ACTA SCIENTIARUM POLONORUM *Acta Sci. Pol., Technol. Aliment. 4(2) 2005, 89-96*

CHANGES IN PHYSICO-CHEMICAL PROPERTIES OF HORSEMEAT DURING FROZEN STORAGE

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Summary. The objective of this paper was to determine the effect of cold-storage time (in frozen condition) on selected physical and chemical characteristics of horsemeat and fat. Samples of the longest dorsal muscle and nape fat from horse carcasses were tested. Two time periods of 1 and 3 months were applied as a comparative criterion for meat and fat. The research was performed on 26 carcasses of adult horses (8-10 years old). It has been shown that the frozen storage process causes darkening of meat color as well as reduces the meat capacity to bind and retain water. Moreover, the frozen storage improves the meat tenderness. With the time of cold storage the peroxide value and acid number were observed to rise as the evidence of oxidizing and hydrolytic processes taken place in horse fat.

Key words: horsemeat, freezing, meat quality

INTRODUCTION

Poland is the country that matters on the horsemeat market [Kondratowicz and Sobina 1999, Kondratowicz and Podlejska 2000]. Horsemeat is exported to such countries as Italy, France, Belgium and Germany. In the 1990-ties Japan became a financially favorable the horsemeat market where superfat-marble, deboned and deep-frozen meat was still sold [Kondratowicz 2001 b].

Horsemeat has a cohesive and firm structure. Muscle fibers are thin and delicate and are interspersed with fat tissue, thus providing the marble-like effect [Kortz and Gardzielewska 1998]. Horsemeat, especially that from young animals is characterized by good tenderness, the characteristic that tells mainly about the content of connective tissue, including its main protein – collagen. Besides, horsemeat is characterized by relatively good water-holding capacity, but its small content of intra-muscular fat and its low melting temperature combine to the fact that its juiciness does not differ much from other meats [Kondratowicz and Kowałko 2001, Kondratowicz 2002 b]. The outstanding characteristic of horsemeat is its dark-red color with slight brown tinge. This slightly

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less favorable property results from high content of the myoglobin muscle pigment [Kondratowicz 2001 b, Kondratowicz at al. 2000, Kondratowicz and Podlejska 2000]. Typical sweetish taste of horsemeat on the other hand is mainly due to its high content of glycogen [Kondratowicz and Bąk 1998, Kondratowicz 2001 a].

In respect of its nutritional value, horsemeat is as good as other meats, and quite often better. High biological value of horsemeat is complemented by relatively high level of vitamins, especially B1, B2, E, PP, A, as well as mineral salts, especially phosphorus, calcium and iron [Korzeniowski at al. 1999, Kondratowicz at al. 2000].

Despite advanced research on horsemeat up to now, the information published in domestic and international literature on physico-chemical changes taking place in that raw product during frozen storage is fragmentary. Therefore, the research described in this paper is devoted to the study of physico-chemical changes taking place in horsemeat frozen and kept in nitrogen vapors for 1 and 3 months in frozen conditions.

MATERIALS AND RESEARCH METHODS

The research was performed in 2003-2004. The research material in this paper was the carcasses of horses in good health and fat-content condition purchased from the individual farmers from the region of the south-eastern as well as from the north-eastern and central Poland.

Slaughtered animals were 8 to 10 years old, and had a pre-slaughter weight ranging from 450 to 550 kg. The physico-chemical analysis of muscle tissue was carried out on 26 horse carcasses.

In order to determine the chemical composition and perform determinations of physical and chemical properties of horse meat, three series of samples of 700 g were taken each time from the longest dorsal muscle (*m. longissimus dorsi*) at the height of the 12-14th thoracic vertebra. Then they were cleaned from external fat, connective tissue and tendons. One sample was intended for laboratory analyses, and it was kept in cool conditions (temperature of 6°C). Determinations on cooled meat were carried out 48-50 hours after slaughtering.

The water content was determined in accordance with the PN-ISO 1442:2000 [2000] standard. The protein was determined by the Kjedahl method, in which the determined nitrogen content was recalculated to protein according to the PN-75/A-04018 [1975] Polish standard. The fat content was determined with Soxhlet method, according to recommendations in the PN-ISO 1444:2000 [2000] standard. The total ash was determined in accordance with the guidelines specified in the PN-ISO 936:2000 [2000] standard.

The remaining two series of samples were subjected to freezing in liquid-nitrogen vapors (at –75°C). Horsemeat freezing was done in a freezing cabinet of Hopkins type, upon packing them previously under vacuum in bags of the PA/PE foil. The average temperature of samples at the starting moment of freezing was 4°C. It dropped down to –75°C during freezing, and the time of the freezing was approx. 1 hour. After freezing the meat samples were stored for 1 and 3 months periods at the temperature of –23°C. After the predetermined period of storage the samples were moved to the laboratory for analyses. Sample quality testing was preceded by thawing through putting (packed

samples) in air at the temperature of approx. 20°C. Freezing was interrupted once the temperature of about 0°C was reached inside the tested meat.

Then the following physico-chemical determinations were performed:

– meat color lightness – by spectro-photometric method (% of reflection) using the "Spekol" spectrophotometer with the Rd 45/0 reflection attachment at the wavelength of 560 nm [Kortz at al. 1968],

– cutting force applied to cut the meat sample, indicative of meat tenderness – Warner-Bratzler shear-meter ($N \cdot cm^{-2}$) [Tyszkiewicz 1969],

– thermal drip – by the Walczak method (%) [Walczak 1953],

– water – holding capacity – by the Grau and Hamm [1953] method (%) by modyfication Pohja and Niinivaara [1957],

– thawing drip/loss (%),

– value pH – by potentiometric method, using pH-meter of CP-215 type.

In order to perform determinations of physico-chemical characteristics of fat, two series of samples of 500 g each were taken from the nape fat fold. Both series of samples were packed under vacuum in bags of PA/PE foil and then subjected to freezing in liquid-nitrogen vapors (at –75°C) and stored at the temperature of –23°C for 1 and 3 months. Thawing was performed in air at about 20°C until reaching the temperature of about 0°C inside the tested fat sample.

The following physico-chemical determinations were performed after thawing:

– peroxide value – according to PN-ISO 3960:1996 [1996] standard, with the result specified in mili-equivalents of active oxygen per kilogram of sample

– acid number – in accordance with the guidelines contained in PN-ISO 660: 1998/Az1:2000 in mg KOH/g.

Collected numerical data were statistically processed using the Statistica program.

RESULTS

In the opinion of many authors [Kondratowicz 2001 b, Kondratowicz and Sobina 2001, Jurczak 2004, Korzeniowski at al. 1994] chemical composition of horsemeat depends largely on the condition, fatness, type and age of the animal, as well as on the kind of stock it is coming from, type of muscle and meat quality class.

Numerical data obtained from own tests and characterizing the chemical composition of fresh horsemeat are presented in Table 1. As indicated by the data in this table, horsemeat is characterised by the water content of 68.55%, the protein content of 21.21%,

Table 1. Chemical composition of (fresh) horsemeat, %
Tabela 1. Skład chemiczny (świeżego) mięsa końskiego, %

Content Zawartość	$\bar{x}$	S
Water – Woda	68.55	3.51
Protein – Białko	21.21	2.11
Fat – Tłuszcz	6.73	3.09
Ash – Popiół	1.07	0.10

the fat content of 6.73% and the ash of 1.07%. Calculated values concerning chemical composition may be compared with literature data. According to Krupa and Szmulik [1996] they are as follows: the protein content – 21.4%, the fat 5.9%, the ash 1.1%. Jurczak [2004] on the other hand specifies the protein content in horsemeat as 21.5%, the fat at 2.6% and the water at 74.1%.

Numerical values characterizing horsemeat in respect of its physicochemical properties depending on the time length in cold (frozen) storage that have been obtained in author own research are presented in Table 2.

Table 2. Analysis of the effect of storage time on selected physico-chemical properties of meat and fat tissue
Tabela 2. Analiza wpływu czasu przechowywania na wybrane cechy fizykochemiczne mięsa i tkanki tłuszczowej

Physico-chemical properties Cechy fizykochemiczne	Time of storage, months – Czas przechowywania, miesiące			
	1 month – 1 miesiąc		3 months – 3 miesiące	
	$\bar{x}$	S	$\bar{x}$	S
pH	5.44	0.09	5.46	0.09
Lightness of meat color (560), % Jasność barwy mięsa (560), %	6.18	1.64	5.62	2.02
Meat tenderness, $N \cdot cm^{-2}$ Kruchość mięsa, $N \cdot cm^{-2}$	48.05	8.63	45.99	7.25
Thermal drip in meat, % Wyciek termiczny mięsa, %	24.80Aa	4.45	30.95Bb	4.19
Water-holding capacity, % Zdolność zatrzymywania wody, %	21.53	5.03	22.5	5.66
Thawing drip/loss, % Wyciek rozmrażalniczy, %	6.74	3.45	8.68	3.33
Peroxide value, mili-equivalent/kg Liczba nadtlenkowa, milirównoważnik/kg	1.43Aa	0.65	2.90Bb	0.42
Acid number, mgKOH/g Liczba kwasowa, mgKOH/g	1.02a	0.11	1.14b	0.16

Statistical significance of differences between groups at the level $\alpha \leq 0.01$ are denoted with capital letters; that at the level of $\alpha \leq 0.05$ are denoted with lower case letters.

Dużymi literami oznaczono statystyczną istotność różnic pomiędzy grupami gdy poziom $\alpha \leq 0{,}01$, a małymi literami jeżeli poziom $\alpha \leq 0{,}05$.

The meat acidity is one of the most practical and objective indices defining meat quality [Kondratowicz 2001 b, Kondratowicz et al. 2000]. In present experiment it was shown, on the basis of active acidity of meat (measured after thawing), that acidity does not depend on the length of frozen storage time. On the basis of the analysis of the average pH value of meat in experimental groups it may be said that the acidity of frozen horsemeat did not vary much, reaching the pH values of 5.44 and 5.46 after 1 and 3 months of storage, respectively, so the differences were not statistically significant.

The results obtained are not consistent with the reports presented by other authors [Kondratowicz 2001 b, Kondratowicz and Sobina 2001, Kondratowicz and Sobina 1999, Kondratowicz 2002, Kondratowicz at al. 2000], who showed a clear rise in pH values (drop in acidity) in horsemeat with longer time of cold storage. The rise of the pH value in research of the authors during the storage may be connected with the specifics of horsemeat (high content of glycogen, its structure and the activity of glycolytic enzymes), as well as with using other methods of freezing. The complexity of causes that limit the rate of the glycolysis may clarify the results obtained for the pH variation versus meat storage time [Kondratowicz and Sobina 2001, Kondratowicz 2001 b].

The lightness of meat color may be affected by many factors such as the concentration of hydrogen ions and fat content. However, it is determined mostly by the level of meat pigments [Kondratowicz and Sobina 2001]. In cases of longer storage of frozen meat its color changes as a result of myoglobin oxidation to metmyoglobin, as well as partial compaction of meat pigments in surface layers that leads to its browning [Olszewski 2002]. Taking into account the above observations during the experiment, it may be said that meat after 1-month of frozen storage exhibited lighter color (higher percentage of light reflection, 6.18%). After longer storage time, 3 months, the meat color became darker (5.62%). The obtained results are confirmed by the research performed by other authors, who showed that with longer storage time there is a noticeable tendency of horsemeat to darken in its color [Kondratowicz 2001 b, Kondratowicz at al. 2000, Kondratowicz and Sobina 2001].

The other physico-chemical characteristic serving as the basis for meat quality determination is the shear necessary to cut a meat sample, the indication of its tenderness. The analysis of the effect of meat storage period on this characteristic indicates that meat after a 3-month storage period exhibited more favorable values of that characteristic (45.99 $N \cdot cm^{-2}$) compared to meat stored in frozen condition for 1-month (48.05 $N \cdot cm^{-2}$). Lower values of cutting shear applied to cut a sample of frozen meat after 3-month period of cold storage compared to those used to cut a sample of frozen meat after 1-month, confirm the positive effect of cold storage on that physico-chemical property. It shows that freezing process and cold storage improved meat tenderness but the differences were not statistically significant.

Another physico-chemical characteristic of horsemeat was the thermal drip of horsemeat that informs of losses to be expected as a result of its heat treatment. The determination of meat juice losses permits correct control of steaming, comminuting and grinding processes. Meat exhibiting small water loss in heat treatment processes is said to be more water-holding capacity. The author research indicates that meat after 1-month of frozen storage had a significantly lower drip (24.80%) when heat treated, compared to meat stored for 3 months (30.95%).

A significant indication of meat quality and suitability for processing is its water – holding capacity or the ability of the protein structure of its muscle tissue to keep water [Znaniecki 1983, Kondratowicz 2002 a]. With the extending time of frozen storage, there is a noticeable tendency to water – holding capacity increasing from 21.53% after 1-month to 22.5% after 3 months of frozen storage.

The thawing loss is regarded as one of the indicators for quality assessment of meat subjected to frozen storage. The magnitude of thawing loss testifies to the extent of irreversible changes that took place in histological structure and to the degradation of compounds responsible for water binding during freezing and frozen storage. Oozing

sarcoplasma contains many precious nutritional constituents – proteins, valuable non-protein nitric substances, sugars and their derivatives, mineral substances and vitamins [Kopeć 2003]. The results specified in Table 2 proved that longer horsemeat storage in frozen condition causes larger thawing losses. After 1-month it was at the level of 6.74% and grew to 8.68% after 3 months. The extension of meat storage time increased the outflow by approx. 2% on average (this tendency is not statistically confirmed).

It is commonly known that processes of hydrolytic and oxidative changes of lipids limit critically meat stability during frozen storage. A detailed analysis of numerical values indicates that unfavorable transformations taking place in fats were statistically significant and they depend on the time of frozen storage. On the basis of the acid number and peroxide values determined for horse tallow, a growing tendency of these indices with longer time frozen storage was discovered. The peroxide value after 1-month of storage was 1.43 mili-equivalents/kg, while the acid value was 1.02 mg KOH/g. After 3 months of storage these values grew to 2.90 mili-equivalents /kg and 1,14 mg KOH/g, respectively. Also, Sobina and Kondratowicz [2000] observed in their research the growth in peroxide content and free fatty acids with extended freezing storage.

CONCLUSIONS

1. Horsemeat freezing and frozen storage from 1 to 3 months caused meat color darkening as well as a reduction of meat capacity to retain and bind water. Extending of frozen storage period from 1 to 3 months improved meat crispness, while reducing the meat cutting force by approx. 2 $N \cdot cm^{-2}$.

2. With longer frozen storage periods the peroxide value and acid number of meat were observed to rise, thus indicating the appearance of peroxides and free fatty acids testifying to oxidative and hydrolytic processes taking place in meat.

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ZMIANY WŁAŚCIWOŚCI FIZYKOCHEMICZNYCH MIĘSA KOŃSKIEGO PODCZAS ZAMRAŻALNICZEGO PRZECHOWYWANIA

Streszczenie. Celem niniejszej pracy było określenie wpływu czasu przechowywania zamrażalniczego na wybrane właściwości fizykochemiczne mięsa i tłuszczu końskiego. Badano próby mięśnia najdłuższego grzbietu i tłuszczu karkowego pochodzące z tusz końskich. Porównywano mięso i tłuszcz po dwóch okresach przechowywania: 1 i 3 miesiące. Badania przeprowadzono na 26 tuszach koni dorosłych (8-10 lat). Wykazano, że proces składowania zamrażalniczego powoduje pociemnienie barwy mięsa, zmniejsza zdolność do zatrzymywania i wiązania wody, a ponadto wpływa na polepszenie kruchości mięsa. Wraz z wydłużaniem czasu składowania zamrażalniczego zaobserwowano wzrost wartości liczby nadtlenkowej i kwasowej, co świadczy o przebiegu procesów oksydacyjnych i hydrolitycznych zachodzących w tłuszczu końskim.

Słowa kluczowe: konina, zamrażanie, jakość mięsa

Accepted for print – Zaakceptowano do druku: 29.09.2005 r.

***For citation – Do cytowania**: Stanisławczyk R., Znamirowska A., 2005. Changes in physico--chemical properties of horsemeat during frozen storage. Acta Sci. Pol., Technol. Aliment. 4(2), 89-96.*