OPEN ACCESS
Potravinarstvo® Scientific Journal for Food Industry

*Potravinarstvo*, **vol. 9, 2015, no. 1, p. 562-572**
**doi:10.5219/521**
Received: 25 September 2015. Accepted: 14 December 2015.
Available online: 17 December 2015 at www.potravinarstvo.com
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ISSN 1337-0960 (online)
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# EFFECT OF CHROMIUM NICOTINATE ON OXIDATIVE STABILITY, CHEMICAL COMPOSITION AND MEAT QUALITY OF GROWING-FINISHING PIGS

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## ABSTRACT

The effect of different organic sources of Cr on growth, feed efficiency and carcass value is known but there is a lack of information between chromium nicotinate (CrNic) and pork quality. Therefore, purpose of this research was to investigate the effects of CrNic on chemical composition, quality and oxidative stability of pork meat. In the study, pigs of Large White breed (40 pcs) were used. The pigs were divided into two groups, namely the control and the experimental of 20 pcs with equal number of barrows and gilts. The pigs were fed the same diet which consisted of three feed mixtures applied at the different growth phases, from 30 – 45 kg OS-03, 45 – 70 kg OS-04 and 70 – 100 kg OS-05. The pigs were allowed *ad libitum* access to feed and water. The diet of experimental group was supplemented with 0.75 $mg.kg^{-1}$ CrNic in the form of chromium-inactivated yeast *Saccharomyces cerevisiae*. The fattening period in pigs lasted from 30 to 100 kg. The chromium supplementation led to a significantly higher content of chromium in *longissimus thoracis muscle* (LT) of experimental pigs. In addition, the results showed a statistically significant difference ($p \leq 0.05$) in retention of chromium in the LT, monounsaturated and omega-3 polyunsaturated fatty acids content in experimental group compared with control. Moreover, there was highly significant ($p \leq 0.05$) difference in essential fatty acids, as well as in oxidative stability in 7 days, among the groups. The highly significant differences were also observed among sexes, namely in total water, protein and intramuscular fat contents, colour CIE b* in both times, and oxidative stability. However, physical-technological parameters (pH, drip loss, shear force and meat colour) were not affected when pigs were fed the supplement. On the whole, the positive effect of chromium nicotinate in most of investigated parameters may be beneficial not only for pork industry but also for consumers.

**Keywords**: chromium nicotinate; meat quality; chemical composition; oxidative stability; pork

## INTRODUCTION

Chromium (Cr) is known to be an essential trace mineral element **(Lien et al., 2005**; **Kim et al., 2009)**. Trivalent chromium is a component of glucose tolerance factor and plays an important role in the metabolism of lipids, carbohydrates, proteins, nucleic acids **(Amoikon et al., 1995**; **Lindemann et al., 1995**; **Real et al., 2008**; **Wang et al., 2009**; **Jiajun et al., 2011)** and cholesterol in the body of animals **(Jacela et al., 2009)**. However, most grains and feedstuffs are deficient in Cr and must be supplemented with a bioavailable source of Cr **(Bunting, 1999)**. Animals cannot utilize glucose when chromium is deficient in feed **(Tang et al., 2001)**.

It is generally accepted that organic sources of Cr like chromium picolinate and chromium nicotinate are utilized more efficiently than inorganic Cr sources **(Page et al., 1993**; **Matthews et al., 2001)**, such as chromium chloride **(Jacela et al., 2009)**. Chromium picolinate has been demonstrated to exhibit a significant number of health benefits in animals **(Shrivastava et al., 2002)**. Recent studies have shown that chromium picolinate decreases backfat thickness and the rate of fat deposition, increase the carcass leanness **(Boleman et al., 1995**; **Wenk et al. 1995**; **Arvizu et al., 2011)**, and stimulate muscle development in pigs **(Mooney and Cromwell, 1995**; **Jackson et al., 2009)**.

On the other hand, no effect on shear force **(Waylan et al., 2003)** and sensory traits **(Dikeman, 2007**; **Sales and Jančík, 2011)** was detected. Chromium picolinate also increases farrowing rate and total number of pigs born alive **(Real et al., 2008)**. Further, the chromium propionate and nicotinate are the potential organic source of chromium **(Matthews et al., 2003**; **Matthews et al., 2005)**. Chromium nicotinate improved feed efficiency **(Dikeman, 2007)** and had significant effect on carcass and meat quality of pigs **(Štefanka, et al., 2013)**.

Supplemental chromium nanoparticle (CrNano) has shown beneficial effects on carcass characteristics and pork quality in finishing pigs **(Wang and Xu, 2004)**. Research with four organic sources (Cr-tripicolinate, Cr-propionate, Cr-methionine, Cr yeast) in concentration 5000 $\mu g.kg^{-1}$ of Cr was reported **(Lindemann et al., 2008)**. The effects of the forms of Cr fed on the meat quality and the carcass measurements were minimal. Selenium-yeast combined with chromium-yeast has positive effect on performance and carcass composition of finishing lambs **(Domínguez-Vara et al., 2009)**.

Also, enhancement of the immune function and increasing carcass quality by dietary chromium supplementation have been reported in several studies (**Lien et al., 2001**; **Xi et al., 2001**; **Shelton et al., 2003**; **Dikeman, 2007**; **Wang et al., 2007**; **Jacela et al., 2009**; **Zhang et al., 2011**). The aim of the experiment was to verify the effect of chromium-nicotinate on the physical-chemical and technological parameters of the quality, nutritional value and oxidative stability of pork.

## MATERIAL AND METHODOLOGY

***Animals and diets***

The experiment was carried out in an Experimental Centre near the Department of Animal Husbandry at the Slovak University of Agriculture in Nitra. In the study, 40 pigs of Large White breed were used. The genotype of all pigs on the marker RYR-1 (malignant hyperthermia syndrome) was analysed by the DNA test. All the experimental animals were detected as homozygous dominant (NN).

The pigs were divided into a control group and an experimental group (each of 20 animals) with equal number of barrows ($S_1$) and gilts ($S_2$). Both, control ($G_1$ = Cont) and experimental group ($G_2$ = CrNic) of pigs were fed the same diet which consisted of three feed mixtures applied at the different growth phases, from 30 – 45 kg OS-03, 45 – 70 kg OS-04 and 70 – 100 kg OS-05 (Table 1). The diet of experimental group was supplemented with 0.75 $mg.kg^{-1}$ nicotinate (CrNic) in the form of chromium-inactivated yeast *Saccharomyces cerevisiae* fermented on the substrate which was from natural resources with a higher content of chromium during the whole fattening period. The pigs were housed in an environmentally controlled finishing barn with two pigs in each pen. They were allowed *ad libitum* access to feed and water. The fattening period in pigs lasted from 30 to 100 kg. The growth performance of pigs was controlled by weighing with an accuracy of 0.5 kg. The weighing was realised in two-week intervals (30 – 90 kg) and one-week intervals (90 – 100 kg).

***Slaughter and sample collections***

The slaughtering and the carcass dissection of pigs were carried out in the slaughterhouse of Experimental Livestock Centre near the Department of Animal Husbandry. The pigs were slaughtered at an average live weight of 102.5 kg and the dissection of carcasses was done according to standard practices STN 466164. Carcasses were chilled at 3 – 4 °C overnight. The samples (100 g) for chemical analysis and determination of some meat quality traits were taken from LTon right half-carcass 24 hours *post mortem*. The place of sampling was above the last thoracic vertebra. After that, the samples were labelled and stored frozen at -19°C ±0.5 °C for 14 days until analysis.

***Chemical analysis***

The chemical composition of pork in LT was determined from samples of muscle homogenate (50 g) using the FT IR method (Nicolet 6700). The analysis of infrared spectra of muscle homogenate was done by the method of molecular spectroscopy.

The principle of the method was the absorption of infrared radiation by the transition the sample, in which were changes in rotation vibrational energy states of molecules in response to changes in dipole moment of the molecule. The analytical output was an infrared spectrum which was a graphical display of functional dependence of the energy, usually expressed in percentage of the transmittance (T) or in units of absorbance (A) on the wavelength of the incident radiation. The transmittance (throughput) was defined as the ratio of the intensity of the radiation that passed through the sample (I) and the intensity of the radiation emitted by the source (Io). The

**Table 1** Composition of basal diet and nutrient content.

| Trait | $G_1$ = Cont | | | $G_2$ = CrNic | | |
|---|---|---|---|---|---|---|
| | **OS-3** | **OS-4** | **OS-5** | **OS-3** | **OS-4** | **OS-5** |
| Barley (%) | 26.5 | 26.0 | 26.0 | 26.5 | 26.0 | 26.0 |
| Wheat (%) | 26.0 | 24.4 | 26.0 | 26.0 | 24.4 | 26.0 |
| Corn (%) | 17.7 | 26.3 | 27.0 | 17.7 | 26.3 | 27.0 |
| Soybean meal (%) | 26.5 | 20.0 | 15.2 | 26.5 | 20.0 | 15.2 |
| Wheat bran (%) | 0.0 | 0.0 | 3.0 | 0.0 | 0.0 | 3.0 |
| Mineral and vitamin supplement (%) | 3.0 | 3.0 | 2.8 | 3.0 | 3.0 | 2.8 |
| Fodder acid (%) | 0.3 | 0.3 | 0.0 | 0.3 | 0.3 | 0.0 |
| **Nutrient composition** | | | | | | |
| Drymatter (%) | 90.74 | 90.17 | 90.81 | 90.74 | 90.17 | 90.81 |
| Crude protein (%) | 15.28 | 11.65 | 11.46 | 15.28 | 11.65 | 11.46 |
| Metabolisable energy, MJ | 13.55 | 13.38 | 13.06 | 13.55 | 13.38 | 13.06 |
| Lysine (g) | 9.48 | 7.41 | 6.30 | 9.48 | 7.41 | 6.30 |
| Chromium added ($\mu g.kg^{-1}$) | - | - | - | 750 | 750 | 750 |
| Chromium analysed ($\mu g.kg^{-1}$) | 132 | 147 | 135 | 744 | 752 | 724 |

**Legend:** $G_1$ – control group; $G_2$ – experimental group; OS – growth phases of pigs.

absorbance was defined as the common logarithm of 1/T. The energy dependence on the wavelength was logarithmic; the wave number was used, which was defined as the reciprocal of the wavelength, and thus the energy dependence of the wave number will be a linear function. Individual groups of fatty acids ($g.100g^{-1}$ FAME, Fatty Acid Methyl Ester) were determined from the muscle homogenate of LT in the Laboratory of gas chromatography at Faculty of Natural Sciences (Comenius University, Bratislava, Slovakia).

***Preparation of fatty acid methyl esters***

Small amount (4 – 5 g) of muscle tissue was sampled and homogenized by grinding. From the obtained homogeneous mixture, 1 g sample was collected. After that, 4 mL of mixture for the extraction was used, chloroform: methanol (2:1) and the sample was shaken for 1h. After extraction, 2 mL of saline solution (0.9% NaCl) was added and shakedagain for 10 minutes. After few minutes, it was taken approximately 2 mL of lower layer which was subsequently centrifuged. From the adjusted sample, it was collected 1 mL for the transesterification.

Discovery Ag-Ion SPE preseparation columns were developed for the separation of methyl esters according to the degree of saturation of fatty acids using a method of **Kramer et al., (2008)**.

***Meat quality measurements***

The physical characteristics of meat quality were measured in the laboratory conditions of the Experimental Centre near the Department of Animal Husbandry, SUA in Nitra. The meat colour was determined on the cut of the LTabove the last thoracic vertebra 24 h *post mortem* using a spectrophotometer CM-2600d. Commission Internationale de I'Eclaire (CIE) L*, a*, and b* values were determined using the CIE Lab space with a D65 illuminate.

The actual acidity - log molc./H+/ - pH muscle was assessed 45 minutes and 24 hours *post mortem* using combined micro-capillary electrodes (portable acidometer brand Sentron-Titan).

For determination of drip loss, the methodology described by **Honikel (1998)** was used. In time 24 h to 48 h *post mortem*, a sample (approximately 50 g) was taken from the LT, placed in vacuum plastic bagsand hung in the refrigerator at 4 – 6 °C.

After 7 day-storage at temperature 4 ±1 °C, the Warner-Bratzler shear force was analysed. The samples were heated to temperature of 71 ±1 °C for 30 minutes and then cut for chips in 1x1 cm across fibers. Shear force was determined using the device Chatillon.

***DNA analysis of RYR1 gene***

DNA was determined by the salting-out method according to **Miller et al., (1988)** for the laboratory conditions of Department of Genetics and Animal Breeding Biology. The samples of DNA were stored frozen for the later analysis. The purified DNA was then used for PCR-RFLP analysis of the RYR1 gene. To amplify specific sectors of a gene RYR1, the following oligonucleotide primers FOR and REV taken from the work of **Kaminski et al., (2002)** were used.

***TBA method***

Procedure for the sample preparation and determination of MDA was done according to the method of **Marcinčák et al., (2009)**. A ground sample (1.5 g) was weighed in a 50 ml centrifuge tube and 1 mL EDTA (complex-forming agent) was added immediately. After gentle agitation, 5 mL 0.8% BHT was added, and the tube was gently shaken again. Just before homogenization, 8 mL 5% TCA was added to the tube and homogenization was carried out for 30 s at maximum speed. After homogenization, the sample stood for 10 minutes and then it was centrifuged for 5 min (3500 rpm, 4 °C). After centrifugation, the top hexane layer was discarded and the bottom layer was filtered through Whatman filter paper No. 4 into a 10 mL volumetric flask and diluted to volume with 5% TCA. After that, a 1 mL of TBA was added to the tube of 4 mL sample. The samples and MDA standards were incubated in a water bath for 90 min at 70 °C. After cooling in an ice bath, samples were incubated at room temperature for 30 min and extinction of samples was measured by UV-spectrophotometer at a wavelength of 532 nm.

***Preparation of calibration curve***

From the stored MDA solution, 1 mL was pipetted to 25 mL volumetric flask and added 0.1 $mol^{-1}$ HCl. The resulting MDA working solution with a concentration of 0.1748 $\mu g.mL^{-1}$ was used to preparation of the calibration curve.

***Statistical analysis***

The parameters of meat quality were statistically evaluated by statistical methods described by **Grofík and Fľak (1990)** and by statistical package Statistix, Version 8 and 9 **(Anonymous, 2001)**. At first, the basic statistical characteristics, means ($\bar{y}$) and standard deviations (*SD*) of analysed traits were computed. The differences of analysed traits between studied groups ($G_i$), sex ($S_j$), their interactions (GS) and pens ($P_k$) were evaluated by two-factor analysis of variance (AOV) with repeated measurements/animals on pens factor. The colour of meat was evaluated by three-factor AOV, with these same factors and factor time (24 hours and 7 days). The linear regression method was used for describing the dependence of oxidative stability of LT muscle after Cr-supplementation on time of storage.

## RESULTS AND DISCUSSION

***Chemical parameters***

Supplementation of the diet with 0.75 $mg.kg^{-1}$ chromium nicotinate resulted in a significantly higher content of chromium in the LT of experimental pigs than that of control pigs (0.199 vs. 0.153 mg) as shown in Table 2. The percentage of total water content in LT muscle was the same in both control pigs and pigs fed chromium. The percentage of total protein content was lower in the control group compared with the experimental, but the effect was not significant.

**Table 2** Means ±*SD* of analysed traits in *longissimus thoracis* muscle of pigs according to group of treatment.

| Trait | $G_1$ = Cont | | $G_2$ = CrNic | | Total | |
|---|---|---|---|---|---|---|
| | $\bar{y}$ | *SD* | $\bar{y}$ | *SD* | $\bar{y}$ | *SD* |
| Chromium ($mg.kg^{-1}$) | 0.152 | 0.017 | 0.199 | 0.023 | 0.176 | 0.031 |
| Total water (% ) | 72.20 | 0.63 | 72.20 | 0.72 | 72.20 | 0.67 |
| Protein (%) | 24.29 | 0.60 | 24.58 | 0.65 | 24.44 | 0.63 |
| Intramuscular fat (%) | 1.88 | 0.94 | 1.59 | 0.54 | 1.734 | 0.77 |
| Monounsaturated fatty acids ($g.100g^{-1}$ FAME) | 51.63 | 2.22 | 53.61 | 2.21 | 52.62 | 2.41 |
| Polyunsaturated fatty acids | 9.59 | 2.06 | 10.76 | 1.84 | 10.18 | 2.02 |
| ω3 polyunsaturated fatty acids | 0.420 | 0.072 | 0.469 | 0.059 | 0.445 | 0.070 |
| ω6 polyunsaturated fatty acids | 8.84 | 2.37 | 9.87 | 1.56 | 9.35 | 2.05 |
| Essential fatty acids | 6.65 | 1.43 | 7.80 | 1.16 | 7.23 | 1.41 |
| Eicosapentaenoic acid | 0.107 | 0.054 | 0.150 | 0.073 | 0.128 | 0.067 |
| Docosahexaenoic acid | 0.043 | 0.029 | 0.062 | 0.035 | 0.052 | 0.033 |
| $pH_1$ - log molc. ($H^+$) | 6.22 | 0.10 | 6.19 | 0.12 | 6.21 | 0.11 |
| $pH_{24}$ - log molc. ($H^+$) | 5.71 | 0.07 | 5.74 | 0.07 | 5.72 | 0.07 |
| Drip loss (24 hours) % | 5.78 | 2.70 | 5.98 | 2.58 | 5.88 | 2.61 |
| Colour (24 hours) CIE L* | 58.16 | 2.19 | 57.97 | 1.93 | 58.06 | 2.047 |
| CIE a* | 4.19 | 4.69 | 4.37 | 3.55 | 4.28 | 4.10 |
| CIE b* | 3.783 | 7.891 | 0.055 | 7.437 | 1.919 | 7.800 |
| Colour (7. day) CIE L* | 58.66 | 2.35 | 57.95 | 2.67 | 58.30 | 2.51 |
| CIE a* | 6.19 | 3.44 | 9.09 | 5.10 | 7.64 | 4.53 |
| CIE b* | 6.35 | 7.86 | 1.36 | 8.12 | 3.86 | 8.28 |
| Shear force (W-B) (kg) | 4.56 | 0.83 | 4.46 | 1.11 | 4.51 | 0.97 |
| Oxidative stability ($mg.kg^{-1}$) 1. day | 0.032 | 0.027 | 0.030 | 0.033 | 0.031 | 0.030 |
| 3. day | 0.097 | 0.071 | 0.056 | 0.049 | 0.077 | 0.063 |
| 5 . day | 0.204 | 0.180 | 0.122 | 0.082 | 0.163 | 0.144 |
| 7. day | 0.314 | 0.208 | 0.161 | 0.095 | 0.238 | 0.177 |

Note: ȳ– mean; *SD* – standard deviation; $G_1$ – control group; $G_2$ – experimental group.

According to **Jacela et al., (2009)**, chromium increases the carcass leanness causing enhanced deposition of dietary protein in muscle cells, what also happened in our experiment. Dietary Cr supplementation in dos of 0.2 $\mu g.g^{-1}$ could promote protein deposition **(Zhang et al., 2011)**.

Some studies **(Wang et al., 2007**; **Wang et al., 2009)** noted that addition of Cr from the chromium nanocomposite or chromium picolinate increased the concentrations of the total protein in the serum ($p \leq 0.05$). In our study, the biggest difference was shown in the percentage of the intramuscular fat. Control pigs reached a higher intramuscular fat content than experimental group but the difference was not significant, what is consistent with the results of **Wenk et al., (1995)**; **Xi et al., (2001)**; **Jacela et al., (2009)** and **Mrázová et al., (2013)**. Similarly, **Page et al., (1993)** and **Jackson et al., (2009)** reported that the Cr supplementation decreased the $10^{th}$-rib backfat and increased the percentage of lean meat. Other research has shown similar results in lambs that organic chromium reduces the dorsal fat and meat fat content **(Arvizu et al., 2011)**. **Domínguez-Vara et al., (2009)** indicated that fat content and retained fat in carcass lambs showed a linear reduction as Cr-yeast increased.

According to study of **Štefanka et al., (2013),** addition of selenium with chromium nicotinate has reduced cholesterol content in the pork muscles. In our experiment, the differences in the fatty acids content in intramuscular fat of LT ($g.100\ g^{-1}$ FAME) are presented in Table 2. There are highly significant differences caused by sex in total water, protein and intramuscular fat content.

**Table 3** Means ±*SD* of analysed traits in *longissimus thoracis* muscle of pigs in subgroups according to group of treatment and sex.

| Trait | $G_1$ = Cont | | | | $G_2$ = CrNic | | | |
|---|---|---|---|---|---|---|---|---|
| | $G_1S_1$ = Barrows | | $G_1S_2$ = Gilts | | $G_2S_1$ = Barrows | | $G_2S_2$ = Gilts | |
| | $\bar{y}$ | *SD* | $\bar{y}$ | *SD* | $\bar{y}$ | *SD* | $\bar{y}$ | *SD* |
| Chromium ($mg.kg^{-1}$) | 0.154 | 0.010 | 0.151 | 0.022 | 0.202 | 0.023 | 0.196 | 0.024 |
| Total water (%) | 71.92 | 0.50 | 72.48 | 0.65 | 71.88 | 0.62 | 72.51 | 0.69 |
| Protein (%) | 23.94 | 0.65 | 24.63 | 0.29 | 24.43 | 0.59 | 24.7 | 0.69 |
| Intramuscular fat (%) | 2.51 | 0.78 | 1.25 | 0.61 | 1.69 | 0.49 | 1.49 | 0.60 |
| Monounsaturated fatty acids | 51.53 | 1.88 | 51.72 | 2.62 | 53.89 | 2.93 | 53.34 | 1.26 |
| Polyunsaturated fatty acids | 9.25 | 1.82 | 9.93 | 2.31 | 10.43 | 1.78 | 11.0 | 1.93 |
| ω3 polyunsaturated fatty acids | 0.424 | 0.080 | 0.416 | 0.067 | 0.468 | 0.058 | 0.47 | 0.064 |
| ω6 polyunsaturated fatty acids | 8.54 | 1.96 | 9.13 | 2.80 | 9.54 | 1.48 | 10.2 | 1.64 |
| Essential fatty acids | 6.35 | 1.49 | 6.95 | 1.393 | 7.61 | 1.27 | 7.99 | 1.07 |
| Eicosapentaenoic acid | 0.114 | 0.064 | 0.100 | 0.044 | 0.165 | 0.072 | 0.134 | 0.074 |
| Docosahexaenoic acid | 0.037 | 0.027 | 0.049 | 0.031 | 0.063 | 0.039 | 0.061 | 0.033 |
| $pH_1$ - log molc. ($H^+$) | 6.19 | 0.10 | 6.25 | 0.10 | 6.22 | 0.16 | 6.16 | 0.08 |
| $pH_{24}$ - log molc. ($H^+$) | 5.71 | 0.09 | 5.71 | 0.03 | 5.77 | 0.09 | 5.70 | 0.03 |
| Drip loss (24 hours) (%) | 5.65 | 3.27 | 5.92 | 2.17 | 5.55 | 2.32 | 6.41 | 2.88 |
| Colour (24 hours) CIE L* | 57.97 | 2.01 | 58.34 | 2.45 | 58.73 | 1.59 | 57.2 | 2.01 |
| CIE a* | 1.82 | 3.50 | 6.56 | 4.64 | 4.54 | 3.83 | 4.20 | 3.44 |
| CIE b* | 8.56 | 6.31 | -1.00 | 6.39 | 0.47 | 7.59 | -0.36 | 7.67 |
| Colour (7. day) CIE L* | 59.10 | 2.57 | 58.21 | 2.15 | 58.41 | 2.83 | 57.4 | 2.57 |
| CIE a* | 4.50 | 1.82 | 7.87 | 3.90 | 9.37 | 5.67 | 8.80 | 4.74 |
| CIE b* | 10.51 | 6.20 | 2.20 | 7.32 | 1.69 | 8.19 | 1.03 | 8.47 |
| Shear force (W-B) (kg) | 4.62 | 1.05 | 4.51 | 0.57 | 3.97 | 1.16 | 4.95 | 0.87 |
| Oxidative stability ($mg.kg^{-1}$) 1.day | 0.028 | 0.007 | 0.035 | 0.038 | 0.024 | 0.015 | 0.037 | 0.044 |
| 3.day | 0.084 | 0.059 | 0.111 | 0.083 | 0.038 | 0.014 | 0.07 | 0.064 |
| 5.day | 0.135 | 0.086 | 0.273 | 0.225 | 0.087 | 0.034 | 0.15 | 0.101 |
| 7.day | 0.248 | 0.119 | 0.381 | 0.259 | 0.118 | 0.039 | 0.20 | 0.115 |

**Note:** ȳ – mean; *SD* – standard deviation; $G_1$ – control group; $G_2$ – experimental group; $G_1S_1$, $G_1S_2$, $G_2S_1$, $G_2S_2$ – subgroups.

The content of monounsaturated fatty acids was significantly lower in the control (51.63 g) compared with the experimental group (53.61 g). Also, the content of the essential fatty acids in the control group was significantly lower than that of experimental group (6.65 g vs. 7.80 g), see Tables 2 and 3. On the other hand, the chromium supplementation resulted in the significant increase ($p \leq 0.05$) of omega 3-polyunsaturated fatty acids in experimental pigs compared with the control ones (0.47 vs. 0.42 g). **Lien et al., (2001)** suggest that the carcass of the pigs that received the chromium picolinate supplemented diet (400 µg/kg) contained less oleic acid (C18:1) and total unsaturated fatty acids ($p \leq 0.05$). The total saturated fatty acid content in chromium fed group was higher than that in control.

***Physical and technological quality of pork***

The results for the physical and technological quality of pork are presented in Table 2 and Table 3. There were not statistically significant effects of chromium supplementation on pH, drip loss, shear force and meat colour 24 h *post mortem* observed.

These results are in agreement with findings of the other studies (**Page et al., 1992**; **Matthews et al., 2003**; **Wang and Xu, 2004**; **Lindemann et al., 2008**; **Arvizu, 2011**; **Sales and Jančík, 2011**; **Bednářová et al., 2014**). Also, **Waylan et al., (2003)** identified no effect of Cr-nicotinate supplementation on sensory traits and pH values in *longissimus* muscle. **Boleman et al., (1995)** showed that sensory and shear force values were not affected by chromium picolinate.

On the other hand, addition of selenium with chromium nicotinate significantly increased shear force (**Štefanka et al., 2013**). Further, the reports of **Dikeman (2007)** were similar to our results and showed no differences for *longissimus* colour display or shear force in pigs supplemented by chromium nicotinate.

**Table 4** Means squares (MS) of two factor analyses of variance with repeated observations on nested factor pen in the main group factor of analysed traits of pigs.

| Trait | Group,G | Error (Pen:Group) E (P:G) | Sex, S | Group*Sex GS | Error, e |
|---|---|---|---|---|---|
| | $f_{G=1}$ | $f_{E(P:G)} = 18$ | $f_S = 1$ | $f_{GS} = 1$ | $f_e = 18$ |
| Chromium (mg.kg$^{-1}$) | 0.02120$^{*}$ | 0.00022 | 0.00023 | 0.00002 | 0.00064 |
| Total water (%) | 0.00001 | 0.4916 | 3.5641$^{*}$ | 0.0130 | 0.2745 |
| Protein (%) | 0.8702 | 0.4385 | 2.4701$^{*}$ | 0.3764 | 0.2269 |
| Intramuscular fat (%) | 0.8526 | 0.4853 | 5.3729$^{*}$ | 2.8409$^{*}$ | 0.3082 |
| Monounsaturated fatty acids (g.100 g$^{-1}$ FAME) | 39.4420$^{*}$ | 5.3852 | 0.3349 | 1.3690 | 4.8917 |
| Polyunsaturated fatty acids (g.100g$^{-1}$ FAME) | 13.6890 | 3.2606 | 4.5024 | 0.0022 | 4.5266 |
| ω3 polyunsaturated fatty acids(g.100 g$^{-1}$ | 0.0245$^{*}$ | 0.0051 | 0.00006 | 0.00030 | 0.0040 |
| ω6 polyunsaturated fatty acids (g.100g$^{-1}$ | 10.5987 | 4.0605 | 3.8751 | 0.0133 | 4.2309 |
| Essential fatty acids (g.100g$^{-1}$ FAME) | 13.2250$^{*}$ | 1.2891 | 2.3426 | 0.1188 | 2.1528 |
| Eicosapentaenoic acid (g.100g$^{-1}$ FAME) | 0.0181 | 0.0054 | 0.0048 | 0.00085 | 0.0029 |
| Docosahexaenoic acid (g.100g$^{-1}$ FAME) | 0.0037 | 0.0009 | 0.00034 | 0.00047 | 0.0012 |
| $pH_1$ - log molc. ($H^+$) | 0.0055 | 0.01386 | 2.500E-06 | 0.0378 | 0.01143 |
| $pH_{24}$ - log molc. ($H^+$) | 0.0081 | 0.0038 | 0.0093 | 0.0141 | 0.0054 |
| Drip loss (24 hours) (%) | 0.3706 | 6.4221 | 3.1866 | 0.8791 | 8.1158 |
| Colour (24 hours) CIE L* | 0.3553 | 1.7234 | 3.3466 | 9.0155 | 6.5847 |
| CIE a* | 0.3098 | 17.1412 | 48.4880 | 64.6176$^{*}$ | 13.0161 |
| CIE b* | 138.9430 | 69.4600 | 270.2440$^{**}$ | 190.3140$^{*}$ | 29.0670 |
| Colour (7. day) CIE L* | 4.9914 | 7.2778 | 8.0910 | 0.00272 | 5.6227 |
| CIE a* | 83.9551 | 21.9907 | 19.6420 | 38.5926 | 14.6029 |
| CIE b* | 249.4500 | 85.8650 | 201.1070$^{*}$ | 146.0390$^{*}$ | 29.5270 |
| Shear force (W-B) (kg) | 0.1026 | 1.1620 | 1.8387 | 2.9921$^{*}$ | 0.60178 |
| oxidative stability (mg.kg$^{-1}$) 1. day | 0.00001 | 0.00076 | 0.0010 | 0.00007 | 0.0011 |
| 3. day | 0.0169 | 0.00502 | 0.0100 | 0.00025 | 0.0023 |
| 5. day | 0.0687 | 0.0185 | 0.1082$^{*}$ | 0.0116 | 0.0163 |
| 7. day | 0.2349$^{**}$ | 0.0221 | 0.1207$^{*}$ | 0.0053 | 0.0260 |

**Note:** $^{*}F_{0,05}(1, 18) = 4.4139$.

Some other reports have indicated that Cr-propionate may improve some aspects of pork quality (**Shelton et al., 2003**; **Matthews et al., 2005**; **Jackson et al. 2009**). The decrease of the drip loss by Cr-picolinate was reported by **O´Quinn et al., (1998)**. Study of **Xi et al., (2001)** showed the decrease of drip loss in pig muscles after Cr-nanoparticle supplementation what is different comparing our result.

In our study, an effect of chromium supplementation on some meat colour parameters 7 days *post mortem* was determined. The values of meat colour were not significantly different between experimental and control group. The differences between sexes in CIE b* in 24 hours and 7 days were significant. The means of meat colour CIE L*, a* and b* in LT 24 hours and 7 days by groups, sex and time are presented in Table 6. It was found out that the differences between analysed groups, sexes and time were not significant for CIE L*. The results showed that there was a highly significant difference between Time and interaction Group x Time in parameter CIE a*. Highly significant difference in CIE b* was caused by differences of Sex and Time. Also, there was a significant interaction in Group x Sex.

***Oxidative stability***

The effect of dietary chromium supplementation on the antioxidative stability of LT muscle is presented in Tables 2, 3 and 5. It was showed a highly significant difference between groups in 7$^{th}$ day (0.161 mg.kg$^{-1}$ in $G_2$ group vs. 0.314 mg.kg$^{-1}$ in $G_1$ group). The means and standard deviations of the oxidative stability of LT for total observations in the 1$^{st}$, 3$^{rd}$, 5$^{th}$ and 7$^{th}$ day, for groups and sex and also for subgroups $G_iS_j$ are presented in Table 5.

The linear regression parameter estimates, the corresponded analyses of variance and significance of differences between elevations and slopes of oxidative stability of LT muscle are presented in Table 4.

**Table 5** Means ±*SD* of oxidative stability (mg.kg$^{-1}$) of *longissimus thoracis* muscle.

| Source | n | $\bar{y}$ | *SD* | Source | $\bar{y}$ | *SD* |
|---|---|---|---|---|---|---|
| Total | 160 | 0.1271 | 0.1429 | | | |
| Day 1 | 40 | 0.0309 | 0.0298 | Day 5 | 0.1629 | 0.1444 |
| 3 | 40 | 0.0766 | 0.0638 | 7 | 0.2378 | 0.1773 |
| $G_1$ | | | | $G_2$ | | |
| Day 1 | 20 | 0.0315 | 0.0269 | Day 1 | 0.0303 | 0.0331 |
| 3 | 20 | 0.0972 | 0.0712 | 3 | 0.0561 | 0.0489 |
| 5 | 20 | 0.2043 | 0.1804 | 5 | 0.1215 | 0.0816 |
| 7 | 20 | 0.3144 | 0.2079 | 7 | 0.1612 | 0.0945 |
| $G_1$ | 80 | 0.1619 | 0.1770 | $S_1$ | 0.0951 | 0.0898 |
| $G_2$ | 80 | 0.0923 | 0.0855 | $S_2$ | 0.1590 | 0.1759 |
| $G_1S_1$ | 40 | 0.1238 | 0.1118 | $G_2S_1$ | 0.0665 | 0.0464 |
| $G_1S_2$ | 40 | 0.2000 | 0.2190 | $G_2S_2$ | 0.1180 | 0.1062 |

**Note:** n – number; $\bar{y}$ – mean; *SD* – standard deviation; $G_1$ – control group, $G_2$ – experimental group; $S_1$ –barrows,$S_2$ – gilts; $G_1S_1$, $G_1S_2$, $G_2S_1$, $G_2S_2$ – subgroups.

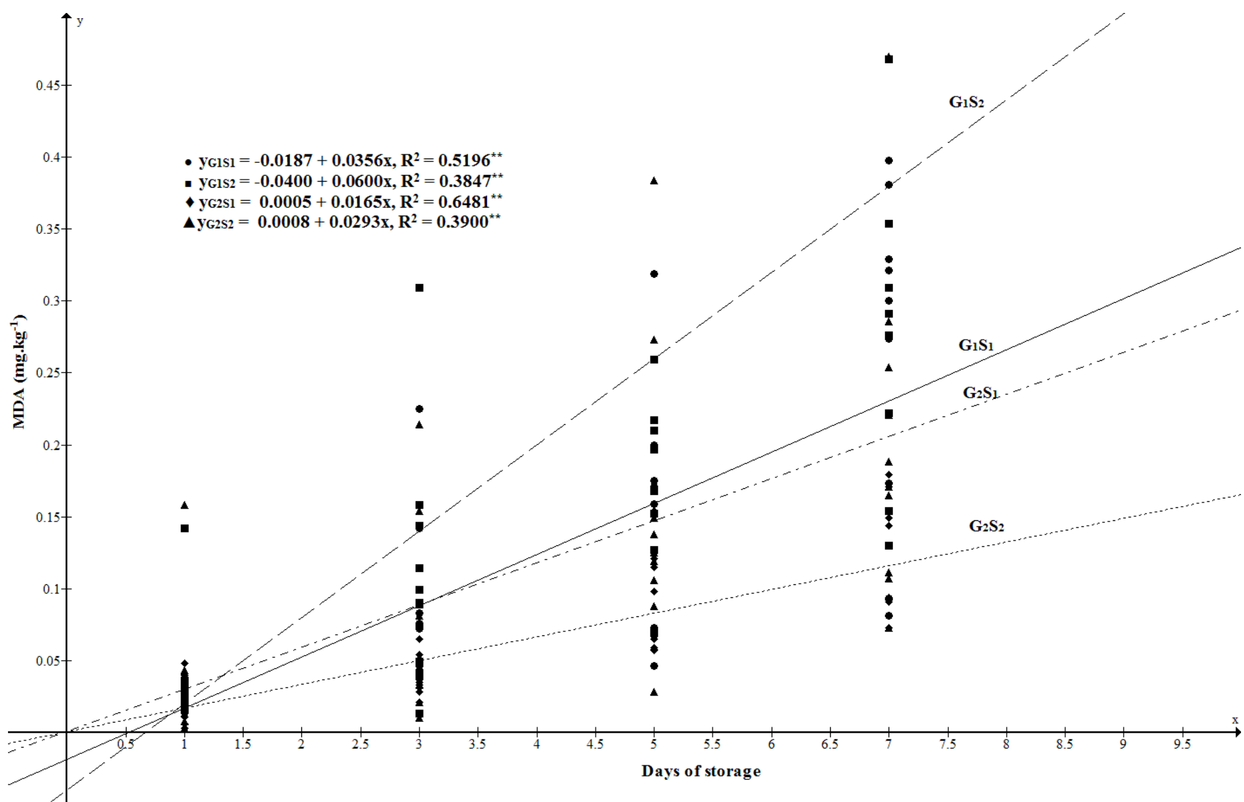


**Figure 2** Linear regressions of oxidative stability of *longissimus thoracis* muscle after Cr-supplementation for subgroups $G_iS_j$, ($G_1$ = Contr, $G_2$ = CrNic, $S_1$ = barrows, $S_2$ = gilts).

The dependence of oxidative stability on time of storage (x = t = 1, 3, 5, and 7 days) was highly significant. The deviations from linearity, i. e. nonlinearity (NonLin) were not significant. The dependence of oxidative stability had a pure linearity form. The comparison between groups and sexes showed significant or highly significant differences between elevations andslopes (Table 4).

There was a similar situation by comparison of sexes ($S_j$) in analysed groups ($G_i$). Figure 1 and 2 illustrate the linear functions. The coefficients of determination $R^2$ were highly significant. The slope in the $G_i$ = Cont was two times higher thanslope in the $G_2$ = CrNic group ($b_1$ = 0.0478 vs. 0.0229 MDA). The reverse situation was observed by comparison of sexes.

Recent research indicates that there are two mechanisms for chromium to affect the pork quality. It is an effect on carbohydrate metabolism or effect on stress. The investigation has shown that Cr-propionate and Cr-picolinate increases insulin sensitivity (**Amoikon et al., 1995**; **Matthews et al., 2001**). We can assume that

**Table 6** Means of meat colour CIE L*, a* and b* in *longissimus thoracis* muscle.

| Source | Hours/day | CIE L* | CIE a* | CIE b* |
|---|---|---|---|---|
| Group | 1. – 24 h | 58.406 | 5.186 | 5.068 |
| | 2. – 7. d | 57.958 | 6.726 | 0.707 |
| | SE Mean | 0.378 | 0.949 | 1.944 |
| Sex | 1. – 24 h | 58.552 | 5.057 | 5.308 |
| | 2. – 7. d | 57.813 | 6.859 | 0.467 |
| | SE Mean | 0.512 | 0.726 | 1.160 |
| Time | 1. – 24 h | 58.061 | 4.279 | 1.919 |
| | 2. – 7. d | 58.303 | 7.637 | 3.856 |
| | SE Mean | 0.286 | 0.395 | 0.323 |

**Note:** h – hour, d –day.

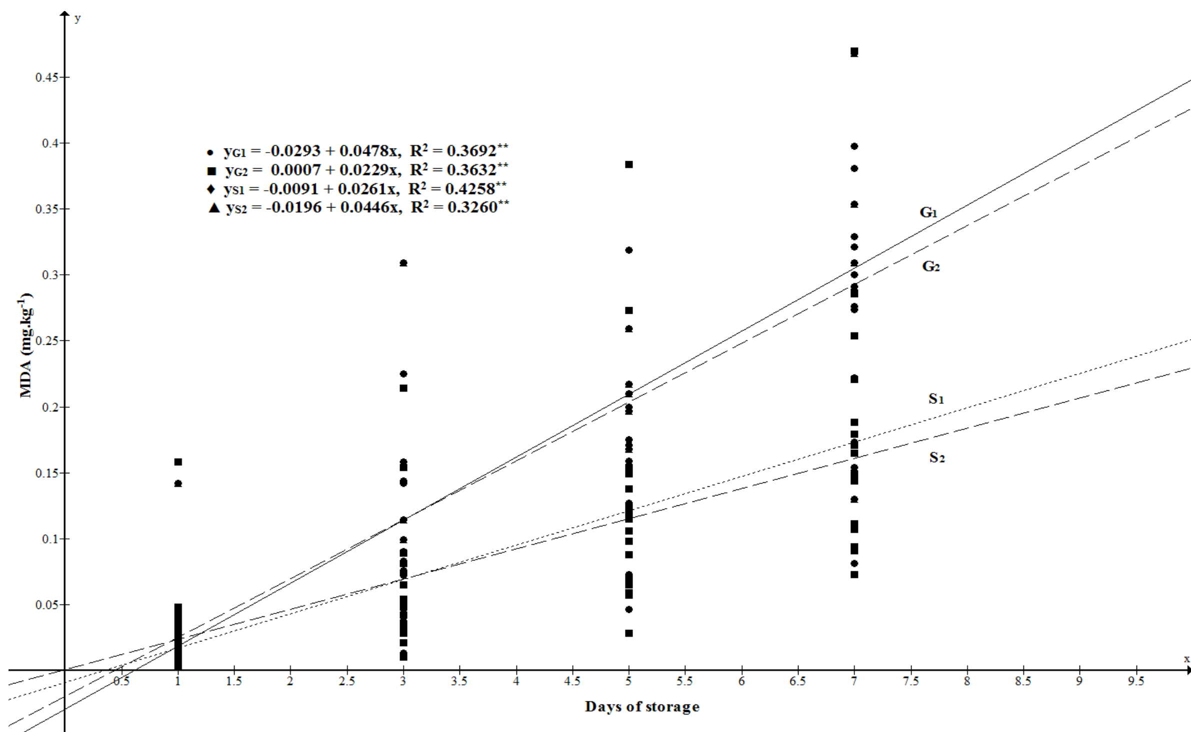


**Figure 1** Linear regressions of oxidative stability of *longissimus thoracis* muscle after Cr-supplementation for groups $G_i$ and $S_j$, ($G_1$ = Contr, $G_2$ = CrNic, $S_1$ = barrows, $S_2$ = gilts).

Cr-nicotinate may have a similar effect. Some studies **(Ward et al., 1994**; **Berrio et al., 1995)** have suggested decreasing insulin binding in certain tissues (porcine hepatic) and increasing in the other ones (adipocytes, red blood cells).

These findings would be indicated that the Cr may affect glycolytic potential in muscles and subsequently impact the pork quality. The glycolytic potential of muscle tissue also plays an important role in the preslaughter stress. Some research has mentioned that Cr may partially mitigate the effect of short-term stress **(National Research Council, 1997)**.

## CONCLUSION

According to the results obtained *in vivo* experiment, it can be concluded that the supplementation of organic chromium as chromium nicotinate (0.75 $mg.kg^{-1}$) in the pig diet resulted in a higher retention of chromium in LT. The dietary addition of organic chromium to growing and finishing diets for pigs caused a higher content of monounsaturated fatty acids and essential fatty acids in intramuscular fat of LT. However, the feeding with the supplementation increased the content of polyunsaturated and omega 3 fatty acids in the experimental group of pigs. On the other hand, the chromium nicotinate have no effect on the chemical composition of meat and meat quality traits, except with some colour parameters after 7-days storage. The Cr-addition had significantly positive impact on the oxidative stability of pork during its storage. It could be demonstrated that Cr consistently affects pork quality, so that may be beneficial from pork industry and consumer point of view. However, more research is needed to investigate the consistency in which the chromium nicotinate may improve the pork quality.

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**Acknowledgments:**

This work was supported by grant VEGA No. 1/0129/13.

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