The significance of pork as a source of dietary selenium – an evaluation of the situation in the Czech Republic

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Abstract

The aim of this paper is to review current knowledge of the significance of pork as a source of Se for human consumption, and to evaluate the selenium content in pork produced in the Czech Republic. Selenium has an important role in human health. Pork could possibly be an important source of Se for the human diet. The Se content in meat can be increased by a higher dietary intake of selenium in animal feed. The magnitude of this increase is higher when organic Se from Se-enriched yeast is ingested. Selenium intoxication in pigs occurs only when very high Se concentrations are used in their diet (more than 5 mg/kg of Se). Organic Se sources produce fewer clinical signs of high toxicity than inorganic sodium selenite. Organic Se does not have a negative effect on meat quality.
Altogether, 135 pork samples from 9 different herds in the Czech Republic were collected and analyzed for Se content.
The average selenium content found in pork in our study was 87.10 μg/kg. Because the average annual consumption of pork in the Czech Republic is 42.0 kg per person, the annual selenium intake from pork represents 18.2% of the minimum yearly requirement for humans.
The results of our study show that pork contributes significantly to the selenium intake of the human population in the Czech Republic.

ARTICLE OUTLINE:

REVIEW

1. THE ROLE OF SELENIUM IN HUMAN HEALTH

Selenium is an essential nutrient with diverse physiological actions. Optimum selenium intake is of the upmost priority because of its importance in maintaining antioxidant and metabolic functions (Finley, 2006). Primarily, it has an antioxidant role through enzymes like glutathione peroxidase (Sunde, 1994), thioredoxin reductase (Becker *et al.* 2000) and melatonin (Wiktorska *et al.* 2007).

Selenoproteins have been associated with continued fertility (Rayman, 2000), the enhancement of immune functions (Beck *et al.* 2001) and reducing the risk of cancer (Duffied - Lillico *et al.* 2003).

Selenium deficiency can be attributed to a number of diseases such as cancer (Combs, 1999), cardiovascular disease (Huttunen, 1997) and Keshan disease (Finley, 2006). An adequate amount of selenium is also required for protection against viral infections (Beck & Levander, 2000). According to Rokyta *et al.* (2003) and Bujalska & Gumulka (2008), the co-administration of selenium compounds with analgesics enhances analgesic activity and reduces oxidative stress.

Daily selenium intake by humans varies greatly among different regions of the world. The amount of selenium consumed by humans is relatively low in countries. (Kabata & Pendias, 2001). As pork is consumed in large quantities throughout much of the world, it is a convenient selenium source for our diet.

2. SELENIUM SUPPLEMENTATION IN GROWING-FINISHING PIGS

The selenium levels in pigs can be adjusted depending on whether or not inorganic or organic sources are used. Sodium selenite represents the inorganic form. Organic Se compounds are a component of an organic mixture of amino acid analogs. Organic Se from Se-enriched yeast is commercially available for pig production. In Se enriched yeast, selenomethionine represents the main part of seleno-amino acid analogs (Kelly & Power, 1995; Schrauzer, 2000).

The bioavailability of selenomethionine and its retention in organisms is higher than that of inorganic sodium selenite (Mahan & Parrett, 1996; Mahan *et al.* 1999). This is not caused by a higher rate of absorption, but by the different metabolism of the organic Se (Finley, 2006). After absorption, selenomethionine is converted to selenocysteine. The selenocysteine is degraded further in the liver into serine and selenite. The selenite is subsequently used for selenoprotein synthesis, such as GSH-Px (glutathione peroxidase). Any selenomethionine that is not immediately metabolized is incorporated into tissues having high rates of protein synthesis, such as skeletal muscle. Sodium selenite enters a reductive pathway and is finally degraded in the liver to form selenite (Schrauzer, 2000; Suzuki & Ogra, 2002).

Although inorganic selenite is also used for selenoprotein biosynthesis, only selenomethionine is incorporated non-specifically by body proteins in place of methionine (McConnel & Hoffman, 1972).

In growing/finishing pigs, the more desirable biovailabilty of selenomethionine is manifested due to higher Se concentrations in tissues. Mahan *et al.* (1999) reported that at the end of the growing period (55 kg BW (body weight)), the pigs receiving Se from Se-enriched yeast retained more Se in muscle and pancreatic tissue than pigs that were fed sodium selenite, although both Se sources were equally retained in the liver. At the end of finishing period (105 kg BW) a higher Se content in pigs fed the organic Se was found also in the liver. There is an agreement among authors that pigs having reached market weight that are fed organic Se will have a higher Se content in all tissues. (Kurkela & Kaantee, 1984; Mahan *et al.* 1999; Zhan *et al.* 2007).

The Se content in meat can be increased by a higher dietary intake of either Se source, but the magnitude of the increase is greater in the case of an organic Se source (Mahan *et al.* 1999). Moreover, according to Finley (2006), sodium selenite will not accumulate in tissue beyond a certain point. This is because sodium selenite can easily be incorporated into selenoproteins, in which expression is tightly regulated. This was confirmed in growing/finishing pigs where Se concentrations in a serum plateau were at a dietary level of 0.2 mg/kg of Se (Groce *et al.* 1973). When higher dietary levels of Se were used, the excess amount of Se was not retained in the tissue, but was excreted in the urine (Lindberg & Lannek, 1965). On the other hand, because selenomethionine is a substitute for methionine and thus accumulates in large protein masses such as muscle, the total Se body burden for selenomethionine is much higher than that for inorganic Se salts (Beilstein & Whanger, 1986).

The serum GSH-Px activity can be used as the measurement criterion for dietary Se requirements in pigs. The Se supplement of 0.3 mg/kg/day of Se is routinely used in growing-finishing pigs. Even relatively low dietary Se concentrations are required for the maintenance of adequate serum GSH-Px activities in pigs. According to Mahan & Parret (1996) and Mahan *et al.* (1999) serum GSH-Px activities reaches a plateau at the 0.10 mg/kg of Se diet concentration for the growing pigs and at 0.05 mg/kg of Se diet concentration for the finishing pigs.

3. SELENIUM TOXICOSIS

Cases of acute selenosis are very rare and can be caused by an injection of a large dose of Se (more than 1.65 mg/kg BW) (Diehl *et al.* 1975). The acute toxicity is characterized by ataxia, respiratory distress and death (Kim & Mahan, 2001a).

Selenium toxicity after dietary intake occurs in growing/finishing pigs only when very high Se concentrations are used in the diet. According to Wahlstrom & Olson (1959) the lowest continuously fed dietary Se level shown to produce toxicity in swine is about 7.5 mg/kg of Se. Mahan & Moxon (1984) reported that chronic selenosis occurred when dietary Se exceeded 5 mg/kg of Se over a long time period. Chronic selenosis is characterized mainly by reduced feed intake and growth rate (Mahan & Moxon, 1984; Kim & Mahan, 2001a). Other signs include a general body weakness, staggering gait, hair loss and hoof separation (Ekermans & Schneider, 1982; Kim & Mahan 2001a). Red or black-haired pigs appear to be more resistant to selenosis than white-haired pigs (Kim & Mahan, 2001b).

Kim & Mahan (2001a) found that organic Se sources produce fewer clinical signs of toxicity than sodium selenite. This can be explained by the higher retention of organic Se in tissues, which reduces the availability of Se for precipitating selenosis. Moreover, selenite was found to act as a pro-oxidant in vitro (Kitahara *et al.* 1993). This property has not been reported for selenomethionine (Stewart *et al.* 1999).

4. SELENIUM AND ITS RELATION TO MEAT QUALITY

Both Se concentration and meat quality are important to consumers. No differences between inorganic and organic Se sources were found in major carcass measurements (hot weight, meat thickness, fat thickness, percentage of lean muscle) (Mahan *et al.* 1999). Other aspects of meat quality traits are very complex.

It has been suggested that antioxidants stored in the cell membrane have an effect on lipid oxidation and muscle cell membrane integrity, and therefore on the kinetics of drip loss (Ashgar *et al.* 1989). Moreover, these antioxidants also protect myoglobin against oxidation and thus stabilize the redness of the meat (Zhan *et al.* 2007). Therefore, an enhanced antioxidant status in the muscle tends to improve meat quality by stabilizing cell membrane integrity and meat colour.

No negative effects from a non-supplemented basal diet on drip loss were found in the studies of Mahan *et al.* (1999) and Wolter *et al.* (1999). This indicates that the content of endogenous selenium in basal diets was sufficient for the stabilization of cell membranes.

As far as the effects of different Se sources on meat quality traits are concerned, there are many discrepancies in the available literature.

Zhan *et al.* (2007) found that selenomethionine has a higher ability to stabilize the redness of meat colour by enhancing the antioxidant ability to protect myoglobin against oxidation. The same authors also reported lower drip loss when selenomethionine was ingested. The antioxidant property of selenomethionine can be explained by its capacity to act as a scavenger of the powerful oxidant peroxynitrite (Padmaja *et al.* 1996; Sies & Arteel, 2000). To the contrary, Mahan *et al.* (1999) and Mateo *et al.* (2007) reported that organic Se did not affect pork quality. This discrepancy is probably caused by the fact that Zhan *et al.* (2007) used 100% synthetic senomethionine, whereas Se-enriched yeast used in other studies contained a lower percentage of selenomethionine.

It has been documented that inorganic sodium selenite given in high dietary concentrations has a pro-oxidative potential. In fact, inorganic Se may cause damage to cellular components (Torrent, 1996; Spallholz, 1994). This is consistent with the findings of Mahan *et al.* (1999) and Mateo *et al.* (2007) who reported that inorganic Se could possibly have a detrimental effect on pork quality, as reflected by a higher drip loss and a paler colour. On the contrary Wolter *et al.* (1999) found no negative effects on meat quality in diets supplemented with sodium selenite. It can be suggested that the dosage used in their studies (0.3 mg/kg of Se) did not cause significant oxidative stress.

Further studies are needed to fully clarify the effects of different Se sources on meat quality traits. Based on current knowledge, it can be concluded that organic Se does not have a negative effect on meat quality. Inorganic sodium selenite has pro-oxidative potential and possibly might negatively influence pork quality.

5. SELENIUM STATUS OF PORK MEAT PRODUCED IN THE CZECH REPUBLIC

Altogether we collected 135 pork samples from 9 different herds located in the Czech Republic. Fifteen samples of muscle tissue were collected from the slaughter - house after inspecting the meat from each selected farm. Muscle tissue samples (300g) were taken from *musculus biceps femoris.* There was no attempt to standardize diets or slaughter weights, so that the samples would reflect the conditions within that particular region. In all cases inorganic sodium selenite was used as a Se supplement in the pig´s diets. We did not discover any farm using organic Se source in diets for growing-finishing pigs. The results were evaluated by statistical analysis.

One way ANOVA model was applied as the only parametric test to difference among herds to the overall experimental variability. Differences between herds were analyzed by post – hoc test (Tukey test). For herds Blansko one outlier was removed prior to analysis (11^{th} sample, value 114.16 μg/kg) for conservation of normality. All statistical analyses were performed using STATISTICA 8.0 and SPSS 16.0 for Windows.

Concentrations of Se in muscle tissue were measured using the following steps: samples of muscle were mineralized in a closed system using a microwave (MLS-1200, Milestone, Italy) digestion technique with HNO 3 and H 2O 2. Samples were then evaporated and the mineral residue was dissolved in water to which 20% HCl was added. Selenium was then determined with a Solar 939 AA Spectrometer (Unicam, UK) using a hydride AAS technique with detection limit of 0.762

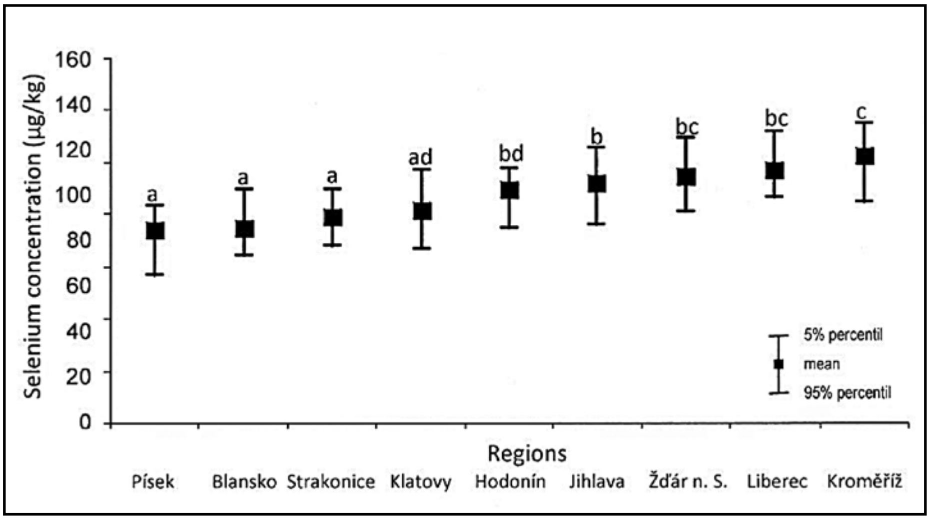

Figure 1. Distribution of concentration of Se in muscle in particular herds in the Czech Republic.
Groups with different alphabetic superscripts differ significantly at p<0.001 (ANOVA)

$\mu g.kg^{-1}$ and determination error (4.6-15%). Similar studies showed large variations in pork Se content from around the world. For instance, in Slovakia the average Se content in pork was 105.6 µg/kg (Kadrabova *et al.* 1996), in New Zealand, 57.0 µg/kg (Thompson & Robinson, 1980); in Thailand 180.0 µg/kg (Sirichakwal *et al.* 2005).

In our study we have found that there were statistically significant differences in pork Se content among regions of the Czech Republic (***Figure 1***). The average Se content in pork found in our study was 87.10 µg/kg. This is in agreement with Mahan *et al.* (2005). Their study demonstrated a wide variance in Se concentrations in the diets, even though selenite was added. This indicates that the organic components contained in the basal diet (grains) are the reason for the major differences in Se concentrations among diets.

The Se content in plants depends on its concentration in the soil and it varies significantly between regions. For instance, the average concentration of Se in US wheat is 0.3 mg/kg of Se; however, in South Dakota it is between 5-15 mg/kg of Se (Hintze *et al.* 2002). Moreover, it has been demonstrated that the addition of selenite to the pig's diet (generally at 0.3 mg/kg of Se) has little effect on muscle Se levels.

The recommended daily selenium intake varies around the world. In the USA, Canada (Standing Committee on the Evaluation of Dietary Reference Intakes, 2000) and Europe (Scientific Committee for Food, 1993) 55 µg/day of Se are recommended for both men and women. In the United Kingdom (Department of Health, 1991) 75 µg/day of Se are recommended for men and 60 µg/day of Se for women. Provided that the average annual consumption of pork in the Czech Republic is 42.0 kg per person (Czech Statistical Office) with an average selenium content of 87.10 µg/kg, the selenium intake from pork represents 18.2 % of the requirement for men and women per year (calculated with an intake of 55 µg/day of Se).

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