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Changes of sensory properties of horse meat during cold and frozen storage

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In terms of nutritional and dietary value, sensory attractiveness and safety of consumption, horse meat is classified as one of the finest food products of animal origin (Kondratowicz and Sobina, 2001). Information in the subject literature indicate that this meat has cohesive and firm structure (Kondratowicz and Kawałko, 2001). Its consistency is relatively compact (hard) (Stanisławczyk and Rudy, 2010). Muscle fibres are thin and delicate, interwoven with fat tissue that gives the meat a marble-like effect. Horse meat, especially from young animals, usually has good tenderness, because this feature is primarily associated with the connective tissue content, including its main protein – collagen (Kondratowicz and Bąk, 1998; Kondratowicz and Kawałko, 2001). However, raw material obtained from the older specimens is often characterized by undesirable stringiness and hardness, which is a result of a greater proportion of connective tissue compared to other types of this raw material (Arcos-Garcia et al., 2002; Stanisławczyk and Rudy, 2010). Horse meat is characterized by high resistance to spoilage and rotting processes. It is a raw material of very high stability. This property of meat is a result of specific post-mortem changes occurring in muscles due to high glycogen level that is associated with persistent acidification inside the muscles (Kondratowicz, 2002; Stanisławczyk and Rudy, 2010). Horse meat is dirty-red with slight light blueish shade that darker and takes on black and dark brown colour on exposure to air (Kondratowicz, 2001; Kondratowicz and Kawałko, 2001).

Physical methods of meat preservation based on the influence of low temperatures enable to store it raw, while maintaining the initial quality of fresh meat. Low temperatures applied during cold storage do not cause any damage to meat tissue structure. Cold storage consists in prolonging meat stability thanks to depriving it of a certain amount of heat and lowering the temperature to the level close to 0°C, but maintained above the meat's freezing point. Prolonging storage time of raw materials and meat products in refrigeration conditions is a result of a decrease in the rate of microbiological, chemical and biochemical decomposition processes in the temperature several degrees above the water freezing temperature (Palich, 2006). Freezing is a commonly used method that enables to maintain high quality and stability of perishable meat. In addition, freezing together with freezing storage technology are irreplaceable when managing meat raw material during its excess supply on the market (Domaradzki et al., 2011). Freezing meat causes changes in its quality, directly associated with the process of freezing and the subsequent storage in frozen condition (Chwastowska and Kondratowicz, 2005). As a result of freezing meat, the processes of post-slaughter maturation are slowed down or even stop.

On the other hand, processes related to freezing of water and the formation of ice crystals inside muscle structures occur intensively. As a result of freezing meat, the capillary structures in the muscle tissue are loosened, which in consequence leads to a decrease in the water-holding capacity during defrosting and more significant losses during heat treatment, thus reducing the juiciness of meat (Marchel et al., 2013). As reported by Stiebing and Hegerding (2004), numerous sensory changes may occur in products stored in frozen condition. The most important factors determining the quality of frozen meat include: good raw material, appropriate conditions (primarily the freezing rate) of freezing, storage and defrosting. This means that the quality of frozen meat depends both on the primary changes preceding the freezing and the secondary changes occurring at the individual stages of freezing and frozen storage treatment (Domaradzki et al., 2011).

Considering the above information, studies were conducted in order to analyse the changes in sensory properties of horse meat during cold and frozen storage.

Material and methods

The study material consisted of longissimus dorsi muscle specimens collected from 16 horse sides that weighed between 325-640 kg prior to slaughter and were aged between 4 and 19 years. In order to perform sensory assessment of the meat, four meat specimens weighing 700 g each were taken from the part of longissimus dorsi muscle at the level of 13-14 thoracic vertebrae. The specimens were then cleared of the external fat, connective tissue and tendons. One part of the meat specimens was subjected to sensory assessment after 48 hours from the moment of slaughter, being kept in cold conditions (at the temperature of 6°C). To analyze the influence of the maturation process on the changes of sensory properties of muscle tissue, the assessment was also performed after the maturation period had ended, i.e. after 120 hours after slaughter. The remaining three series of meat specimens were frozen in liquid nitrogen vapour. The freezing of horse meat was performed in Hopkins freezer cabinet after vacuum packing them in PA/PE foil bags. The mean temperature of the specimens at the beginning of freezing was about 4°C. During freezing process, the temperature was lowered to -75°C and this procedure lasted for about 1 hour. After freezing, the horse meat specimens were kept at -22°C for the period of 1, 3 and 6 months. After the designated period of frozen storage, the specimens were transferred to laboratory for sensory assessment. Before the specimens were tested for quality, they were air-defrosted in packagings at approximately 10°C. The defrosting was stopped after the inner temperature of the studied meat reached 0°C. The sensory assessment of frozen stored meat was performed directly after defrosting and after 72 hours after defrosting.

For the sensory assessment of the longissimus dorsi muscle, 1 cm thick slices were cut against the muscle fibres. The meat was fried in fat heated to 250°C. The heat treatment of the meat lasted 4 minutes (2 minutes on each side of the slice). Afterwards, the temperature was reduced to 150°C and the meat was fried for 1.5 minutes on both sides.

The sensory assessment of the meat was performed by a team consisting of 7 members chosen in accordance with PN-ISO 8586-1:1996 standard and checked for sensory sensitivity according to PN-ISO 3972:1998 standard. A 5-point sensory assessment scale of partial quality was used, assessing the following quality indicators: aroma, juiciness, tenderness, tastiness (Nowak, 2004) according to the sensory assessment chart (Table 1).

Table 1. Sensory Assessment Chart (Baryłko-Piekielna, 1998; Nowak, 2004)

Pts	*Aroma*	*Juiciness*	*Tendernes*	*Tastiness*
1	*very negative*	*very dry*	*very hard, very fibrous*	*very negative*
2	*negative*	*dry*	*hard, fibrous*	*negative*
3	*neutral*	*slightly juicy*	*slightly tender*	*neutral*
4	*desirable*	*juicy*	*tender*	*desirable*
5	*very desirable*	*very juicy*	*very tender*	*very desirable*

Table 2. Sensory properties of horse meat stored through 48 hours in cold conditions and directly after defrosting of that raw material frozen stored (pts)

Meat properties	*Meat stored in cold conditions, 48 h post mortem*	*Meat stored 1 month in frozen conditions, directly after defrosting*	*Meat stored 3 months in frozen conditions, directly after defrosting*	*Meat stored 6 months in frozen conditions, directly after defrosting*
	±S	±S	±S	±S
Aroma: intensity	3.83 A ± 0.19	3.93 A ± 0.14	3.91 A ± 0.18	3.63 B ± 0.27
desirability	4.07 $\bar{x}$A ± 0.14	4.20 $\bar{x}$B ± 0.18	4.15 $\bar{x}$ ± 0.18	4.$\bar{x}$7 ± 0.43
Juiciness	3.92 ± 0.36	4.12 ± 0.21	4.09 ± 0.18	4.17 ± 0.33
Tendernes	3.94 A ± 0.41	4.27 B ± 0.25	4.15 B ± 0.23	4.20 ± 0.39
Tastiness: intensity	4.00 A ± 0.27	4.28 B ± 0.22	4.07 B ± 0.23	4.22 B ± 0.38
desirability	3.97 A ± 0.26	4.31 B ± 0.23	4.11 B ± 0.24	4.16 B ± 0.39

A, B – difference significant at P≤ 0.05.

Table 3. Sensory properties of horse meat stored for 120 hours in cold conditions and 72 hours after defrosting of that frozen stored raw material (pts)

Meat properties	*Meat stored in cold conditions, 120 h post mortem*	*Meat stored 1 month in frozen conditions, 72 h after defrosting*	*Meat stored 3 months in frozen conditions, 72 h after defrosting*	*Meat stored 6 months in frozen conditions, 72 h after defrosting*
	$\overline{x}$ ±S	$\overline{x}$ ±S	$\overline{x}$ ±S	$\overline{x}$ ±S
Aroma:				
intensity	4.02 A ± 0.13	3.90 A ± 0.20	3.93 A ± 0.13	3.60 B ± 0.22
desirability	4.17 A ± 0.18	4.22 A ± 0.13	4.12 ± 0.31	3.88 B ± 0.35
Juiciness	4.22 A ± 0.25	4.14 ± 0.20	4.08 ± 0.23	3.96 B ± 0.21
Tenderness	4.22 A ± 0.34	4.25 ± 0.21	4.20 ± 0.30	4.07 B ± 0.29
Tastiness:				
intensity	4.29 A ± 0.25	4.29 B ± 0.20	4.18 ± 0.28	4.00 B ± 0.32
desirability	4.48 A ± 0.72	4.29 B ± 0.22	4.25 ± 0.35	3.99 B ± 0.37

A, B – difference significant at P≤ 0.05.

Tables 2 and 3 contain arithmetic means ($\overline{x}$) of each of the studied features and the values of standard deviation (S). In order to assess the effect of cold and frozen storage on changes in the sensory properties of horse meat, test of significant differences was applied and one-way analysis of variance was performed that was verified with the use of Tukey's confidence intervals.

All the statistical calculations were conducted using STATISTICA software, version 10.0.

Results and discussion of results

Sensory analysis is defined by Baryłko-Piekielna (1998) as the measurement and assessment of product properties (qualitative features) with the use of one or several senses applied as a measuring device, with the appropriate assessment conditions and requirements for the people conducting it, as well as methods adjusted to the tasks established for the assessment.

Data on the sensory assessment of horse meat quality are presented in tables 2 and 3. In the studies, both the effect of storage conditions and the duration of cold and frozen storage on sensory quality of the studied meat were noted. Moreover, the numeric values obtained in authors' original studies indicate that the most unfavourable sensory quality corresponded to the horse meat fter 48-hour cold storage, except from the assessment of aroma of the raw material stored in frozen conditions for 6 months (table 2). Analysis of arithmetic means obtained in case of horse meat cold stored for 120 hours (table 3) demonstrated a tendency to higher grades for all the quality features of the The majority of consumers consider tenderness as the most important qualitative feature of meat (Nowak, 2005). Meat tenderness changes together with the development of post-slaughter changes in muscle tissue. An increase in meat tenderness is attributed to many factors. In general, it is thought that in acidified muscles the conditions for the proteolytic activity of muscular enzymes were created. Proteolysis of some proteins gives the meat favourable tenderness (Stanisławczyk, 2013 a).

Juiciness depends on water-holding capacity of meat as well as on the intramuscular fat content. Horse meat is characterised by relatively well water-holding capacity, however, low intramuscular fat

content and its low melting temperature cause that in terms of juiciness it is not particularly distinctive compared to other types of meat (Kondratowicz and Kawałko, 2001). In my own studies (according to the chart contained in table 1) horse meat was assessed as juicy, because grades obtained for this feature amounted to 3.92 to 4.22 points. The process of freezing and frozen storage of horse meat contributed to the improvement of juiciness of the studied raw material compared to the meat stored for 48 hours in cold conditions. However, statistically significant differences were observed only between juiciness of meat stored for 120 hours in cold conditions and the meat stored for 6 months in frozen conditions – 72 hours after defrosting (table 3).

In author's own studies, tenderness of horse meat should be interpreted in words as tender, because the numeric values assigned in the assessment of this feature ranged from 3.94 to 4.27 points. Similar as in case of assessment of juiciness, it was observed that the process of freezing and frozen storage of horse meat contributed to the improvement of tenderness of the studied raw material compared to the meat stored for 48 hours in cold conditions. Statistically significant differences were observed between tenderness of meat stored for 48 hours in cold conditions and meat stored in frozen conditions for 1 month and 3 months – directly after defrosting (table 2). Moreover, statistically significant differences were also demonstrated between tenderness of meat stored for 120 hours in cold conditions and raw material stored in frozen conditions for 6 hours – 72 hours after defrosting (table 3).

Features deciding on sensory properties of horse meat are aroma and taste that are generally described as tastiness (Stanisławczyk, 2013 b). Tastiness is an important element of qualitative features of meat. Its components are very often varied. Peptides, amino acids, lipid derivatives are very important indicators of meat tastiness (Cierach et al., 2009). In author's own studies it was observed that there is a statistically confirmed tendency to higher grades for tastiness statistically significant differences between horse meat stored for 120 hours in cold conditions and horse meat stored for 1 and 6 months in frozen conditions – 72 after defrosting (table 3). It was observed that in case of frozen horse meat, extending the duration of cold storage both to 120 hours and to 72 hours contributes to the improvement of tastiness intensity of the studied raw material.

Raw meat is a source of tastiness precursors and only to a small extent of taste-active and aroma-active compounds. It has serum-like taste, similar to the taste of blood (Zymon, 2014). Raw meat aroma is weak, similar to the aroma of industrial lactic acid (Kołczak, 2007). Thanks to glycogen content in the muscle tissue amounting to 0.9%, horse meat has typically slightly sweet taste and aroma, that unfortunately is regarded as a quite important drawback by consumers (Stanisławczyk, 2013 b). Numeric values obtained in author's (desirability and intensity) of meat subjected to freezing process and frozen storage for 1,3 and 6 months compared to the raw material stored for 48 hours in cold conditions (table 2). Studies on tastiness of raw material demonstrated original studies indicate that the duration of cold and frozen storage had a significant effect on the assessment of intensity and desirability of horse meat aroma. It was demonstrated that cold storage process has the effect on the improvement of aroma (intensity and desirability) of the studied raw material. After 120 hours of cold storage, the aroma of horse meat was characterised by higher grades compared to the aroma of raw material analysed 48 hours after the slaughter, that indicates the enrichment of aroma profile during the post-slaughter meat maturation. Such results should have been expected, because post-slaughter transformations of nucleotides, carbohydrates, proteins and lipids lead to the formation of precursors and even taste and aroma substances. They include, among others, inosinic acid, glucose, inorganic phosphates, lactic acid, free amino acids, free fatty acids, ammonia, electrolytes etc. (Litwińczuk et al., 2004).

The results obtained in author's own studies have shown that the process of freezing and extending the duration of frozen storage to 1 month and 3 months improved the intensity and desirability of horse meat aroma compared to the meat stored after slaughter for 48 hours in cold conditions (table 2). It should be emphasized that the highest numeric values characterising the desirability of horse meat aroma were noted after 1 month of frozen storage, both immediately after defrosting (4.20 points) and 72 hours after defrosting (4.22 points). Taking into consideration the numeric data presented in tables 2 and 3, it should be stated that further frozen storage of horse meat up to 6 months has statistically significant effect on the development of aroma assessment. Analysis of the results of aroma assessment of the studied raw material has shown that these values decreased together with extension of frozen storage time to 6 months. There was a pronounced decrease in the assessment of aroma intensity – to 3.63 points directly after defrosting and 3.60 points 72 hours after defrosting that – according to the chart contained in table 1 – corresponds to neutral assessment.

The results of published national studies conducted on the similar experimental material also demonstrated an improvement in all the quality features of horse meat sensory assessment as a result of freezing process. Moreover, extension of frozen storage period from 1 month to 3 months contributed to the further improvement of sensory quality of the analysed raw material (Stanisławczyk, 2013 b).

Studies on changes in sensory properties of horse meat during cold storage were also conducted by Kwiatkowska (2002). Kwiatkowska demonstrated that horse muscles stored at 4°C from 24 to 96 hours were sensorically assessed as very poor, demonstrating their insufficient tenderness. After 144 hours, meat tenderness was assessed as unsatisfactory, and after 216 hours there was still no improvement in meat tenderness n organoleptic assessment. Only horse muscles stored at 12°C for 96, 144 and 216 hours were considered tender enough. After 312 hours of further storage in the above-mentioned conditions, tenderness of muscle samples was assessed as excessive and undesirable. As a result of the conducted studies, Kondratowicz and Kawałko (2001) observed the effect of storage duration on sensory quality of horse meat. Aroma grades of the examined raw material samples (desirability) after 0.5 month and 6 months of storage were significantly higher from the grades obtained after 3 months. What is more, during 6-month frozen storage, a more pronounced decrease in sensory quality features were observed, such as: tastiness (desirability and intensity), aroma (desirability), tenderness and juiciness of horse meat frozen with the use of liquefied carbon dioxide compared to the raw material frozen using air-blast method.

Summary and conclusions

1. Sensory quality of horse meat clearly depends on the duration of cold storage. As cold storage time of the studied raw material was extended, all the quality features in the sensory assessment of horse meat improved.
2. The process of freezing and frozen storage of horse meat for 1 month and 3 months contributes to the improvement in sensory quality of the analysed raw material in comparison with meat stored for 48 hours in cold conditions.
3. Together with extending the duration of frozen storage of horse meat to 6 months, further improvement in sensory quality of horse meat, predominantly juiciness, tenderness and tastiness occurred, whereas aroma intensity of the studied raw material decreased.

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CHANGES OF SENSORY PROPERTIES OF HORSE MEAT DURING COLD AND FROZEN STORAGE

Abstract

The aim of this paper was to analyze the changes of sensory properties of horse meat during cold and frozen storage. Samples of the *longissimus dorsi* muscle from horse carcasses were tested. It was concluded from the present study that the process of cold storage contributes to improvements in all the quality characteristics and sensory assessment of horse meat. The process of freezing and frozen storage of horse meat to 1 and 3 months results in improvement of sensory properties of the analyzed material in comparison to the meat cold stored for 48 hours. As the duration of frozen storage increased to 6 months, further improvement of the sensory quality of horse meat took place, mainly in terms of juiciness, tenderness and tastiness, with a decrease of aroma intensity.

Key words: horse meat, sensory properties