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Bioavailability of trace elements proteinates in pigs

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Summary

A four-week experiment was carried out on piglets to observe the effects of Fe, Cu, Zn, Mn, and Se bioplexes on the micromineral profile of blood serum, excretion of these trace elements in faeces and urine, and body weight. Organic trace element supplementation resulted in a significant increase in blood serum concentrations of Fe ($P < 0.01$), Cu ($P < 0.05 - 0.001$), Zn ($P < 0.05 - 0.01$), Mn ($P < 0.01$); the concentration of Fe in liver ($P < 0.05$); Se in the heart ($P < 0.05$), kidneys ($P < 0.01$), bones ($P < 0.05$); and Mn and Zn in bones ($P < 0.01$). Conversely a positive decrease in the levels of excreted trace elements in faeces and the urine of pigs in the prefattening period was observed. The optimisation of homeostasis was manifested by the higher weight gain during the experiment.

Keywords: bioavailability, bioplexes trace elements, micro-mineral profile, pigs

Trace minerals constitute a small percentage of the pigs diet, but they play a vital and important role in nutrition, being part of structural materials, constituents of the soft tissues and cells, and regulating many vital biological processes. The trace elements iron, copper, zinc, selenium, and manganese fulfil important structural, physiological, catalytic, and regulatory functions in animal bodies (14). Particularly, they act as components or activators of enzymes, co-enzymes, and hormonal mechanisms of animal bodies, affecting in this way the function of cardiovascular, central nervous, immune, and reproductive systems (11).

Concentrations of trace elements in animal tissues depend mostly on their content in animal diet, mineral absorption, and homeostatic control mechanisms of the body. Insufficient proportion of trace elements in the diet results in their decreased concentrations in body tissues. On the contrary, excessive uptake of trace elements causes their higher tissue deposition and excretion in excrements before or after their absorption (12).

Supplementation of diet with organic forms of minerals bound to amino acids or short-chain peptides is one of the methods that can be used to increase the availability of trace elements to pigs. The organic-bound trace elements are more resistant to reactions with other chemical compounds during digestion, better soluble, and therefore they are more easily absorbed and integrated into biological reactions and body structures (12).

The aim of the experiment was to evaluate the bioavailability and incorporation of organic-bound trace elements into the organism of pigs in the pre-fattening period. Besides live body weight, we evaluated concentration of Zn, Fe, Cu, Mn, and Se in the blood serum, heart, liver, kidneys, loin muscles, bones, faeces, and urine of pigs.

Material and methods

The piglets of the same age (age at beginning of experiment was 65 days, body weight about 20 kg) were divided into two groups: experimental (n = 10) and control (n = 10).

Tab. 1. The micromineral composition of premixes and the mixed foods ($mg \cdot kg^{-1}$)

Title	Fe	Cu	Zn	Mn	Se
Aminovitan P1CH	10 000	1000	10 000	4000	30
Aminovitan P1	10 000	1000	10 000	4000	30
Organic KZ OŠ-03	282.50	13.90	143.42	32.60	0.121
Anorganic KZ OŠ-03	321.25	10.28	109.22	30.84	0.100

In the experiment lasting 4 weeks, experimental group was fed a special dry food mixture OŠ-03 (Tajba a. s., Čaňa; tab. 1) containing 1% premix of vitamins and minerals (Aminovitan® P1CH – Biofaktory s. r. o.; tab. 1) with organic forms of Cu, Fe, Zn, Se, and Mn (Alltech s. r. o.). Control group was fed classic dry food mixture OŠ-03 (Tajba a. s., Čaňa; tab. 1) with 1% premix of vitamins and minerals (Aminovitan® P1 – Biofaktory s. r. o.; tab. 1) containing the same amount of inorganic forms of trace elements. We used a divided type of feeding (three times daily) corresponding to age category (1.50-1.75 kg of dry food mixture per head and day). The pigs were housed in four pens at the II[nd] Clinical Department for Internal

Diseases of the UVM in Košice. The blood was sampled from the ophthalmic sinus (7) in one-week intervals, except two weeks between the 1st (72nd day of age) and 2nd (86th day of age) sampling. The faeces and urine were sampled weekly during spontaneous urination and defecation after noon feeding. The body weight of pigs was also determined in one-week intervals. At the end of the experiment (day 93 of age), altogether 8 animals (4 from each group) were slaughtered and the samples of heart (*Apex cordis*), liver (*Lobus hepatis dexter medialis*), kidneys (*Cortex renis*), loin muscles (*M. longissimus lumborum*), and bones (*Os pubis*) were taken and stored at –18°C till the analyses.

Tissue samples were subjected to wet mineralization in a microwave oven MLS 1200. Tissue and serum concentrations of Cu, Fe, and Zn were determined by flame AAS method (Perkin Elmer AAnalyst 100), concentrations of Se and Mn by the flameless AAS method (Perkin Elmer 4100 ZL).

The obtained results were processed by Student's t-test.

Results and disscussion

Concentrations of Fe in blood serum of experimental group showed an increasing tendency. Significant differences between the groups were recorded in the 2nd and 3rd sampling ($P < 0.01$; tab. 2). Similarly concentrations of Cu in the blood serum had increasing tendency. Significant changes between the groups were observed during the whole experiment ($P < 0.05$-$P < 0.001$; tab. 2). Lower concentrations of Mn in the first half of the experiment (tab. 2) were followed by their significant increase in 2nd and 3rd samplings ($P < 0.01$). The comparison of serum Zn between the groups showed statistical changes from the 1st sampling onward ($P < 0.05$-$P < 0.01$). During the whole experiment, we did not observe any significant differences in the concentrations of Se in blood serum. The peak value (1.30 μmol. l^{-1}) was reached in the 3rd sampling in the experimental group.

The highest mean tissue concentrations of trace elements were observed in the liver (Fe, Cu, Mn; tab. 3), kidneys (Se), and bones (Zn) in the experimental group. Supplementation of organic-bound trace elements resulted in significantly higher levels of Fe in the liver ($P < 0.05$); Se in the heart, bones ($P < 0.05$), and kidneys ($P < 0.01$); Mn and Zn in the bones ($P < 0.01$).

The comparison of trace elements in faeces (tab. 4) between the groups showed significant differences in concentrations of Mn in 0th collection ($P < 0.05$). During the experiment there was an insignificant decrease in concentrations of Zn, Mn, Cu (except 2nd sampling), Fe (except 3rd sampling), and Se (except 0th and 1st samplings) excreted in the faeces of experimental group.

Concentrations of Fe in the urine of experimental group reached significantly lower values in 0th and 1st samplings ($P < 0.05$-0.01; tab. 5). Urine is the main route of Se excretion; insignificantly lower concentrations of this element were recorded in the experimental group in all the samplings.

During the whole experiment, we did not observe any significant

Tab. 2. The concentrations of trace elements in the pig blood serum (μmol · l^{-1})

Trace element	Group	Sampling 0	1	2	3
		age of pigs: 65th day	72nd day	86th day	93th day
Fe	Experiment	16.11 ± 2.31	17.14 ± 2.28	17.52** ± 2.18	18.29** ± 2.12
	Control	15.43 ± 1.79	15.33 ± 1.62	13.88 ± 1.59	14.66 ± 1.06
Cu	Experiment	19.78* ± 1.90	21.02** ± 1.86	21.02***± 1.26	22.71*** ± 2.29
	Control	17.70 ± 0.84	17.90 ± 1.24	17.11 ± 1.17	17.80 ± 0.94
Mn	Experiment	0.38 ± 0.03	0.40 ± 0.03	0.58** ± 0.04	0.57** ± 0.04
	Control	0.39 ± 0.04	0.42 ± 0.04	0.43 ± 0.10	0.43 ± 0.09
Zn	Experiment	8.84 ± 1.39	9.39* ± 1.06	9.17** ± 0.88	9.82** ± 0.69
	Control	8.21 ± 1.40	8.02 ± 1.22	7.54 ± 1.25	8.50 ± 1.04
Se	Experiment	1.25 ± 0.14	1.26 ± 0.07	1.27 ± 0.09	1.30 ± 0.08
	Control	1.26 ± 0.13	1.27 ± 0.10	1.26 ± 0.13	1.29 ± 0.11

Explanations: *** $P < 0.001$; ** $P < 0.01$; *$P < 0.05$

Tab. 3. The concentrations of trace elements in the tissues (mg · kg^{-1})

Trace element	Group	Heart	Liver	Kidney	Muscles	Bone
Zn	Experiment	17.72 ± 0.94	45.85 ± 9.14	24.10 ± 2.29	12.01 ± 1.98	49.28** ± 2.6
	Control	17.37 ± 1.35	42.67 ± 9.67	23.07 ± 1.58	13.01 ± 0.47	36.00 ± 0.65
Cu	Experiment	2.52 ± 0.18	5.03 ± 0.54	3.52 ± 0.68	0.45 ± 0.25	0.87 ± 0.34
	Control	2.91 ± 0.30	5.73 ± 0.33	2.90 ± 0.36	0.97 ± 0.67	0.73 ± 0.20
Fe	Experiment	32.4 ± 3.37	198.9* ± 34.1	42.9 ± 13.92	7.40 ± 3.53	37.10 ± 11.19
	Control	29.33 ± 0.78	109.1 ± 46.2	39.20 ± 8.29	6.86 ± 1.40	35.26 ± 1.67
Se	Experiment	0.095* ± 0.01	0.479 ± 0.01	1.10** ± 0.05	0.088 ± 0.01	0.095* ± 0.01
	Control	0.069 ± 0.01	0.413 ± 0.06	0.950 ± 0.06	0.076 ± 0.03	0.069 ± 0.01
Mn	Experiment	0.24 ± 0.02	1.03 ± 0.06	0.79 ± 0.11	0.15 ± 0.06	0.36 ± 0.04**
	Control	0.24 ± 0.03	1.22 ± 0.16	0.92 ± 0.08	0.13 ± 0.04	0.26 ± 0.03

Explanations: * $P < 0.05$; ** $P < 0.01$

differences in the live body weight between the groups (tab. 6). During 4 weeks, the average live body weight increased by 13.46 kg in the control and 14.69 kg in the experimental group that is by 1.23 kg more.

The main role of pre-fattening period of pigs is maximum utilisation of growth and hereditary predispositions of organism with high level of muscle development. Decisive indicator of good feeding and optimal composition of dry food mixture in this category of pigs is achievement of 30 kg of live body weight at the age of 90 days (1). In our experiment, at the age of 93 days, experimental group reached 36.43 kg body weight. During the whole experimental period, the average body weight of the experimental animals was insignificantly higher than in the control. The mean daily weight gain in corresponding weeks reached the higher level in the experimental group: 527 g, 409 g, 591 g, 571 g than in the control group (466 g, 403 g, 591 g, 463 g). During the pre-fattening period (from 65th day to 93rd day of age), the mean body weight gain of experimental pigs reached 525 g in the experimental group (481 g in the control piglets), which was within or higher than the range expected in this category of pigs in the same age (417 g-530 g) (2, 15). Food efficiency (consumption of food per 1 kg of weight gain) in the experimental group of pigs proves more qualitative utilizing of feed: 2.85; 3.67; 2.96; 3.06 than in the control group (3.21; 3.72; 2.96; 3.80).

Feeding trace elements bioplexes had a positive effect on statistical increasing of concentrations of Fe, Cu, Mn and Zn in blood serum of the experimental group of pigs.

The contents of mineral elements in the pig tissues (ash analysis) are relatively equal and represent about 3% of body weight (16). Liver and kidneys belong to organs with the highest cumulation of trace elements, which was also proved in our experiment. Liver contains the highest concentration of Fe, Cu and Mn, kidney the highest concentration of Se. Dry food mixture with trace elements bioplexes (Aminovitan P1 CH) significantly increased concentration of Fe in liver, Se in heart, kidneys and bones, Mn and Zn in bones. However, it is difficult to compare our mean tissue concentrations with published literary reference data related to analyses of micro-mineral profile of tissues and organs (4, 6, 8, 10, 13), because there were differences in composition, quantity and type of dry food mixtures, as well as different category and body weights of pigs.

When judging contents of trace elements estimated in the faeces, there is a need to know that these concentrations are not formed only by unabsorbed, but also by endogenous and absorbed trace elements, that are re-excreted to intestines by biological secretion. From the aspect of mineral excretion in pig faeces, elements:

Tab. 4. The concentrations of trace elements in the faeces ($mg \cdot kg^{-1}$)

Trace element	Group	Sampling 0	1	2	3
Zn	Experiment	136.58 ± 9.55	136.71 ± 8.65	169.72 ± 17.30	176.59 ± 20.43
	Control	156.27 ± 15.13	136.78 ± 9.77	171.17 ± 15.06	178.58 ± 15.67
Cu	Experiment	20.09 ± 1.02	19.33 ± 1.07	20.78 ± 0.83	19.43 ± 2.13
	Control	22.49 ± 1.93	19.94 ± 2.30	20.61 ± 0.99	19.78 ± 0.58
Fe	Experiment	424.32 ± 27.77	360.30 ± 41.85	388.39 ± 14.83	438.79 ± 33.49
	Control	426.04 ± 75.83	377.72 ± 42.09	461.07 ± 97.17	392.35 ± 57.32
Se	Experiment	0.084 ± 0.013	0.086 ± 0.008	0.069 ± 0.012	0.072 ± 0.020
	Control	0.076 ± 0.024	0.077 ± 0.005	0.076 ± 0.020	0.073 ± 0.025
Mn	Experiment	33.01 ± 2.01	35.20 ± 3.30	42.29 ± 4.73	44.80 ± 3.67
	Control	39.39* ± 3.14	37.74 ± 6.07	45.64 ± 3.70	48.00 ± 3.36

Explanation: * $P < 0.05$

Table 5. The concentrations of trace elements in the urine ($mg \cdot kg^{-1}$)

Trace element	Group	Sampling 0	1	2	3
Zn	Experiment	0.78 ± 0.06	0.71 ± 0.06	0.55 ± 0.11	0.54 ± 0.20
	Control	0.64 ± 0.13	0.66 ± 0.07	0.46 ± 0.17	0.53 ± 0.13
Cu	Experiment	0.15 ± 0.07	0.14 ± 0.06	0.39 ± 0.14	0.21 ± 0.05
	Control	0.13 ± 0.06	0.15 ± 0.04	0.33 ± 0.03	0.16 ± 0.03
Fe	Experiment	0.20 ± 0.04	0.26 ± 0.05	0.38 ± 0.06	0.37 ± 0.10
	Control	0.40** ± 0.07	0.43* ± 0.09	0.33 ± 0.03	0.35 ± 0.11
Se	Experiment	0.071 ± 0.018	0.078 ± 0.007	0.083 ± 0.012	0.073 ± 0.005
	Control	0.094 ± 0.021	0.088 ± 0.015	0.093 ± 0.014	0.092 ± 0.019
Mn	Experiment	0.016 ± 0.002	0.017 ± 0.002	0.016 ± 0.002	0.017 ± 0.002
	Control	0.018 ± 0.003	0.018 ± 0.003	0.016 ± 0.002	0.016 ± 0.003

Explanations: * $P < 0.05$; ** $P < 0.001$

Tab. 6. The average live body weight of the pigs (kg)

Group	Weighing 0	1	2	3	4
	age of pigs: 65th day	72nd day	79th day	86th day	93rd day
Experiment	21.74 ± 3.97	25.43 ± 4.33	28.29 ± 4.82	32.43 ± 4.70	36.43 ± 5.91
Control	18.61 ± 3.59	21.87 ± 3.71	24.69 ± 3.85	28.83 ± 4.60	32.07 ± 5.14

zinc and copper are the most important. These trace elements are often added to pre-starter and starter food mixtures in concentrations (2000-3000 ppm Zn, 250 ppm Cu) higher than physiological requirements of pigs. These high pharmacological concentrations of zinc and copper improve body weight gain and reduce occurrence of bacterial diarrhoea of weaning pigs (17). On the other hand, in case of their low bioavailability, their excessive excretion causes environmental pollution and by this way these elements can be toxic for plants, as well as animals (3). In our experiment, zinc (0^{th}, 1^{st}, 2^{nd}, 3^{rd} samplings) and Cu (0^{th}, 1^{st}, 3^{rd} samplings) concentrations in the faeces of experimental group were lower than in the control group. During the whole experiment (1^{st}, 2^{nd}, 3^{rd} sampling), 161.0 ppm and 162.18 ppm of zinc were excreted in the faeces of experimental and control groups, respectively. Lower values were also observed in concentrations of copper (19.89 against 20.12 ppm), iron (391.92 against 410.38 ppm), and manganese (40.76 against 43.80 ppm) in the experimental group, which proves higher bioavailability of organic forms trace elements and consequently their lower excretion by faeces. Concentrations of selenium in faeces of both groups of pigs ranged approximately on equal level (0.075 ppm).

In the same way as faeces play an important role in excretion of Cu, Zn and Mn, on the basis of the homeostatic control mechanism, urine is the main route of selenium excretion (9). Contrary to inorganic forms, organic forms of Se (selenomethionine) are at high percentage reabsorbed (nearly 100%) already from proximal tubule of kidneys and in this way they are returned to blood circulation; whereas surplus of inorganic Se (Se not used for synthesis of selenoproteins) is after methylating of selenium hydride readily excreted by urine (5). During the whole period of our observation, urine concentrations of Se in the experimental group were insignificantly lower than in the control. Urine of experimental group contained also statistically lower concentration of Fe (0^{th} and 1^{st} samplings).

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FOX M. T., BAKER A. S., FARQUHAR R., EVE E.: Pierwsze doniesienie o występowaniu Ornithonyssus bacoti u zwierząt towarzyszących człowiekowi w Zjednoczonym Królestwie. (First record of Ornithonyssus bacoti from a domestic pet in the United Kingdom). Vet. Rec. 154, 437-438, 2004 (14)

Ornithonyssus bacoti, roztocz, który pasożytuje w tropiku, pojawił się w zjednoczonym Królestwie. Jest on przenosicielem filarii *Litomosoides carinii*, gorączki Q, choroby Chagasa i wirusów coxsackie. Chomik chowany w domu, który w okresie od 3 do 13 lipca przebywał w sklepie dla zwierząt w związku z wyjazdem właścicieli, po powrocie do domu ukąsił 2 członków rodziny. Na ciele chomika stwierdzono obecność *O. bacoti*. Zwierzę poddano izolacji i zastosowano terapię przy użyciu iwermektyny w dawce 200 µg/kg masy ciała. W okresie od 11 do 15 września codziennie po leczeniu stwierdzano od 10 do 12 roztoczy. Przypuszcza się, że źródłem zarażenia chomika byli członowie rodziny, którzy, przebywając na kempingu lub w porcie promowym, zarazili się *O. bacoti*.

G.

CASSAR C. A., OTTAWAY M., PAIBA G. A., FUTTER R., NEWBOULD S., WOODWARD M. J.: Brak enteroagregacyjnych szczepów Escherichia coli u zwierząt fermowych w Wielkiej Brytanii. (Absence of enteroaggregative Escherichia coli in farmed animals In Great Britain). Vet. Rec. 154, 237-239, 2004 (8)

Enteroagregacyjne szczepy *Escherichia coli* (EAEC) należą do ostatnio zidentyfikowanej grupy enterozjadliwych pałeczek okrężnicy, które powodują w krajach słabo rozwiniętych biegunki u dzieci. Stosując specyficzna sondę genetyczną pAAEAEC zbadano szczepy pałeczki okrężnicy izolowane z kału zwierząt poddawanych ubojowi w rzeźniach na terenie Wielkiej Brytanii. Ogółem przebadano 1227 szczepów *E. coli*, z których 401 izolowano od bydła, 406 – od owiec i 400 – od świń. Żaden z badanych szczepów *E. coli* nie reagował z sondą genetyczną pAAEAEC. Dodatkowo każdy z izolatów hybrydyzowano z sondą genową Ele specyficzną dla *E. coli*. Wyniki pozytywne uzyskano dla 8,9% izolatów.

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