ACTA VET. BRNO 2008, 77: 503-508; doi:10.2754/avb200877040503

Influence of Chromium and Cadmium Addition on Quality of Japanese Quail Eggs

M. SKALICKÁ[1], B. KORÉNEKOVÁ[2], P. NAĎ[1], J. ŠÁLY[3]

[1]Department of Nutrition, Dietetics and Animal Breeding
[2]Department of Food Hygiene and Food Technology
[3]Internal Clinic, University of Veterinary Medicine, Košice, Slovak Republic

Received December 12, 2007
Accepted October 1, 2008

Abstract

Skalická M., B. Koréneková, P. Naď, J. Šály: Influence of Chromium and Cadmium Addition on Quality of Japanese Quail Eggs. Acta Vet. Brno 2008, 77: 503-508.

The experiment was conducted to evaluate the effect of chromium (Cr) and cadmium (Cd) on the quality of Japanese quail eggs. The birds (n = 60) were divided into 3 groups of 20 animals each. Group 1 was the control group. Group 2 was administered 0.12 mg Cr/day (Cr group) per quail in drinking water, whereas Group 3 was given a combination of 0.12 mg Cd and 0.12 mg Cr/day (Cd-Cr group). The distribution of Cd in eggs, the egg mass, and the strength and thickness of shells was determined after after Day 35 and 58 of administration. Addition of Cr had a positive effect on the weight of eggs. A significant decrease of eggshell strength ($p < 0.05$) and thickness was found after Day 35 and 58 of the experiment in the Cd-Cr group (3) in comparison to the Cr-only group (2) and the control group (1). The content of Cd was significantly lower ($p < 0.05$) in eggshells and in the egg yolk from the Cr-only group (2) in comparison to the Cd-Cr group (3) and the control group (1). The data show that addition of Cr can improve quality indicators of quail eggs and eliminate the negative effect of Cd.

Trace elements, Coturnix coturnix japonica, egg weight, strength, eggshell, thickness

The study of the role of trace elements in animal nutrition may be useful for meeting the true requirements for optimal performance. Environmental stress causes adverse effects on the performance and antioxidant status of poultry. Chromium is used in poultry diet because of its antistress effects and because its requirement is increased during stress (Sahin et al. 2002, 2004).

Chromium occurs primarily in the trivalent state (III), which is the most stable form. Chromium is required for the maintenance of normal glucose tolerance (Baselt 2000). Previous studies on poultry reported a decrease of cholesterol content in the muscles, heart, blood plasma and egg yolks following different sources of dietary chromium supplementation (Debski et al. 2000; Koréneková et al. 2002). Chromium is an essential nutrient for animals that can play an important beneficial role in interaction with some toxic elements.

Cadmium is a highly toxic and carcinogenic environmental contaminant. It presents a serious hazard to animal health and a threat to most life forms (Smith et al. 1994; Kleczkowski et al. 1995; Braeckman et. al 1997). Element toxicity upon the biological systems of animals is affected by route and form of ingestion as well as by interaction between essential and toxic elements. The amount of an element that accumulates in the organs depends on the interval of exposure, the quantity ingested and the production, as well as the animal's age and breed (Massányi et al. 2000).

Japanese quail (*Coturnix coturnix japonica*) is an interesting domestic economic species for commercial egg and meat production beside chickens. Quails are often used for the investigation of physiological process in birds and they are suitable experimental animals for observing the relationship between essential elements and xenobiotics *in vivo* (Koréneková et al. 2004). Nutrition is one of the most important factors required

Address for correspondence:
MVDr. Magdaléna Skalická, PhD.
Department of Nutrition, Dietetics and Animal Breeding,
University of Veterinary Medicine, Komenského 73,
041 81 Košice, Slovak Republic

Phone: +421 915 986 731
Fax: +421 55 6323173
E-mail: skalicka@uvm.sk
http://www.vfu.cz/acta-vet/actavet.htm

to maintain quails in a good physical condition and to enhance physiological growth and egg production. Further improvement of poultry meat and egg quality may be achieved by animal diet optimalisation (Venglovský et al. 2005).

The purpose of our experiment was to determine the effect of Cd and Cr on the weight of Japanese quail eggs, the strength and thickness of eggshells, distribution of Cd in eggs and co-action of both metals.

Materials and Methods

All experiments were performed following ethical requirements for animal handling approved by the University of Veterinary Medicine, Košice, Slovak Republic. Its Ethics Commission approved this experiment and attached the number to this experiment (No. 8/2003/Ethics Commission). The experimental conditions complied with animal welfare and proper care of animals. Sixty Japanese quails (40 days old) were included in the experiment. They were divided into three groups of 20 birds each. In drinking water, Group (2) Cr-only received 0.12 mg Cr/day per quail; group (3) Cd-Cr received a combination of 0.12 mg Cr and 0.12 mg Cd/day. Control group (1) drank tap water without any supplements.

Soluble salts $CrCl_3.6H_2O$ and $CdCl_2.H_2O$ (extra pure, Merck, Germany) were used without further purification to prepare stock solutions in 1 l of distilled water from which the respective doses were given in 1 ml day per quail. The quails were offered drinking water after administration of the above dosage of soluble salts.

The birds were fed a complete feed mixture HYD-10 (manufactured in Agrofarm Product s.r.o., Slanská Huta, Slovak Republic) set as full-value feed for the whole experiment. Feed mixture was provided *ad libitum.* The composition of the feed is given in Table 1; it complied with the Regulation of the Government of the Slovak Republic, 440/2006. The mean feed consumption was about 40 g feed/day per quail.

Table 1. Composition of commercial feed supplied to Japanese quails

Composition	Content ($g \cdot kg^{-1}$)	Minerals	Content ($mg \cdot kg^{-1}$)	Vitamins	Content
Crude protein	153.0	Zinc	60	A	8.000 $IU \cdot kg^{-1}$
Energy	11.5 $MJ \cdot kg^{-1}$	Calcium	45 $g \cdot kg^{-1}$	D_3	1.600 $IU \cdot kg^{-1}$
Ash	160.0	Phosphorus	5.0 $g \cdot kg^{-1}$	E	10 $mg \cdot kg^{-1}$
Fibre	60.0	Sodium	2.5 $g \cdot kg^{-1}$	B_2	4.0 $mg \cdot kg^{-1}$
Lysine	7.0	Manganese	40	B_{12}	10 $\mu g \cdot kg^{-1}$
Methionine	6.0	Iron	40		
Cystine					
Methionine	3.5	Copper	4.0		
Linoleic acid	15.0				

The cadmium content in feed (0.007 $mg \cdot kg^{-1}$) and water (0.001 $mg \cdot l^{-1}$) used in this study was below the maximum permissible limits for Cd in feeds (0.5 mg/kg at 12% moisture) and drinking water (0.003 $mg \cdot l^{-1}$) according to the Regulations of the Government of the Slovak Republic 347 and 438/2006.

The quails were kept in cages under controlled climate conditions favourable to their growth and welfare. Eggs were collected for a period of 58 days. Their weight, strength and thickness of their shell and the distribution of the two elements under study were measured on days 35 and 58 of the experiment.

The eggshell strength was determined by the method established by Marcinka and Gažo (1964). The force needed to break the eggshell was developed by means of an apparatus consisting of a spring with manual tightening of an adjusting screw. A scale in N/cm^2 indicated the force applied by the spring (Bainová 2005). Measurements were made between the poles or at the equator, simulating different risks of breakage under field conditions.

Samples of egg yolk, egg white and egg shell were immediately frozen and stored at -20 °C until analysed. The samples were digested in a MLS 1,200 MEGA (Milestone) microwave oven using a mixture of 5 ml HNO_3 and 1 ml HCl per 1 g of sample.

The digested samples were analyzed for the presence of cadmium using an atomic absorption spectrometer from Unicam Solar Model 939 with a graphite furnace with a background correction for Cd, following the method of Kocourek (1992). Reproducibility of the method of metal determination was tested by analyzing bovine liver reference material (MBH Anal Ltd., England).

The standards were prepared from a 1,000 $mg \cdot kg^{-1}$ stock solution (Merck, Germany). The operating parameters used were those recommended by the instrument manufacturer for Cd: wavelength 228.8 nm and band pass 0.8 nm. The quantization limit was 0.03 $\mu g \cdot l^{-1}$ and the detection limit was 0.01 $mg \cdot l^{-1}$. The graphite furnace was optimised for maximum absorbency and linear response while aspirating known standards. The lamp current was 75%. The signal type was transient for Cd. Measurement time was 3 s. The recovery of the methods was 96–98% and reproducibility was better than 1.0%. The metal concentrations are expressed on a wet weight basis. This method was used also by Kottferová et al. (2003) and Koréneková et al. (2007).

The results were statistically analyzed using Student's *t*-test (Microsoft Excel 7.0) setting significance levels at $p < 0.05$; $p < 0.01$ and $p < 0.001$. The data are presented as means ± standard deviations and the coefficient of variation (V%).

Results and Discussion

The results of egg weight, egg shell strength and eggshell thickness are presented in Table 2.

Table 2. Effect of Cr supplementation of quail egg on quality indicators

Analyzed indicators		35 day			58 day		
		Control	Cr	Cr - Cd	Control	Cr	Cr - Cd
Weight (g)	x	10.79	10.06	9.15	10.00	10.11	9.32
	SD	1.29	0.84	1.03	1.76	1.53	1.14
	X max	12.53	11.60	10.37	12.80	12.40	10.90
	V (%)	12.01	8.37	11.22	18.26	15.16	12.26
Eggshell strength (N)	x	12.09	11.83	10.32*	13.05	11.52	10.66*
	SD	1.99	1.30	1.61	1.41	2.01	1.36
	X max	13.81	14.38	12.96	14.66	15.23	13.95
	V (%)	16.51	11.01	15.57	10.83	17.43	12.78
Eggshell thickness (mm)	x	0.25	0.23	0.23	0.25	0.24	0.23
	SD	0.03	0.02	0.02	0.02	0.01	0.02
	X max	0.30	0.26	0.26	0.28	0.25	0.26
	V (%)	11.66	7.43	7.70	6.47	4.92	6.77

n = 15
*Significant at $p < 0.05$

After 35 days, eggs from the control group weighed 10.79 ± 1.29 g, which is consistent with literature values of 10.07–10.27 g for quails (Baumgartner et al. 2005). As shown in Table 2, the egg weight of Japanese quail was higher in the control group (10.79 g) than in the experimental group (10.06 g) with addition of Cr. At the end of the experiment (day 58), a decrease of egg weight in the control group was observed. On the other hand, non-significant increase of egg weight was observed in Cr-only group (2) (10.11 g). These results are in accordance to Sahin et al. (2002) who observed that Cr supplementation improved the weight of eggs. The weight of Japanese quail was lower in the Cd-Cr group (3) than in the Cr-only group (2) on day 35 as well as on day 58 of the experiment. Egg weight was not affected by Cr supplementation, consistent with the results of Lien et al. (1996) and Uyanik et al. (2002).

The decrease of eggshell thickness was observed in the middle of the study as well as at the end of the experiment in the Cr-only group (2) compared to the control group. A similar decrease of eggshell thickness was found in the Cd-Cr experimental group (3) in comparison to the group with Cr addition. The adverse effect of Cd and other heavy metals has been studied in poultry. According of Šály et al. (2004) several toxic elements (Cd, Pb) caused a decrease in the egg weight, strength and thickness of eggshell. Slightly decreased strength as well as thickness of eggshells after addition of Cr was found also by Sahin et al. (2003).

A significant decrease ($p < 0.05$) of eggshell strength in the Cd-Cr group (3) was found after 35 and 58 day of experiment in comparison to the control and Cr-only group (2). In the present case, the eggshell strength of the control group was increased regardless of the

Table 3. Cd distribution in quail eggs in mg·kg^{-1}

Groups		Day 35 White	Day 35 Yolk	Day 35 Eggshell	Day 58 White	Day 58 Yolk	Day 58 Eggshell
Control	x	0.010	0.013	0.024	0.014	0.019	0.027
	SD	0.003	0.008	0.009	0.004	0.011	0.013
	x max	0.015	0.027	0.039	0.022	0.040	0.050
Cr	x	0.013	0.011	0.017	0.016	0.005*	0.008*
	SD	0.007	0.003	0.009	0.007	0.002	0.001
	x max	0.016	0.015	0.026	0.021	0.008	0.009
Cr-Cd	x	0.068	0.019	0.074	0.022***	0.019	0.029***
	SD	0.016	0.005	0.028	0.011	0.005	0.005
	x max	0.091	0.028	0.107	0.040	0.025	0.037

n = 6
*Significant differences at $p < 0.05$
***Significant differences at $p < 0.001$

age of quails. According to Rahman et al. (2007) exposure to Cd, even at a single dose, can hamper quail reproduction for a very short time, mainly by decreasing egg production and thinning the eggshell. Kottferová (2004) observed a decrease of the eggshell strength in laying hens after a long-term exposure to Cd. On the other hand, Uyanik et al. (2002) found that supplemental Cr (20 ppm) increased the shell breaking strength.

The Cd content in eggshells from the Cr-supplemented group (2) was significantly lower than that of the Cd-Cr group (3) ($p < 0.05$) on day 58 of the experiment. A similar situation was found for Cd levels in the egg yolk ($p < 0.05$). These results show that the co-administration of Cr might alleviate the adverse effects of Cd.

In our study, the contents of Cd in collected quail eggs from the control group were found in the following order: egg shell > egg yolk > egg white throughout the whole experimental period.

A significant decrease of Cd contents ($p < 0.05$) was observed in the egg yolk and eggshell of Cr-only group (2) on day 58 compared to day 35 of the experiment. Similarly, in the experimental Cd-Cr group (3) a significant decrease of Cd contents ($p < 0.001$) was recorded in the eggshell. However, in this experimental group significantly decreased contents of Cd ($p < 0.001$) in the egg white were observed. Apparently, mineral imbalance caused by the interaction of cadmium and chromium in the body was regulated by important homeostatic mechanisms in which toxic elements compete with essential metals.

Chemical analysis has also shown the presence of other minerals in eggs (Dauwe et al. 2005). The effect of essential elements including Cr on reduction of the toxicity of heavy metals was described also by Chowdhury and Chandra (1987). Beňová et al. (2007) found that low doses of ionising radiation improve the adaptive response of certain species (*Artemia franciscana)*. Examination of groups exposed to Cd and Cr, either separately or in combination, showed better viability in irradiated groups. With higher doses of radiation a protective effect of Cr was assumed.

The results of our study suggest that Cr supplementation in Cd-exposed birds has the potential to mitigate the adverse effects of cadmium. Chromium plays an important role in protecting against Cd absorption. The beneficial effect of chromium is in improving quality indicators of quail eggs and the safety of products of animal origin in human nutrition.

Vplyv prídavku chrómu a kadmia na kvalitu vajec Japonských prepelíc

V experimente bol sledovaný vplyv chrómu (Cr) a kadmia (Cd) na kvalitu vajec u japonských prepelíc. Prepelice v počte 60 ks boli rozdelené do 3 skupín po 20 ks, kontrolná skupina a 2 experimentálne skupiny. Skupina (1) kontrola, bola bez prídavkov Cd a Cr. V Cr - skupine (2) bol aplikovaný Cr v dávke 0,12 mg na kus a deň. V Cd-Cr skupine (3) bola aplikovaná kombinácia týchto prvkov v dávke 0,12mg Cd na kus a deň a 0,12 mg Cr na kus a deň. Na 35. a 58. deň po aplikácii Cd sa sledoval jeho vplyv na pevnosť, hrúbku a škrupinu vajec. Štatisticky významné zníženie pevnosti škrupiny ($p < 0,05$) bolo zaznamenané na 35. a na 58. deň experimentu v Cd-Cr skupine (3) v porovnaní s Cr- skupinou (2). V Cr -skupine (2) boli hladiny Cd nižšie ($p < 0.05$) v škrupine a vo vaječnom žĺtku v porovnaní s Cd-Cr skupinou (3) a kontrolnou skupinou (1). Samotný Cr pozitívne vplýval na hmotnosť vajec. Z experimentu vyplýva, že prídavok Cr v diéte japonských prepelíc eliminuje negatívne účinky Cd s následným pozitívnym efektom na kvalitu vajec.

Acknowledgments

The present work was supported by VEGA Scientific Grants 1/0677/08 and VEGA 1/0403/08 from the Ministry od Education of the Slovak Republic.

References

BAINOVÁ MM 2005: Recent advances in assessment of eggshell quality and their future application. Worlds Poult Sci J **12**: 268-277

BAUMGARTNER J, KOPECKÝ J, KONČEKOVÁ Z, BENKOVÁ J 2005: Technological qualities eggs of lines of Japanese quails selected on lowered yolk cholesterol. In: Proceedings of International Scientific Poultry Days, Vol. 1. Nitra (Slovak Republic), pp. 50-56 (ISBN 80-8069-576-8)

BASELT RC 2000: Disposition of toxic drugs and chemicals in man. Chemical Toxicology Institute, Forster City, CA, pp. 93-94

BEŇOVÁ K, DVOŘÁK P, FÁLIS M, SKLENÁŘ Z 2007: Interaction of low doses of ionising radiation potassium dichromate and cadmium chloride in *Artemia franciscana* Biotest. Acta Vet Brno **76**: 35-40

BRAECKMAN B, RAES H, VAN HOYE DV 1997: Heavy metal toxicity in an insect cell line: Effects of cadmium chloride, mercuric chloride and methylmercuric chloride on cell viability and proliferation in *Aedes albopictus* cell. Cell Biol Toxicol **13**: 389-397

DAUWE T, JANSSENS E, BERVOETS L, BLUST R, EENS M 2005: Heavy metal concentrations in female laying great tits (*Parus major*) and their clutches. Arch Environ Contam Toxicol **49**: 249-256

DEBSKI B, ZALEWSKI W, KRYNSKI A 2000: Influence of Cr-yeast supplementation on cholesterol concentration in broilers tissues and egg yolk composition. In: Proceedings of lectures and posters. Hygiena Alimentorum **21**: 216-219

CHOWDHURY BA, CHANDRA RK 1987: Biological and health implications of toxic heavy metal and essential trace element interactions. Prog Food Nutr Sci **11**: 55-113

KLECZKOWSKI M, KLUCINSKI W, STALINSKI M, DZIEKAN P, SIKORA J 1995: Biochemical ecology and diseases of animals. Med Weter **51**: 443-445

KOCOUREK V 1992: Metody stanovení cizorodých látek v potravinách. Laboratorní příručka. (Methods of analysis of residual substances in food. Laboratory manual), Prague, Czech Republic, 110 p.

KORÉNEKOVÁ B, SKALICKÁ M, KORÉNEK M 2002: Chromium in the relationship of animal organism. Infovet **4**: 35-36

KORÉNEKOVÁ B, SKALICKÁ M, NAĎ P, KORÉNEK M 2004: Feed and genesis of the Japanese quails. Magazín chovateľa **7-8**: 46-47

KORÉNEKOVÁ B, SKALICKÁ M, NAĎ P, ŠÁLY J, KORÉNEK M 2007: Effects of cadmium and zinc on the quality of quail's eggs. Biol Trace Elem Res **116**: 103-109

KOTTFEROVÁ J 2004: Selected mineral substances, their importance, interactions and elimination from organism. Habilitation thesis. UVM, Košice, 127 p.

KOTTFEROVÁ J, KORÉNEKOVÁ B, SIKLENKA P, JACKOVÁ A, HURNÁ E 2003: Biological availability of cadmium: the effect of vitamin D3 on hens. Chem Inž Ekolog **10**: 559-562

LIEN T, CHEN S, SHIAU S, FROMAN D, HU CY 1996: Chromium picolinate reduces laying hen serum and egg yolk cholesterol. Profess Anim Sci **12**: 77-80

MARCINKA K, GAŽO M 1964: Pevnosť škrupiny vajec z klietkového chovu nosníc. II. Príspevok k stanoveniu pevnosti vaječnej škrupiny. (The eggshell strength of feed cage laying hens, II. Determination of the eggshell strength). Vedecké práce VÚCHH v Ivánke pri Dunaji, **2**: 237-243

MASSÁNYI P, TRANDŽÍK J, LUKÁČ N, STRAPÁK P, KOVÁČIK J, TOMAN R 2000: The contamination of bovine semen with cadmium, copper, lead, and zinc and its relation to the quality of spermatozoa used for insemination. Folia Vet **44**: 150-153

RAHMAN MS, SASANAMI T, MORI M 2007: Effects of cadmium administration on reproductive performance of Japanese quail (*Coturnix japonica*). J Poult Sci **44**: 92-97

REGULATION OF THE GOVERNMENT OF THE SLOVAK REPUBLIC 440/2006

REGULATION OF THE GOVERNMENT OF THE SLOVAK REPUBLIC 347, 438/2006

SAHIN K, OZBEY O, ONDERCI M, CIKIM G, AYSONDU MH 2002: Chromium supplementation can alleviate negative effect of heat stress on egg production, egg quality and some serum metabolites of laying Japanese quail. J Nutr **132**: 1265-1268

SAHIN N, SAHIN K, ONDERCI M, OZCELIK M, SMITH MO 2003: *In vivo* antioxidant properties of vitamin E and chromium in cold-stressed Japanese quails. Arch Tierernahr **57**: 207-215

SAHIN K, ONDERCI M, SAHIN N, GURSU MF, VIJAYA J, KUCUK O 2004: Effects of dietary combination and biotin on egg production, serum metabolites, and egg yolk mineral an cholesterol concentrations in heat-distressed laying quails. Biol Trace Elem Res **101**: 181-192

SMITH JB, PIJUAN V, ZHUANG Y, CHEN YC 1994: Transmembrane signals and protooncogene induction evoked by carcinogenic metals and prevented by zinc. Environ Health Perspect **105**: 181-189

ŠÁLY J, BARANOVÁ D, PEŠEK L, ŠEVČÍKOVÁ Z, KOŠČÁK D, ŠUTIAK V, NEUSCHL J, KREMEŇ J 2004: Effect of lead on health and productivity of layers. Bull Vet Inst Puławy **48**: 75-80

UYANIK F, KAYA S, KOLSUZ AH, EREN M, SAHIN N 2002: The effect of chromium supplementation on egg production, egg quality and some serum parameters in laying hens. Turk J Vet Anim Sci **26**: 379-387

VENGLOVSKÝ J, SASÁKOVÁ N, VARGOVÁ M, PAČAJOVÁ Z, PLACHÁ I, PETROVSKÝ M, HARICHOVÁ D 2005: Evolution of temperature and chemical parameters during composting of the pig slurry solid fraction amended with natural zeolite. Bioresour Technol **96**:181-189