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Content of nitrates and nitrites in unprocessed raw beef

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Abstract: The aim of the study was to examine the contents of nitrates and nitrites in raw beef coming from cattle of the Polish Holstein-Friesian breed, black-and-white type, originating from different parts of Poland. The research material comprised *semitendinosus* and *longissimus thoracis* muscles obtained from 176 heads of cattle. The content of nitrites in the examined muscles ranged from 0.6 to 13.3 mg kg^{-1} in rump muscles and from 0.8 to 13.7 mg kg^{-1} in muscles of the back. The most samples were characterised by the presence of nitrites in the range from 1 to 5 mg kg^{-1}, and the least samples from 11 to 14 mg kg^{-1}. The contents of nitrates were significantly higher, ranging from 10.2 to 73.5 mg kg^{-1} in the *semitendinosus* muscle and from 10.4 to 74.3 mg kg^{-1} in the *thoracis longissimus* muscle. Such and higher level of contamination may be the cause of meat discolouration after heat treatment despite the absence of curing ingredients. It is necessary to continuously monitor the concentration of nitrates in raw materials, water and feed to ensure the complete safety of food of animal origin.

Keywords: food safety; uncured meat; contamination

The excessive accumulation of nitrites and nitrates in raw food materials is the object of continuous interest on the part of food technologists and nutritionists due to the risk of toxic effects of these compounds and their derivatives on the human body. In rural areas, farming activity is the main source of nitrates. Unused residues of fertiliser components, especially nitrogenous ones, can permeate surface waters and groundwater, causing their pollution (Raczuk et al. 2009). The degree of contamination of food raw materials with nitrates depends on the region where they come from, which stems from agricultural practices and applied production processes, soil quality, climate, and environmental pollution (Hsu et al. 2009). Vegetables carry the most nitrites into the diet – about 43%, cured meat products are also a serious source of these compounds – about 28%, 16% are transferred by cereal products, 5% dairy, and 8% others. In the case of nitrates, it is estimated that as much as 87% come from vegetables, of which, e.g. spinach, lettuce, cabbage or carrots, have a high capacity to accumulate these compounds (Cierach 2007; Tietze et al. 2007). Dąbek (2011) noted that nitrophilic plants accumulate larger amounts of nitrogen compounds in leaves as compared to stems and roots. Meat and cereal products contribute approximately 5% of nitrates, dairy products 2%, and others approx. 3% (Siderer et al. 2005).

Nitrites and nitrates are used in the meat curing process as an irreplaceable, so far antibacterial agent protecting against the growth of *Clostridium botulinum*. These compounds are involved in forming the characteristic, pink-red colour and flavour/scent profile of cured meat products, subjected to heat treatment, and, what is more, they have an antioxidant effect on muscle lipids. The levels of the addition of these substances are strictly limited by permission. However, the accumulation of these compounds in meat raw materials, technological water and spices is not taken into account, which may lead to exceeding the limit of their residues in the finished product. High consumption of nitrites and nitrates is associated with an increased risk of gastric cancer (Joossens et al. 1996; Park et al. 2015). However, the contamination of beef with nitrites and nitrates is mainly considered in terms of their role as precursors of carcinogenic nitroso compounds, which can be formed during frying or roasting of meat, but can also be synthesised in the stomach by reaction with peptides,

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amino acids and amines. When N-nitrosamines get into the human body, they can lead to changes in the translation of genetic information, as they are inhibitors of DNA and RNA synthesis (Archer 2002; Kühne 2004). Moreover, they have strong free radical properties, can affect metabolism and cause cancer of the stomach, oesophagus and other parts of the gastrointestinal tract, as well as cancer of the bladder, lungs, liver, or kidneys (Stachelska 2006; Sebranek and Bacus 2007). Therefore, the aim of this study was to examine the content of nitrites and nitrates in raw, uncured beef meat obtained from cattle of the Polish Holstein-Friesian breed, black-and-white variety, originating from different parts of Poland, in order to obtain present information to what extent the situation poses a threat and requires in-depth monitoring in the context of food safety.

MATERIAL AND METHODS

Chemicals and sample. Study material comprised two beef muscles: *musclus semitendinosus* and *musclus longissimus lumborum et thoracis*, obtained from carcasses of young cattle for slaughter, Polish Holstein-Friesian breed, black-and-white variety. The cattle were kept in an extensive fattening system, where pasture fattening was used from spring to autumn, and roughage (hay, silage) and concentrated feed as supplementation were used in the winter period. The animals were fattened to a weight of approx. 400–500 kg for approx. 16–18 months. They came from various parts of Poland but were slaughtered in the same meat processing plant. Slaughter was carried out in accordance with applicable European Union regulations (EC No. 1099/2009). Half-carcasses were cooled down by a one-degree method at the temperature of 1 °C until meat reached the temperature of less than 7 °C. The muscles were cut from half-carcases 48 h after slaughter, packed and transported to the laboratory. Meat from 176 heads of cattle was examined.

Instrument setup. The contents of nitrites and nitrates in meat were examined by the spectrophotometric method (Tajner-Czopek and Kita 2005; Wardak et al. 2015). It was based on a colourimetric measurement of the hue that nitrites along with salicylic acid give in the presence of sulphuric acid and nitrates with rivanol in the presence of hydrochloric acid.

RESULTS AND DISCUSSION

The nitrite content in the muscles of the hind leg (*m. semitendinosus)* ranged from 0.6 to 13.3 mg kg^{-1} (Figure 1), while in the back muscles (*m. longissimus thoracis*) it was from 0.8 to 13.7 mg kg^{-1} (Figure 2). The nitrite contents observed in most samples ranged from 1 to 5 mg kg^{-1}. In case of *m. semitendinosus*, 123 samples, i.e. approx. 70%, and in case of *m. longissimus thoracis*, 130 samples, i.e. approx. 74% (Figures 1 and 2). However, the level of nitrites in meat samples is very high. The highest concentration of these compounds, of about 11−14 mg kg^{-1}, was recorded only in few samples. In the case of both examined muscles, the nitrite content was characterised by a similar quantitative distribution, and the trend lines were similar to rectilinear ones and indicated a decrease in the number of samples with an increase in the nitrite concentration.

The concentration of nitrates in the tested meat was significantly higher than that of nitrites. In the *semitendinosus* muscle, it ranged from 10.2 to 73.5 mg kg^{-1} (Figure 3), and in the *longissimus thoracis* muscle, it was in the range of 10.4 to 74.3 mg kg^{-1} (Figure 4). In both muscles, the largest number of samples was characterised by the nitrate content of approx. 25 mg kg^{-1}, and in a number of samples the content of even 70–75 mg kg^{-1} was recorded, which may be the effect of curing, particularly to maintain the red-pink colour after heat treatment.

Summarising the results for the two types of muscles, the comparison of changes in the number of samples for different nitrate concentrations showed similar change trends. The initial increase in the size of samples to a concentration of approx. 25 mg kg^{-1}, and then the decrease in the size of samples along with the increase in the concentration of nitrates. The exception is the nitrate content types in *longissimus thoracis* muscle concentrations of 45, 50, and 55 mg kg^{-1}. These are very high concentrations detected in this muscle for more than 27 samples. This fact is difficult to explain. One of the reasons might be fragmented agriculture in Poland, low pasture acreage, rapid progress in breeding beef cattle and associated with it intensive pasture fertilising to provide an appropriate amount of feed. Accumulation of nitrates and nitrites in beef depends on the concentration of these compounds in roughage. However, in the following researches, the main issue was to investigate the content of nitrates and nitrites in randomly chosen cattle from various parts of Poland. Regions that are regarded as ecological as well as regions regarded as contaminated, perhaps with industrial waste.

Nutritional research which may confirm correlations between roughage quality and nitrate and nitrite content in beef was not conducted. Only meat after slaughter was

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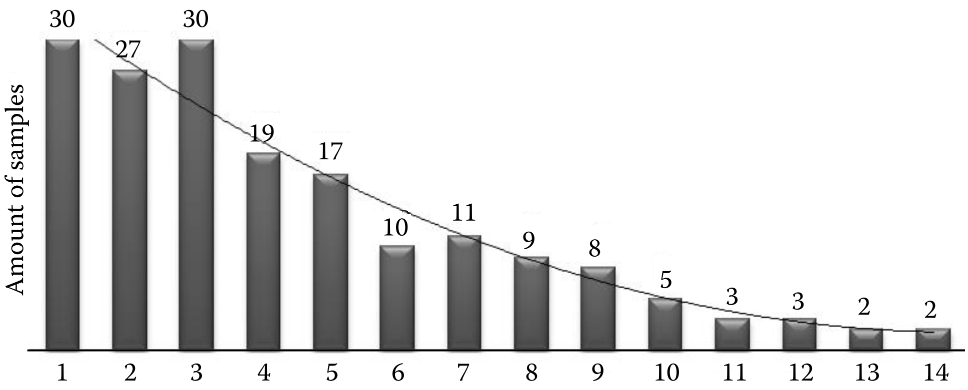

Figure 1: Nitrates content in beef – *semitendinosus* muscle (mg kg^{-1})

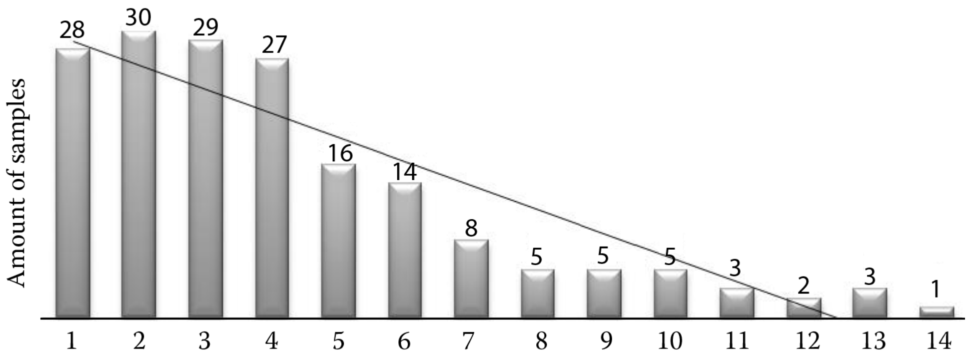

Figure 2: Nitrates content in beef – *longissimus thoracis* muscle (mg kg^{-1})

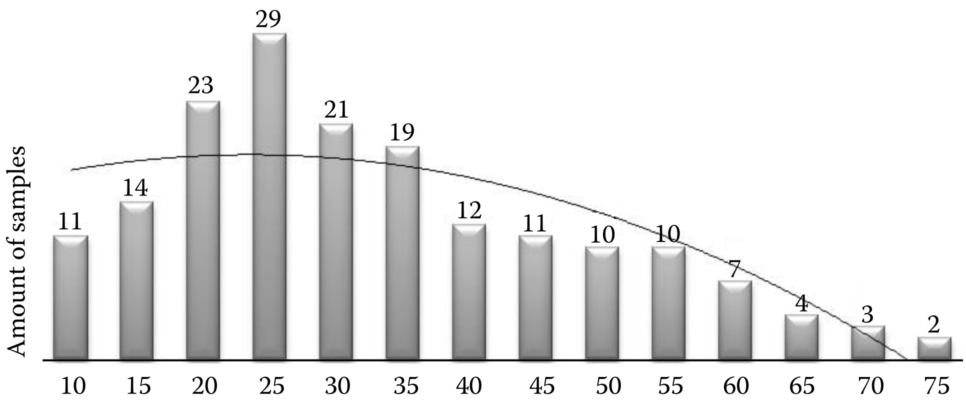

Figure 3: Nitrates content in beef – *semitendinosus* muscle (mg kg^{-1})

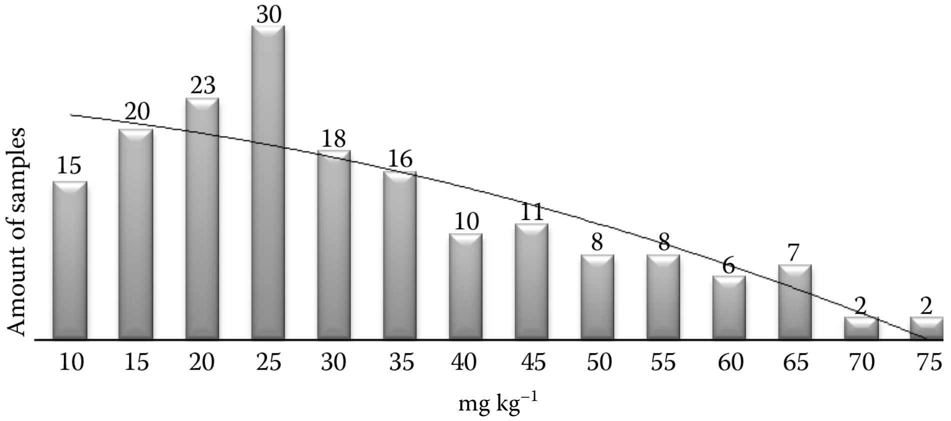

Figure 4: Nitrates content in beef – *longissimus thoracis* muscle

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examined. The fattening system with pasture fattening, roughage and concentrated feed may cause difficulties in estimating concentrations of nitrates and nitrites. However, correlations between the fattening system and the nitrate or nitrite level exist. Probably a significant impact on the content of nitrates and nitrites in raw beef might be exerted by animal race, age during slaughter, slaughter weight, sex, breeding climate, fatness and individual characteristics. The problem of meat contamination with nitrates concerns not only beef but also turkey, for example. In the raw, uncured turkey breast muscle, Ahn and Maurer (1987) measured nitrate content ranging from 3.8 to 21 mg kg^{-1} and nitrites from 0 to 0.7 mg kg^{-1}.

In minced beef and beef tenderloin, available in retail chains in Sydney, Hsu et al. (2009) did not detect any nitrites at all, and the nitrate content was about 19 mg kg^{-1} and about 39 mg kg^{-1}. These values were lower than those obtained in this work. It could be concluded that the observed variations in the high nitrate contents in the various muscles are conditioned environmentally, and they result from the method of cattle feeding and, above all, from the degree of feed contamination by these compounds.

Such high nitrate contamination of uncured raw meat, which was noted in this paper, is very dangerous from both the nutritional and technological point of view. In a situation where the maximum acceptable daily intake (ADI) of nitrates by humans should not exceed 3.7 mg kg^{-1} body weight and expressed as nitrate ions (5 mg kg^{-1} body weight expressed as sodium nitrate), and in the case of nitrites, this value should not exceed 0.07 mg kg^{-1} body weight; it is possible to significantly exceed the assumed levels of the intake of these compounds in the case of subjecting beef raw material, contaminated with nitrates, to curing and then consuming other foods rich in nitrates. Therefore the authors presenting research results appreciate the difficulty of estimating the raw beef safety level. All the more, the content of nitrates/nitrites might significantly change as a result of the high reactivity of these components in different technological conditions (heat treatment, meat ageing, pH value changes, accessibility of protein breakdown products as potential reagents, lipids, reactions with meat pigments, breakdown to nitrogen oxide etc.). It should be mentioned that the maximum acceptable level of nitrites in meat products amounts to 60 mg kg^{-1}, but also 100 or 150 mg kg^{-1} of the product. Another threat resulting from the presence of nitrates in beef meat is associated with heat treatment of this meat at a high temperature. Beef is increasingly consumed in the form of fried or grilled steaks and burgers, during the preparation of which there are real possibilities for the formation of carcinogenic and mutagenic N-nitrosamines (Jo et al. 2010; Li et al. 2012).

From the technological point of view, the raw meat material containing nitrogen may undergo an adverse colour change in the process of uncured meat production (Li et al. 2012). The colour of such meat products is heterogeneous, grey with pink-red discolouration, which is difficult for consumers to accept.

CONCLUSION

Based on the research carried out, low amounts of nitrites (1–5 mg kg^{-1}) were determined in most of the samples. In the case of nitrate content, several tens of tested samples (approx. 30% of the test material) showed a high contamination level (above 40 mg kg^{-1}). Such a high content of nitrates in muscles can cause a decrease in their technological usefulness, constitute the potential risk of exceeding the permitted limits, and create the possibility of an adverse effect on consumers' health. In order to ensure the absolute safety of food of animal origin, it is necessary to monitor the content of nitrates in raw materials, water, but also in feed given to animals during fattening.

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