The analysis of the carcass characteristics and physical-technological quality of pork after using diet with the addition of organic chromium and selenium

Analýza jatočnej hodnoty a kvality bravčového mäsa po použitý organického selénu a chrómu v kŕmnej dávke ošípaných

Peter ŠTEFANKA[1*], Ondřej BUČKO[2], Branislav GÁLIK[2], Margita ČANIGOVÁ[1] and Ondrej DEBRECÉNI[2]

[1]Faculty of Biotechnology and Food Science, Slovak University of Agriculture in Nitra,

[2]Faculty of Agrobiology and Food Resources, Slovak University of Agriculture in Nitra,

[*]Corresponding author: xstefanka@uniag.sk

Abstract

The aim of the study was to analyze the effect of selenium and combination of selenium with chromium in the feed mixture on carcass and meat traits of finishing pigs. A total 90 castrates (Large White) were divided into the three groups. The control group received basal diet (BD) without selenium and chromium; the experimental group (Se) 0.3 mg Se*kg^{-1} in the form of selenomethionine was added to the basal diet. Experimental group (SeCr) was fed basal diet with added selenomethionine plus chromium nicotinate (0.3 mg Se*kg^{-1}, 0.75 mg Cr*kg^{-1}). We found that added selenomethionine to the feeding ration increased carcass length ($P < 0.001$). Technological parameters were affected by selenium: reduced pH_{24} of ham and drip loss of *muscle longissimus thoracic* after 7-day *post mortem* ($P \leq 0.01$), and increased cooking loss in *muscle abductor*. Combination of selenium and chromium in the feeding ration significantly increased firmness of meat (Warner - Bratzler) in each muscle ($P < 0.001$). Cholesterol in muscles was lower ($P < 0.01$) in animals supplemented with a combination of selenomethionine and chromium. These results suggest that supplementation of organic selenium and chromium nicotinate in the feed had significant effect on carcass and meat quality of pigs.

Keywords: carcass characteristics, chromium nicotinate, pig, quality of meat, selenomethionine

Abstrakt

Cieľom práce bolo hodnotenie vplyvu prídavku organického selénu a chrómu na jatočnú hodnotu a fyzikálno-technologické parametre kvality bravčového mäsa. Celkovo 90 ošípaných plemena Biele ušľachtilé bolo rozdelených do troch skupín, kontrolnej a dvoch pokusných. Kontrolná skupina (BD) bola kŕmená kŕmnou zmesou bez prídavku organického selénu a chrómu. Pokusné skupiny prijímali kŕmnu zmes s prídavkom organického selénu Se (0,3 mg Se*kg^{-1}), resp. jeho kombinácia s organickým chrómom SeCr (0,3 mg Se*kg^{-1}, 0,75 mg Cr*kg^{-1}). Z jatočných parametrov selén ovplyvnil iba dĺžku tela (*P* < 0,001), z technologických parametrov pH_{24} stehna (*P* ≤ 0,01), straty odkvapom po 7 dňoch vo svale *musculus longissimus thoracis* (*P* < 0,01) a straty tepelným opracovaním vo svale *musculus abductor* (*P* < 0,01). Kombinácia oboch prvkov SeCr zvýšila tuhosť mäsa (Warner-Bratzler) v každom svale pri preukaznosti *P* < 0,001. Obsah cholesterolu v mäse bol priaznivo ovplyvnený po súčasnom podaní oboch prvkov, pričom v kontrolnej skupine to bolo 69,97 ± 9,54 mg*100g^{-1} a v pokusnej (SeCr) 58,58 ± 10,50 mg*100g^{-1} pri preukaznosti *P* < 0.01. Výsledky naznačujú, že prídavok organického selénu a chrómu v kŕmenej dávke ošípaných má vplyv na technologické vlastnosti mäsa a obsah cholesterolu.

Klúčové slová: chromium nicotinate, jatočná hodnota, kvalita mäsa, ošípané, selenomethionine

Introduction

The ultimate quality of meat and meat products is dependent on the technological parameters of pork, especially on the pH and water holding capacity. The pH is responsible for two deficiencies of meat; pale, soft and exudative (PSE) meat and a normal color but exudative meat named as red, soft, exudative (RSE); (Kauffman et al., 1992 and Cheah et al., 1998). The water holding capacity is responsible for weight loss in raw, cooked and processed meats, which related to pH. These parameters affect the economic results and efficiency. Choosing the right breed, feeding strategy, transporting, pre-slaughter procedures can reduce the impact on the meat quality and meat products. Dietary supplementation of selenium enriched yeast (SeY), selenomethionine (SeMet) or organic Se-enriched feed in pig, chicken, lamb can improve the water-holding capacity and oxidative stability of pork or chicken (Downs et al., 2000; Mateo et al., 2007; Wang et al., 2009).

Several authors have examined a positive effect of selenium on the meat quality. The selenium (Se) is recognized as an essential trace element and also it has been associated with impaired growth, fertility, and health in farm livestock (Weiss et al., 1990). Selenium enters to the food chain through plants from the soil (sodium selenite) and as organic forms of the element, mainly as (SeMet), which is subsequently non-specifically incorporated into proteins. Organic Se has been reported to have higher bioavailability than the inorganic Se (sodium selenite), (Wang and Lovell, 1997). To increase meat quality and oxidative stability had been added selenium to the feed of farm animals, leading to an improved meat quality (Mahan et al. 1999; Downs et al., 2000). Selenium supplementation has recently been shown to decrease total cancer incidence.

Chromium (Cr) is an essential trace element for humans and animals. Trivalent Cr [Cr (III)] is a component of glucose tolerance factor (GTF) and is vital in carbohydrate, fat, and protein metabolism presumably by potentiating the action of insulin (Anderson, 1987; Mertz, 1993). There have been a number of studies on the effect of Cr (III) supplementation on growth performance, carcass characteristics, pork quality, reproduction, and tissue deposition in domestic animals (Mooney and Cromwell, 1995; Lindemann et al. 1995; Shelton et al., 2003). Dietary Cr supplementation has been shown to positively affect growth rate and food efficiency in growing poultry (Sahin et al., 2001). Boleman et al. (1995) reported no effect of Cr supplementation on shear force and on the drip or cooking loss. No researches have been done concerning the effect of combination selenomethionine with chromium nicotinate on the carcass trait and meat quality of finishing pigs.

In the present study was evaluated the effect of two elements, selenomethionine and combination selenomethionine with chromium nicotinate in feeding ration of pigs on the carcass traits and technological quality of pork meat.

Material and methods

Animals and treatment

A total of 90 pigs (Large White) was allotted to three treatments, basal diet (BD) group and two experimental groups, as selenium (Se) and selenium plus chromium (SeCr), respectively. The pigs received the same basal diet based on barley-wheat-maize meal with *ad libitum* access to feed and water in each group (Table 1.). Organic selenium was added to the diet at 0.3 mg Se*kg^{-1}, as Se-enriched yeast. Chromium nicotinate (CrNic) was added to feed in amount 0.75 mg Cr*kg^{-1} in inactivated form of the yeast *Saccharomyces cerevisiae* fermented on the substrate which originated from natural source with a higher content of chromium and combination with organic selenium 0.3 mg Se*kg^{-1}. Pigs were slaughtered at 105 kg live weight. The trial was conducted at the Experimental center of Livestock, Department of Animal Husbandry, Slovak University of Agriculture in Nitra.

Table 1. Composition of basal diet

Components	25-40 kg l.w.	45-80 kg l.w.	80-105 kg l.w.
Barley %	26.5	26.5	27
Wheat %	26	25	27
Maize %	17.7	26.7	27
Soybean meal 48 % of CP	26.5	18.8	13
Eurovital %	3	3	3
Schaumacid %	0.3	0.3	0.3
Nutrient composition (g*kg^{-1})			
Crude protein	202.47	197.79	151.71
Lysine	29.86	27.7	26.21
Crude fiber	33.28	31.41	32.71
Ash	31.91	28.4	24.62
Ca	56.6	56.43	56.33
P – total	6.48	6.24	6.3
P – digestible	1.25	1.1	1.09
Mg	1.5	1.36	1.37
ME (MJ*kg^{-1})	13.14	13.11	12.99

[a]Selenomethionine and chromium nicotinate were premixed in meal and added to the diets at 0.3 mg Se*kg^{-1}, 0.75 mg Cr*kg^{-1} respectively.

Carcass analysis

After electric stunning and slaughtering process were measured parameters of carcass body and collected samples of muscle from *musculus semimembranosus* (MSM), *musculus abductor* (MA) and m*usculus longissimus thoracis* (MLT) for the others analysis. The pH was measured after 45 minutes and 24 hours *post-mortem* in the left of carcass in two points, pH of ham and pH of m*usculus longissimus thoracis* with portable pH meter and glass electrode. Also to the 45 minutes were measured weight of carcass body, thickness of backfat and muscle method ZP (zwei punkte) for categorize in SEUROP system. Thickness of backfat was measured in mm, as a lower layer above *musculus gluteus medius*. Muscle thickness, also in mm was measured, as the shortest connection from the dorsal edge of the spinal canal to the front edge of the cranial part *musculus gluteus medius.* Measured back fat and muscle thickness was calculated in SEUROP equation. During cutting were measured carcass length from cranial edge of first rib to caudal edge of *symphysis pubis* and thickness of backfat midline over 9 vertebrae (fat 1), last rib (fat 2) and sacral vertebrae (fat 3) respectively. Technological parameters as drip losses of loin were determined by Honikel (1998). Samples were weighed and vertically hung in the plastic bags at 4 ºC, and final loin weight was determined after 24 h. The cooking losses were determined as losses incurred during cooking in hot water 72 - 75 ºC for 30 min, from 50g piece. Losses were expressed as different weight before cooking minus weight after cooking × 100, in %. After that was determined firmness of meat with Warner-Bratzler (WB) sheare force; prism of meat sample 1 cm^2 was measured on the device Chatillon and value was expressed in $kg*cm^{-2}$.

Cholesterol analysis

Around 0.5 g (MLT) sample of pure tissue removed from fat was weighted and homogenized with a solution of chloroform and methanol. A homogenized sample stood at room temperature 24 hours and after that was filtrated. The filtrate was evaporated in water bath at 60 ºC. To the evaporated sample were added chloroform, acetic anhydride and sulfuric acid. The intensity of the green color was measured against blank at 625 nm with Spectrophotometer T80. The amount of cholesterol is expressed in mg/100g of meat sample; mg cholesterol in 100 g of muscle = extinction of sample/ extinction of standard × 100.

Determination of chromium and selenium

Samples were analyzed using a VARIAN AA240FS atomic absorption spectrometer. Samples of meat (2 g) were mineralized in a concentrated mixture of HNO_3 and distilled water. After that were samples mineralized in microwave digestion MARS X-press (USA). Time and temperature programs for mineralization are in table 2. Mineralized samples were filtrated to the tubes and filled with water to the mark and measured by atomic absorption spectroscopy. Chromium atomization was performed at a wavelength of 357.9 nm and standard K_2CrO_4.

Table 2. Process of mineralization – time, temperature (total time 70 min.)

Phase	Power (W)	Power (%)	Onset (min.)	Temperature	Stay
1. Initialization	800	90	15	160	
2. Mineralization	800	90		160	20
3. Cooling	-	-	-	-	20

The selenium content in meat samples was analyzed at the University of Veterinary Medicine and Pharmacy in Kosice according to method modified by Rodriguez et al. (1994). Homogenized samples and 4 ml HNO_3-$HClO_4$ (4:1) were placed in a beaker closed and left overnight. Next morning, the acid mixture was heated 140 ºC for 20min., 180 ºC for 20min., and 205 º C for 50min. After fumes of $HClO_4$ was solution cooled. Then, 1 ml of HCl was added and heated to 100 ºC for 30 min and cooled. Consecutively, 2 ml of Na_2 EDTA and 1 ml of DAN were added to the tube. After that tube was inserted into the ultrasonic bath (> 70 ºC for 30min.). Followed cooling, added 2 ml of cyclohexane and the complex was shaken for 45 sec., then the organic phase was separated by centrifugation at 2000 rpm and the fluorescence of this phase measured at λ_{ex} = 377 nm and λ_{em} = 516 nm.

Statistics

The significance of the difference between mean values was determined by the analysis of variance using the Scheffe test. Differences at P < 0.05 were considered as statistically significant.

Results

Concentrations of selenium and chromium in meat samples are shown in Table 3. Content of selenium in experimental groups was significantly higher than in the control group (*P* < 0.001). Content of chromium was significant higher in group enriched by chromium. The impact of selenomethionine and combination with chromium on growth performance and carcass traits of sampled pigs are shown in Table 4. Thickness of muscle was significantly different between experimental groups (*P* < 0.05). Selenium added to feed increased carcass length (*P* < 0.001) in comparison to control group.

Table 3. Effect of Se and Cr source on absolute tissue mineral concentration in meat samples

Element	BD	BD + Se	BD + SeCr	*P*-value
Selenium $mg*kg^{-1}$	0.084 ± 0.005^A	0.136 ± 0.02^B	0.133 ± 0.02^B	<0.001
Chromium $mg*kg^{-1}$	0.154 ± 0.02^A	0.152 ± 0.02^A	0.203 ± 0.03^B	<0.001

Data are expressed as means ± S.D; means with different letters within a row are significantly different: A, B (*P* < 0.01).

Table 4. Effect of dietary Se and Cr on pig performance

	BD	BD + Se	BD + SeCr	*P*-value
No. of pigs	29	34	27	-
Live weight (kg)	102.9 ± 3.13	101.5 ± 7.52	104.1 ± 3.0	0.16

Carcass weight (kg)	81.7 ± 2.46	80.8 ± 5.98	82.5 ± 2.35	0.27
Thickness of back fat (mm)	14.7 ± 4.18	14.4 ± 4.96	15.8 ± 4.36	0.48
Thickness of muscle (mm)	71.9 ± 5.29$^{a, b}$	74.0 ± 6.17^{b}	69.9 ± 4.39^{a}	0.02
Carcass length (mm)	96.1 ± 2.6^{A}	98.2 ± 2.72^{B}	95.1 ± 3.37^{A}	<0.001
Thickness of fat 1 (mm)	2.7 ± 0.46	2.4 ± 0.64	2.6 ± 0.72	0.20
Thickness of fat 2 (mm)	1.9 ± 0.41	1.7 ± 0.53	1.9 ± 0.44	0.210
Thickness of fat 3 (mm)	1.2 ± 0.36	1.1 ± 0.46	1.4 ± 0.48	0.066

Data are expressed as means ± S.D; means with different letters within a row are significantly different: $^{a, b}$ ($P < 0.05$), $^{A, B}$ ($P < 0.01$).

Technological parameters are shown in Table 5. Supplementation of Se to the diet significantly decreased the pH_{24} of ham ($P = 0.01$) compared with control group and added SeCr decreased the pH_{24} of MLT ($P < 0.05$) in comparison with selenium group. Drip loss of MLT after 7 days was significantly lower in selenomethionine-treatment group ($P < 0.01$) while combination of SeCr diet did not have a positive effect on this trait in comparison to control pigs. On the other hand, supplementation of Se and SeCr, resp. increased cooking loss in MA, even though in the case of selenium only, the difference with control group was significant. Addition of SeCr to the feeding ration significantly increased firmness of meat in each muscle ($P < 0.001$). Content of cholesterol was significant lower ($P < 0.01$) in group SeCr compared to control and selenium treatment.

Table 5. Effect of selenomethionine and chromium on the technological parameters of meat

	BD	BD + Se	BD + SeCr	*P*-value
pH_1 ham	6.26 ± 0.55	6.14 ± 0.12	6.16 ± 0.15	0.29
pH_1 MLT	6.27 ± 0.21	6.25 ± 0.11	6.24 ± 0.23	0.82
pH_{24} ham	5.77 ± 0.21^{a}	5.66 ± 0.08^{b}	5.72 ± 0.09$^{a, b}$	0.01
pH_{24} MLT	5.68 ± 0.09$^{a, b}$	5.70 ± 0.07^{b}	5.64 ± 0.07^{a}	0.03
Drip losses 24 MSM (%)	8.96 ± 3.55	7.85 ± 3.29	8.75 ± 3.14	0.38
Drip losses 24 MA (%)	5.80 ± 2.23	6.55 ± 2.62	5.97 ± 2.48	0.46
Drip losses 24 MLT (%)	6.92 ± 2.98	8.09 ± 3.06	6.68 ± 2.80	0.14
Drip losses 7 MSM (%)	6.42 ± 3.26	5.50 ± 2.26	5.95 ± 2.93	0.15
Drip losses 7 MA	7.46 ± 2.85	5.73 ± 3.01	6.84 ± 1.67	0.05

(%)				
Drip losses 7 MLT (%)	8.03 ± 2.40^{A}	5.63 ± 2.25^{B}	7.44 ± 1.86^{A}	0.004
Cooking losses MSM (%)	25.43 ± 3.93	28.42 ± 8.31	25.80 ± 3.10	0.10
Cooking losses MA (%)	21.90 ± 2.94^{A}	24.87 ± 4.16^{B}	23.50 ± 2.99^{A,B}	0.008
Cooking losses MLT (%)	23.31 ± 4.98	26.14 ± 2.84	23.42 ± 5.73	0.06
WB MLT kg*cm^{-1}	4.52 ± 0.92^{A}	4.57 ± 0.73^{A}	8.55 ± 2.12^{B}	<0.001
WB MA kg*cm^{-1}	4.31 ± 0.99^{A}	5.18 ± 1.00^{A}	9.00 ± 2.56^{B}	<0.001
WB MSM kg*cm^{-1}	4.31 ± 3.69^{A}	4.88 ± 0.93^{A}	7.14 ± 2.34^{B}	<0.001
Cholesterol mg*100g^{-1}	69.97 ± 9.54^{A}	66.21 ± 15.99^{A}	58.58 ± 10.50^{B}	0.004

Data are expressed as means ± S.D.; means with different letters within a row are significantly different: $^{a, b}$ ($P < 0.05$), $^{A, B}$ ($P < 0.01$).

Discussion

Foods rich in selenium are mainly meat, fish, milk and eggs (Díaz-Alarcón et al., 1996). Increased consumption of selenium-rich animal organs may provide a means of improving the selenium status in populations deficient in this trace element (Daun and Åkesson, 2004). Selenium and chromium have also been associated with cardiovascular disease and gene expression (Vincent, 2000; Anderson et al., 2004; Hummel et al., 2007) and the most frequent manifestation of Cr deficiency is altered glucose tolerance (Navarro-Alarcón et al., 2005). We did not find any articles about effect of SeCr and therefore we compared the effect of Cr on the carcass traits and meat quality.

The pig performance as a body and carcass weight in our study was not affected by selenium, these findings are in agreement with numerous other studies on pigs (Mahan et al., 1999; Zhan et al., 2007).Effect of chromium propionate on growth, carcass traits and pork quality in growing-finishing pigs did not affect 10th - rib backfat, average backfat thickness, and carcass length in study of Shelton et al. (2003). No differences in major carcass measurements were found between the BD and selenium group (hot weight, fat thickness, and percent of lean tissue) in study of Svoboda et al. (2009). However, the positive effects of the organic selenium source on last lumbar backfat thickness and loin-eye area suggests an improvement in carcass lean content for this treatment (Wolter et al., 1999). A decrease in backfat by Cr supplementation was observed by Page et al. (1993) and Lindemann et al. (1995). In study of Speight et al. (2011) carcass length was not affected by organic selenium supplementation in boars feeding.

Several factors can influence the susceptibility to drip losses, which was consistent with the negative correlation between drip loss and pH. In our study pH_1 values in selenomethionine group were similar with those of authors Lagin et al. (2009). Low pH decreases the muscle protein ability to bind to water as well as reduces the negative electrostatic repulsion between filaments, and thus diminishes the space between them and causes shrinkage of myofibrils (den Hertog-Meischke et al., 1997). The pH_{24} value in the ham of Se-supplemented group was significantly lower in comparison to control group which does not agree with the results of Mahan et al.

(1999). Zhan et al. (2007) reported that dietary intake of 0.3 mg*kg^{-1} SeMet significantly decreased the drip loss of meat in comparison with Se-deficient group. Mateo et al. (2007) reported that the addition of 0.1 - 0.3 mg*kg^{-1} Se-yeast to the pig basal diet decreased drip loss of meat even the basal diet containing 0.18 mg Se*kg^{-1}. However, another study reported that the addition of Se to lamb diet did not influence drip loss of meat (Skřivanová et al., 2007). Boleman et al. (1995) reported no effect on drip loss, total loss, or shear force when CrPic was added to swine diets. In study of Arvizu et al. (2011) was observed the effect of supplementation of organic chromium on growth performance, carcass, and meat traits in grazing lambs but there was not seen any effect on shear force in chop.

The amount of cholesterol in meat and meat products depends on numerous factors, but in general it is less than 75 mg*100 g^{-1}, except in the case of some edible offal (heart, kidney, brains, etc.) where the concentrations are much higher (Romans et al., 1994; Chizzolini et al., 1999).Our findings revealed that diet with selenium did not affect the content of cholesterol, but combination of SeCr decreased cholesterol in tissue ($P < 0.01$). Several studies have shown that Cr supplementation decreases serum triglycerides and total cholesterol and increases high-density lipoprotein cholesterol (Riales and Albrink, 1981; Mossop, 1983). In study of Page et al. (1993) serum cholesterol was reduced after adding CrPic to diet.

Conclusion

Selenomethionine as an element in the diet of pigs had a positive effect on carcass length, drip loss in MLT after 7-days storage, and partially on muscle thickness but negative on pH_{24} in ham and cooking loss in MA. A combination of selenium with chromium did not have the effect on these traits. On the other hand, addition of selenium with chromiumnicotinate significantly increased shear force and reduced cholesterol content in pork muscles which suggests negative (in the first) and/or positive (in the second case) effect of chromium.

Acknowledgement: This work was supported by VEGA scientific grant 1/0493/12, VEGA scientific grant 1/2717/12, ECACB - ITMS 26220120015 and ECACB Plus - ITMS: 26220120032.

References

Anderson R.A. (1987). Chromium. In: Mertz W, ed. Trace elements in human and animal nutrition, Vol 1. San Diego: Academic Press, 225-44.

Anderson, J.J.B. (2004). Minerals. In (Mahan L.K., Escott-Stump S. (Eds.). Food, nutrition, and diet therapy (11th ed.), Saunders, Philadelphia.

Arvizu, R.R., Domínguez, I.A., Rubio, M.S., Bórquez, J.L., Pinos-Rodríguez, J.M., González, M., Jaramillo G. (2011). Effects of genotype, level of supplementation, and organic chromium on growth performance, carcass, and meat traits grazing lambs. Meat Science, 88, 404-408.

Boleman, S.L., Boleman, S.J., Bidner, T.D., Souther, L.L., Ward, T.L., Pontif, J.E., Pike, M.M. (1995). Effect of chromium picolinate on growth, body composition, and tissue accretion in pigs. Journal of Animal Science, 73, 2033-2042.

Daun, Ch., Åkesson, B. (2004). Glutathione peroxidase activity, and content of total and soluble selenium in five bovine and porcine organs used in meat production. Meat Science, 66, 801-807.

Den Hertog-Meischke, M.J.A., van Laack, R.J.L.M., Smulder, F.J.M. (1997). The water-holding capacity of fresh meat. Veterinary Quarterly, 19, 175-181.

Díaz-Alarcón, J.P., Navarro-Alarcón, M., López-Garcíade la Serrana, H., López-Martínez, M.C. (1996). Determination of selenium in meat products by hydridegeneration atomic absorption spectrometry – selenium levels in meat, organ meats, and sausages in Spain. Journal of Agricultural and Food Chemistry, 44, 1494-1497.

Downs, K.M., Hess, J.B., Bilgili, S.F. (2000).Selenium source effect on broiler carcass characeteristics, meat quality and drip loss. Journal of Applied Research. 18, 61-72.

Honikel, K. O. (1998). Reference methods for the assessment of physical characteristics of meat. Meat Science, 49, 447–457.

Hummel, M., Standl, E., Schnell, O. (2007). Chromium in metabolic and cardiovasculardisease. Hormone and Metabolic Research, 39, 743-751.

Cheah, K.S., Cheah, A.M., Just, A. (1998). Identification and characterization of pigs prone to producing RSE (Reddish-pink, soft and exudative) meat in normal pigs. Meat Science, 48, 249-255.

Chizzolini, R., E. Zanardi, V. Dorigoni and S. Ghidini, (1999). Calorific value and cholesterol content of normal and low-fat meat and meat products. Trends Food Science Technology, 10, 119-128.

Kauffman, R.G., Cassens, R.G., Scherer, A., Meeker, D.L. (1992).Variations in pork quality. National Pork Producers Council Publications, Des Moines, IA.

Lagin, L., Bobček, B., Obtulovič, P., Mrázová, J., Bučko, O. (2009). The quality of pork meat with the organic selenium suppement to pig feed mixture. Acte fytotechnica et zootechnica, special issue, 337-341.

Lindemann, M.D., Wood, C.M., Harper, A.F., Kornegay, E.T., Andreson, R.A. (1995). Dietary chromium picolinate additions improve gain: feed and carcass characteristics in growing-finishing pigs and increase litter size in reproducing sows. Journal of Animals Science, 73, 457-465.

Mahan, D.C., Clone, T.R., Richert, B. (1999). Effect of dietary levels of Se-enriched yeast and sodium selenite as Se source fed to growing-finishing pigs on performance, tissue glutathione peroxidase activity, carcass characteristics and loin quality. Journal of Animal Science, 77, 2172-2179.

Mateo, R.D., Spallholz, J.E., Elder, R., Yoon, I.K., Kim, S.W. (2007). Efficacy of dietary selenium sources on growth and carcass performance of growing-finishing pigs fed diets containing high indigenous selenium. Journal of Animal Science, 85, 1177-1183.

Mertz, W. (1993). Chromium in human nutrition: a review. Journal of Nutrition, 123, 626-633.

Mooney, K.W.,Cromwell, G.L. (1995). Effects of dietery chromium picolinate supplementation on growth, carcass characteristics, and accretion rates of carcass tissues in growing-finishing swine. Journal Animal Science, 73, 3351-3357.

Mossop, R.T. (1983). Effectofchromium III on fasting blood glucose, cholesterol and cholesterol HDL in diabetics. Central African Journal of Medicine, 29, 80.

Navarro-Alarcón, M., Gil-Hernandez, F., Gil-Hernández, A. (2005). Selenio, manganeso, cromo, molibdeno, yodo y otrosoligielementosminoritarios. Tratadodenutrición, vol. II, Madrid. Acción Médica.

Page, T.G., Southern L.L., Ward T.L., Thomson D.L. Jr.(1993). Effect of chromium picolinate on growth and serum and carcass traits of growing-finishing pigs. Journal of Animal Science, 71, 656-662.

Riales, R., Albrink, M.J. (1981). Effect of chromium chloride supplementation on glucose tolerance and serum lipids including high-density lipoprotein of adult men. American. Journal of Clinical Nutrition, 34, 2670.

Rodriguez, E.M., Sanz, M.T., Diaz Romero, C. (1994). Critical study of fluorimetric determination of selenium in urine. Talanta, 41 (12), 2025-2031.

Romans, J.R., Costello, W.J., Carlson, C.W., Greaser, M.L., Jones, K.W. (1994). The meat weeat. Danville, IL: Interstate Publisher, Inc.

Sahin, K., Kucuk, O., Sahin, N. (2001). The effects of dietary chromium picolinate supplementation on performance, insulin and corticosterone in laying hens under low ambient temperature. Journal of Animal Physiology and Animal Nutrition, 85, 142-147.

Shelton, J.L., Payne, R.L., Johnston, S.L., Bidner, T.D., Southern, L.L., Odgaard, R.L., Page, T.G. (2003). Effecct of chromium on growth, carcass traits, pork quality, and plasma metabolites in growing-finishing pigs. Journal Animal Science, 81, 2515-2524.

Skřivanová, E., Marounek, M., De Smet, S., Raes, K. (2007). Influence of dietary selenium and vitamin E on quality of veal. Meat Science, 76, 495-500.

Speight, S.M., Estienne, M.J., Harper, A.F., Barb, C.R., Pringle, T.D. (2011). Effects of organic selenium supplementation on growth performance, carcass measurements, tissue selenium concentrations, characteristics of reproductive organs, and testis gene expression profiles in boars. Journal Animal Science, 90, 533-542.

Svoboda, M., Saláková, A., Fajt, Z., Kotrbáček, V., Ficek, R., Drábek, J. (2009). Efficacy of Se-enriched Alga *Chlorella* spp. and Se-enriched yeast on tissue selenium retention and carcass characteristics in finisher pigs. Acta vet. Brno, 78, 579-587.

Vincent, J.B. (2000), The biochemistry of chromium. Journa of Nutrition, 130, 715-718.

Wang, C., Lovell, R.T. (1997). Organic selenium source, selenomethionine and selenoyeast, have higher bioavailability than an inorganic selenium source, sodium selenite, in diets for channel catfish (*Ictaluruspunctatus*). Aquaculture, 152, 223-234.

Wang, Z.G., Pan, X.J., Peng, Z.Q., Zhao, R.Q., Zhou, G.H. (2009). Methionine and selenium yeast supplementation of the maternal diets affects color, water holding capacity, and oxidative stability of their male offspring meat at the early stage. Poultry Science, 88, 1096.

Weiss, W.P., Todhunter, D.A., Hogan, J.S., Smith, K.L. (1990). Effect of duration of supplementation of selenium and vitamin E on periparturient dairy cows. Journa of Dairy Science, 73, 3187-3194.

Wolter, B., Ellis, M., McKeith, F.K., Moller, K.D., Mahan, D.C. (1999). Influenceofdieteryseleniumsource on growthperformance, and carcass and meat qualitycharacteristics in pigs. Canadian Journal of Animal Science. 79, 119-121.

Zhan, X.A., Wang, M., Zhao, R.Q., Li, W.F., Xu, Z.R. (2007). Effecteofdifferentseleniumsource on seleniumdistribution, loinquality and antioxidant status in finishingpigs. Animal Feed Science and Technology, 132, 202-211.