcin *et al.* (2004) claims that supplementation of 6 mg I per kg feed is adequate and has no negative influence on the production, egg quality or overall effectivity of the hens, even though Zelenka *et al.* (2006) places the iodine requirement for laying hens at 1 mg of iodine per kg feed (at 115 g feed daily). Idowu *et al.* (2006) found a positive influence of supplementation of 100–300 mg $Cu \cdot kg^{-1}$ feed, although supplementation of 450 mg $Cu \cdot kg^{-1}$ results in production decrease (Güçlü *et al.*, 2008). Zelenka *et al.* (2006) determined the requirement of copper for egg laying hens at 10 $mg \cdot kg^{-1}$ of feed mixture. Increased egg production dependent of zinc supplementation was also shown by Durmus *et al.* (2004), where the amount was established at 70 $mg \cdot kg^{-1}$ of feed (Zelenka *et al.*, 2006). However, surplus supplementation of trace elements has been shown to have several negative effects including inhibited ovulation or increased embryonic mortality for iodine surplus (Lewis, 2004), lower egg weight for surplus of zinc (Kim and Patterson, 2005), decreased egg production for surplus of copper (Chiou *et al.*, 1998 and Güçlü *et al.*, 2008) and decrease of food intake caused by surplus of manganese (Black *et al.*, 1985).

Iodine content in eggs from hens in the CR has been studied by Trávníček *et al.* (2005), who found an average value of 1.1 ± 0.3 mg·kg^{-1} of fresh mass in egg yolk from intensive farm production while only 0.2 ± 0.07 mg·kg^{-1} in backyard farm production. Kroupová *et al.* (1999) show statistically significant dependence between iodine content in egg yolk and its intake from feed. The average content of zinc in egg yolk is according to Kaya *et al.* (2001) 38.4 ± 1.2 mg·kg^{-1} and that of copper 0.8 ± 0.01 mg·kg^{-1} of fresh mass (Idowu *et al.*, 2006). Mabe *et al.* (2003) determined the average content of manganese to 0.63 mg·kg^{-1} of fresh mass. For egg laying hens 70 mg of manganese per kg feed is a necessary daily dosage at 115 g of feed (Zelenka *et al.*, 2006).

The choice of egg yolk as the target material for trace element content determination was based on data obtained by Groppel *et al.* (1989) showing twenty times higher concentration of iodine in egg yolk as compared to egg white, with similar results for concentrations of Zn, Mn and Cu. Keeping track of trace elements in eggs is important not only regarding the health of the hens, but also because eggs are an important trace element source for people.

The aim of this study was to analytically determine the content of iodine, copper, zinc and manganese in yolk of market eggs in Bohemia.

MATERIALS AND METHODS

The content of iodine, copper, zinc and manganese in egg yolk was followed between March 2007 and June 2008 in eggs from twelve backyard farms and six intensive farms in South Bohemian, Central Bohemian and Pilsen regions. Eggs from intensive farms were bought directly on the farms, while eggs from backyard farms were purchased from private farmers. The total of 118 eggs from intensive farms and 136 eggs from backyard farms were examined. It was approximately 20 eggs from each intensive farm and approximately 12 from each backyard farm. Most farms were in South Bohemian region and therefore there were evaluated the most of eggs. Laying hens in intensive farms (all regions) were in the collection of eggs at 26–35 weeks of lay. It was not possible to determine in laying hens of backyard farms. For the analysis of the 4 elements was used 1 egg yolk. Iodine content was determined by the spectrophotometric Sandell-Kolthoff method after incineration in alkaline solution. The principle of the assessment is reduction of Ce^{4+} to Ce^{3+} in the presence of As^{3+} and measuring the catalytic effect of iodine. Cu, Zn and Mn contents were determined by the flame absorption spectrophotometry method (AAS), using atomic absorption spectrophotometer UNICAM 969 from Chromspek, Prague. In order to determine the source of the examined elements, their content in feed mixtures used in the followed intensive farms was established. Obtained results showed 0.81–2.5 mg of iodine, 13.3–15.5 mg of copper, 70.9–92.4 mg of zinc and 99.8–134.0 mg of manganese per one kilogram of dry feed. Laying hens in intensive farms were fed by feed for laying hens called N1. There were no differences in the composition of the mixture between intensive farms. All intensive farms used for breeding of laying hens the battery cages. The feed of laying hens from backyard farms was consisted mainly of a mixture of cereals, especially wheat. Further included bread and kitchen scraps. Laying hens in backyard farms were fed by no premix with minerals or vitamins.

Statistical analysis

Data was analysed using the Statistica 6.0 Cz software. Scheffe's tests were performed on confidence level 95%. Results are expressed in mean values, standard deviations (SD), minimum and maximum.

RESULTS AND DISCUSSION

The average content of iodine in fresh matter of yolk from intensive farm produced eggs was measured to 0.9 ± 0.2 mg·kg^{-1} (Tab. I). Literature sources differ greatly on the iodine content, with higher values reported for example by Trávníček *et al.* (2006), with 1.7 ± 1.2 mg I·kg^{-1} or Haldimann *et al.* (2005) with 1.6 mg I·kg^{-1}. Similar values to our study were presented by for example Kaufmann, (1997) and Herzig *et al.* (2005). Lower average iodine content in egg yolk was found by Dahl *et al.* (2004) at 0.5 mg I·kg^{-1} and also by Lee *et al.* (1994) with only 0.3 mg·kg^{-1}. The lowest average iodine content was found in eggs from intensive farms in Central Bohemian region ($P < 0.01$). Average iodine content found from backyard farms (0.4 ± 0.04 mg·kg^{-1}) was similar to concentrations reported by Herzig *et al.* (2005) and Trávníček *et al.* (2006). The differences between the minimum and maximum values show a tendency to large variability of the measured iodine content (Tab. I) which can be related to the different contents of iodine in feed used on different farms as the iodine content in egg yolk is directly dependent on its intake from feed (Kroupová *et al.*, 1999). Zelenka *et al.* (2006) determined the need of iodine for egg laying hens to 1 mg per kilogram of feed mixture (at 115 g feed per day). Feed mixtures fed to hens in the observed intensive farm establishments varied between 0.81 and 2.5 mg per kg of dry feed. This supply of iodine was estimated as sufficient with tendency on surplus.

Egg yolks from backyard farms were shown to contain less than half the amount of iodine (Tab. I) as compared to egg yolks from intensive farms. These differences were statistically very significant in both investigated years ($P < 0.01$). The higher content of iodine in the yolk from the intensive farm results

I: *Iodine content (mg·kg⁻¹ fresh matter) in yolks from intensive farms and backyard farms eggs*

Number of flock	Region	Iodine in the yolk (mg·kg⁻¹ fresh matter)									
		Eggs	Intensive farms				Eggs	Backyard farms			
		n	mean	SD	min.	max.	n	mean	SD	min.	max.
1	South Bohemian	58[1]	1.1^{a}	0.4	0.3	1.7	88[4]	0.3^{c}	0.03	0.1	0.5
2	Central Bohemian	20[2]	0.6^{b}	0.2	0.2	1.1	24[5]	0.4	0.04	0.2	0.6
3	Pilsen	40[3]	1.0	0.4	0.2	1.9	24[6]	0.6	0.20	0.2	1.2
	Suma	**118**	**0.9^{d}**	**0.2**	**0.2**	**1.7**	**136**	**0.4^{e}**	**0.04**	**0.1**	**1.2**

[a:c; d:e] $P < 0.01$; [a:b] $P < 0.05$

[1]3 farms, [2]1 farm, [3]2 farms, [4]8 farms, [5]2 farms, [6]2 farms

from the use of iodine supplemented feed mixtures in these establishments.

The concentration of copper in fresh matter of yolk from intensive farm eggs was 8.4 ± 2.1 mg·kg⁻¹ on average (Tab. II). In comparison to literature these values are higher. For example Idowu *et al.* (2006) puts the copper content in egg yolk only to 0.77 ± 0.01 mg ·kg⁻¹ and Mabe *et al.* (2003) to 1.64 mg·kg⁻¹. Slightly higher values of copper content are presented by Skřivan *et al.* (2005), namely 3.32 mg·kg⁻¹ dry mass and as early as 1929 Lindow *et al.* (1929) published a study with the value of 4 mg·kg⁻¹.

Lowest concentration of copper obtained in this study was obtained from eggs from intensive farms in Pilsen region, namely 4.3 ± 1.0 mg·kg⁻¹ ($P < 0.01$). The average amount of copper in fresh egg yolk matter from backyard farm production was shown to be 10.8 ± 2.9 mg·kg⁻¹. No significant differences could be seen in copper concentration values between backyard farm produced eggs from different regions. However, these values were significantly higher as compared to the copper contents in intensive farm produced eggs ($P < 0.01$). Feed mixture given to laying hens in intensive farms contained 13.3 to 15.5 mg per kg of dried feed. The stated values twice exceeded the need of copper for laying hens argued by Zelenka *et al.* (2006) about 10 mg·kg⁻¹ feed (at 115 g feed per day). Copper saturation of egg laying hens in the followed farms can be seen as exaggerated although the opinion on the influence of copper content in feed and its effect on its content in egg yolk differ, where already in 1929 Elvehjem *et al.* (1929) found that copper supplementation of feed does not increase its content in eggs and Mabe *et al.* (2003) shown a slight increase of copper content in egg yolk after feed supplementation with inorganic form of copper. On the other hand, Pesti and Bakali, (1998), Güçlü *et al.* (2008), Skřivan *et al.* (2005) as well as Idowu *et al.* (2006) all agree on a positive impact of copper supplementation of feed on its content in eggs.

The average zinc content in fresh matter egg yolk from intensive farms was 29.8 ± 6.9 mg·kg⁻¹ (Tab. III), which is similar to values presented by authors concerned with zinc content in eggs. For example Mabe *et al.* (2003) puts the zinc content in egg yolk at 37.08 mg·kg⁻¹ and Kaya *et al.*, (2001) at 30.35 ± 2.73 mg·kg⁻¹. For backyard farms the average zinc content in fresh matter egg yolk was 32.5 ± 6.9 mg·kg⁻¹ (Tab. III). Significant differences have not been found between different regions, although the type of farming does play a significant role ($P < 0.01$). Laying hens in intensive farms were fed mixtures that contained between 70.9 and 92.4 mg Zn per kilogram of dry mass which surmounts the necessary dosage by about a third according to the 70 mg Zn·kg⁻¹ dry mass (at 115 g feed per day) published by Zelenka *et al.* (2006).

Higher Zn content ($P < 0.01$) in egg yolk from backyard farms shows that the natural form of feed given to hens in this type of establishment is from that point more advantageous. Literature data on the influence of zinc content in feed on its content in egg yolk differ. Verheyen *et al.* (1990) and Stahl *et al.* (1986) for example show significant increase of zinc content in egg yolk in case of zinc supplementation of feed, while Skřivan *et al.* (2005) and Kaya *et al.* (2001) report a decrease of zinc content in egg yolk when supplemented in feed.

Manganese content in fresh matter of egg yolk from intensive farms was 1.2 ± 0.3 mg·kg⁻¹ on average

II: *Copper content (mg·kg⁻¹ fresh matter) in yolks from intensive farms and backyard farms eggs*

Number of flock	Region	Cu in the yolk (mg·kg⁻¹ fresh matter)									
		Eggs	Intensive farms				Eggs	Backyard farms			
		n	mean	SD	min.	max.	n	mean	SD	min.	max.
1	South Bohemian	58[1]	6.3	1.5	1.8	14.3	94[4]	10.6	2.2	1.4	25.1
2	Central Bohemian	20[2]	14.5^{a}	3.0	7.4	14.6	20[5]	11.6	3.1	5.5	16.8
3	Pilsen	40[3]	4.3^{b}	1.0	1.5	10.5	22[6]	11.3	3.0	3.6	19.7
	Suma	**118**	**8.4^{c}**	**2.1**	1.5	14.6	**136**	**10.8^{d}**	**2.9**	1.4	25.1

[a:b] $P < 0.05$; [c:d] $P < 0.01$

[1]3 farms, [2]1 farm, [3]2 farms, [4]8 farms, [5]2 farms, [6]2 farms

III: *Zinc content (mg·kg⁻¹ fresh matter) in yolks from intensive farms and backyard farms eggs*

Number of flock	Region	Zn in the yolk (mg·kg⁻¹ fresh matter)									
		Eggs	Intensive fams				Eggs	Backyard farms			
		n	mean	SD	min.	max.	n	mean	SD	min.	max.
1	South Bohemian	58[1]	28.3	5.1	15.2	38.2	88[4]	33.4	8.1	17.6	50.8
2	Central Bohemian	20[2]	29.3	8.0	16.1	43.8	24[5]	31.8	3.5	21.1	37.3
3	Pilsen	40[3]	31.7	6.8	18.1	36.3	24[6]	32.3	7.3	22.6	53.2
	Suma	**118**	**29.8[a]**	**6.9**	**15.2**	**43.8**	**136**	**32.5[b]**	**6.9**	**22.6**	**53.2**

[a:b] $P < 0.01$
[1]3 farms, [2]1 farm, [3]2 farms, [4]8 farms, [5]2 farms, [6]2 farms

IV: *Manganese content (mg·kg⁻¹ fresh matter) in yolks from intensive farms and backyard farms eggs*

Number of flock	Region	Mn in the yolk (mg·kg⁻¹ fresh matter)									
		Eggs	Intensive farms				Eggs	Backyard farms			
		n	mean	SD	min.	max.	n	mean	SD	min.	max.
1	South Bohemian	58[1]	1.3[a]	0.3	0.2	3.4	92[4]	1.4	0.3	0.2	2.6
2	Central Bohemian	20[2]	1.7[c]	0.4	0.7	3.7	24[5]	1.1	0.4	0.2	2.2
3	Pilsen	40[3]	0.5[b]	0.1	0.1	0.9	20[6]	1.3	0.3	0.4	2.2
	Suma	**118**	**1.2[d]**	**0.3**	**0.1**	**3.7**	**136**	**1.5[e]**	**0.3**	**0.4**	**2.6**

[b:a,c] $P < 0.05$; [d:e] $P < 0.01$
[1]3 farms, [2]1 farm, [3]2 farms, [4]8 farms, [5]2 farms, [6]2 farms

(Tab. IV). Literature data is generally lower than data from this study. For example Mabe *et al.*, (2003) found 0.63 mg Mn kg⁻¹ and USDA (2002) 0.55 mg·kg⁻¹. The lowest Mn content was found for intensive farms in Pilsen region ($P < 0.01$). The average manganese content in fresh matter off egg yolk from backyard farms was 1.5 ± 0.3 mg·kg⁻¹ (Tab. IV). There were no significant differences in manganese concentrations in egg yolk among the backyard farms, but the values were generally higher when compared to the intensive farm values ($P < 0.01$). The minimum and maximum values show considerable variability in the measured manganese content. Feed mixtures given to laying hens in intensive farms contain from 99.8 to 134.0 mg Mn·kg⁻¹ dry mass and these contents are almost double from the 70 mg·kg⁻¹ requirements (Zelenka *et al.*, 2006). Higher content ($P < 0.01$) of Mn in egg yolk from backyard farms also explains the different opinions on the influence the Mn content in feed has on the resulting content in yolk. Ochrimenko *et al.* (1990) for instance found that manganese supplementation has no influence on its content in eggs. Mabe *et al.* (2003) on the other hand showed a slight increase of Mn content in egg yolk while Hill and Mathers, (1968) found a significant increase after an addition of Mn to feed.

CONCLUSION

Eggs from both intensive and backyard farms have the potential of being a natural source of iodine, copper, manganese and zinc for humans. Average content of copper, zinc and manganese was lower in egg yolks from intensive farms ($P < 0.01$) as compared to the egg yolks from backyard farms, while iodine content on the other hand was lower in eggs from backyard farms ($P < 0.01$). Further increase of these trace elements in feed of egg laying hens in intensive farms would be beneficial for neither health nor production of the hens, nor for nutrition of the inhabitants of Bohemia.

SUMMARY

Eggs belong to major components of nutrition for the human population in Bohemia. The aim of this study was to analytically determine the content of iodine, copper, zinc and manganese in egg yolk of consumer eggs from laying hens bred in Bohemia. The concentration of the mentioned trace elements in egg yolk was investigated between March 2007 and June 2008 in twelve small-scale or backyard farms and six large-scale or intensive farms in three administrative regions. The total number of investigated eggs reached 118 from intensive farming and 136 from backyard farms. Iodine content was determined after incineration in alkaline environment by spectrophotometric Sandell-Kolthoff method. Contents of Cu, Zn and Mn were established by flame absorption spectrophotometry (AAS), with atomic absorption spectrophotometer UNICAM 969 from Chromspek Prague. For the assessment of supply of the trace elements to hens, their contents in hen feed mixtures used on the investigated intensive farms were determined with the result of sufficient or surplus concentrations

of these elements found. Average iodine content in fresh egg yolk matter was measured to 0.9 ± 0.2 mg·kg^{-1} in intensive farm eggs and 0.4 ± 0.04 mg·kg^{-1} in the small-scale farm eggs ($P < 0.01$). The average content of the other investigated elements in intensive farm eggs was 8.4 ± 2.1 of copper, 29.8 ± 6.9 of zinc and 1.2 ± 0.3 of manganese, all in mg·kg^{-1} fresh matter. In backyard farm eggs the average contents were measured to 10.8 ± 2.9 of copper, 32.5 ± 6.9 of zinc and 1.5 ± 0.3 of manganese, again in mg·kg^{-1} fresh matter. Eggs from both intensive and backyard farms have the potential of being a natural source of iodine, copper, manganese and zinc for humans. Average content of copper, zinc and manganese was lower in egg yolks from intensive farms ($P < 0.01$) as compared to the egg yolks from backyard farms, while iodine content on the other hand was lower in eggs from backyard farms ($P < 0.01$). Further increase of these trace elements in feed of egg laying hens in intensive farms would be beneficial for neither health nor production of the hens, nor for nutrition of the inhabitants of Bohemia.

Acknowledgement

This study was supported by the Project 022/2010/Z of the Grant Agency of the University of South Bohemia and Internal Grant Agency of FA, MENDELU TP 1/2012.

REFERENCES

BALEVI, T., COSKUN, B., 2004: Effects of dietary copper on production and egg cholesterol content in laying hens. *Br. Poult. Sci.*, 45: 530–534.

BLACK, J. R., AMMERMAN, C. B., HENRY, P. R., MILES, R. D., 1985: Effect of dietary manganese and age on tissue trace mineral composition of broiler-type chicks as a bioassay of manganese sources. *Poult. Sci.*, 64: 688–693.

CHIOU, P. W. S., CHEN, K. L., BI, YU., 1998: Effect of dietary organic arsenicals and cupric sulfate on copper toxicity, liver accumulation and residue in eggs and excreta of laying hens. *Anim. Feed Sci. Technol.*, 73: 161–171.

DAHL, L., JOHANSSON, L., JULSHAMN, K., MELTZER, H. M., 2004: The iodine content of Norwegian foods and diets. *Public Health Nutr.*, 7: 569–576.

DURMUS, I., ATASOGLU, C., MIZRAK, C., ERTAS, S., KAYA, M., 2004: Effect of increasing zinc concentration in the diets of brown parent stock layers on various production and hatchability traits. *Arch. Tier.*, 47: 483–489.

ELVEHJEM, C. A., KEMMERER, A. R., HART, E. B., HALPIN, J. G., 1929: The effect of the diet of the hen on the iron and copper content of the egg. *J. Biol. Chem.*, 85: 89–96.

GROPPEL, B., KÖHLER, B., SCHOLZ, E., 1989: Aktuelle interdisziplinäre Probleme des Iodmangels, der Iodoprophylaxe, des Iodexzesses und antithyreoidaler Substanzen. Leipzig, Karl – Marx – Universität. 69–73.

GÜÇLÜ, B. K., KARA, K., BEYAZ, L.,UYANIK, F., EREN, M., ATASEVER A., 2008: Influence of dietary copper proteinate on performance, selected biochemical parameters, lipid peroxidation, liver, and egg copper content in laying hens. *Biol. Trace Elem. Res.*, 125: 160–169.

HALDIMANN, M., ALT, A., BLANC, A., BLONDEAU, K., 2005: Iodine content of food groups. *J. Food Compos. Anal.*, 18: 461–471.

HERZIG, I., KURSA, J., TRÁVNÍČEK, J., KROUPOVÁ, V., 2005: Milk, meat and eggs as food sources of iodine in the Czech Republic. In: *Abstracts of the 5th International symposium on trace elements in human: New perspectives. October, 13th–15th 2005,* Athens, Greece, 92–93.

HILL, R., MATHERS, J. W., 1968: Manganese in the nutrition and metabolism of the pullet. 1. Shell thickness and manganese content of eggs from birds given a diet of low or high manganese content. *Br. J. Nutr.*, 22: 625–633.

HOSSAIN, S. M., BERTECHINI, A. G., 1998: Effect of varying manganese and available phosphorus levels in the diet on egg production and eggshell quality of layers. *Anim. Feed Sci. Technol.*, 71: 303–308.

IDOWU, O. M. O., LANIYAN, T. F., KUYE, O. A., OLADELE-OJO, V. O., ERUVBETINE, D., 2006: Effect of copper salts on performance, cholesterol, residues in liver, eggs and excreta of laying hens. *Archiv. Zootecnia*, 55: 327–338.

KAUFMANN S., 1997: *Ergänzende Strategien zur Bekämpfung von Jodmangel in Deutschland und Südostasien: Jodanreicherung in Lebensmitteln tierischen Ursprungs.* [Dissertation]. Institut für Ernährungswissenschaft der Technischen Universität München, Fakultät für Landwirtschaft und Gartenbau. 95.

KAYA, S., UMUCALILAR, H. D., HALÍLOGLU, S., ÍPEK, H., 2001: Effect of dietary vitamin A and zinc on egg yield and some blood parameters of laying hens. *Turkish J. Vet. Anim. Sci.*, 25: 763–769.

KIM, W. K., PATTERSON, P. H., 2005: Effects of dietary zinc supplementation on hen performance, ammonia volatilization, and nitrogen retention in manure. *J. Environ. Sci. Health B*, 40: 675–686.

KROUPOVÁ, V., TRÁVNÍČEK, J., KURSA, J., KRATOCHVÍL, P., KRABAČOVÁ, I., 1999: Iodine content in egg yolk during its excessive intake by laying hens. *Czech J. Anim. Sci.*, 44: 369–376.

LEE, S. M., LEWIS, J., BUSS, D. H., HOLCOMBE, G. D., LAWRANCE, P. R., 1994: Iodine in British foods and diets. *Br. J. Nutr.*, 72: 435–446.

LEWIS, P. D., 2004: Responses of domestic fowl to excess iodine: a review. *Br. J. Nutr.*, 91: 29–39.

LINDOW, C. W., ELVEHJEM, C. A., PETERSON, W. H., 1929: The copper content of plant and animal foods. *J. Biol. Chem.*, 82: 465–471.
MABE, I., RAPP, C., BAIN, M. M., NYS, Y., 2003: Supplementation of a corn-soybean meal diet with manganese, copper, and zinc from organic or inorganic sources improves eggshell quality in aged laying hens. *Poult. Sci.*, 82: 1903–1913.
OCHRIMENKO, C., RICHTER, G., LEMSER, A., KRAUSE, U., 1990: Studies of Mn supplementation in the feed for laying hens. *Arch. Tierer.*, 40: 1097–1108.
PESTI, G. M., BAKALLI, R. I., 1998: Studies on the effect of feeding cupric sulfate pentahydrate to laying hens on egg cholesterol content. *Poult. Sci.*, 77: 1540–1545.
STAHL, J. L., COOK, M. E., SUNDE, M. L., 1986: Zinc supplementation: its effect on egg production, feed conversion, fertility, and hatchability. Poult. Sci., 65: 2104–2109.
SKŘIVAN, M., SKŘIVANOVÁ, V., MAROUNEK, M., 2005: Effects of dietary zinc, iron, and copper in layer feed on distribution of these elements in eggs, liver, excreta, soil, and herbage. *Poult. Sci*., 84: 1570–1575.
SKŘIVAN, M., SKŘIVANOVÁ, V., MAROUNEK, M., 2006: Effect of various copper supplements to feed of laying hens on Cu content in eggs, liver, ecreta, soil, and herbage. Arch. Environ. Contam. Toxicol., 50: 280–283.
TRÁVNÍČEK, J., HERZIG, I., KURSA, J., KROUPOVÁ, V., 2005: Uplatnění suplementace stopových prvků hospodářských zvířat v potravním řetězci. In: *Sborník z konference s mezinárodní účastí o zdravotní nezávadnosti a produkční účinnosti krmiv,* "VI. Kábrtovy dietetické dny" 5. 5. 2005. Brno, VFU Brno, 201–206.
TRÁVNÍČEK, J., KROUPOVÁ, V., HERZIG, I., KURSA, J., 2006: Iodine content in consumer hen eggs. *Vet. Med. Czech,* 51: 93–100.
USDA (2002): National Nutrient Database for Standard Reference, Release17. [online] [cit. 2008-12-01]. Dostupný na World Wide Web: http://www.nal.usda. gov/fnic/foodcomp/search.
VERHEYEN, G., HELSEN, J., DECUYPERE, E., 1990: Accumulation of zinc in egg yolk, ovarian follicles and organs after forced resting by high dietary zinc. Br. Poult. Sci., 31: 147–154.
WOLF, P., BAYER, G., WENDLER, C., KAMPHUES, J., 1998: Mineral deficiency in pet birds. *J. Anim. Physiol. Anim. Nutr.,* 80: 140–146.
YALCIN, S., KAHRAMAN, Z., YALCIN, S., YALCIN, S. S., DEDEOGLU, H. E., 2004: Effects of supplementary iodine on the performance and egg traits of laying hens. *Br. Poult. Sci.,* 45: 499–503.
ZAMANI, A., RAHMANI, H. R., POURREZA, J., 2005: Effect of different levels of manganese and zinc on performance traits and breaking eggs in laying hens. *Pakistan J. Biol. Sci.,* 8: 1035–1040.
ZELENKA, J., HEGER, J., PETRIKOVIČ, P., SOMMER, A., 2006: *Potreba živín a výživná hodnota krmiv pre hydinu*. 3. vyd. Nitra: SCPV, 54 s.
ZELENKA, J., ZEMAN, L., 2006: *Výživa a krmení drůbeže*. 1. vyd. Praha: Biofaktory Praha, 117 s.

Address

Ing. Hana Dušová, prof. Ing. Jan Trávníček, CSc., Ing. Zdeněk Peksa, Ing. Václav Pálka, Katedra veterinárních disciplín a kvality produktů, Jihočeská univerzita v Českých Budějovicích, Studentská 13, 370 05 České Budějovice, Česká republika, Ing. Daniel Falta, Ph.D., Ústav chovu a šlechtění zvířat, Mendelova univerzita v Brně, Zemědělská 1, 613 00 Brno, Česká republika, e-mail: HDusova@seznam.cz, Falta.Daniel@seznam.cz