CHANGES IN THE PHYSICOCHEMICAL PROPERTIES OF DEEP-FROZEN RABBIT MEAT AS DEPENDENT ON THAWING METHOD

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Abstract. The objective of this study was to determine changes in the physicochemical properties of deep-frozen rabbit meat thawed in a microwave oven and in the atmospheric air. It was found that samples of *m. longissimus dorsi* thawed in a microwave oven and in the air were characterized by similar acidity and a lighter colour, compared with chilled samples. Cooled muscles were formed by slightly lower pH_1 (6.26). The mean values of pH_{24} were comparable in the experimental groups and were typical of RFN meat. The values of water-holding capacity and natural drip loss were lower in chilled *m. longissimus dorsi* samples (3.62 cm^2 and 0.70% respectively) than in samples thawed by the above two methods. Microwave thawing did not deteriorate the quality and processing suitability of rabbit meat.
Keywords: rabbit meat, microwave oven, atmospheric air, physicochemical properties.

UŽŠALDYTOS TRIUŠIENOS FIZINIŲ IR CHEMINIŲ POKYČIŲ PRIKLAUSOMYBĖ NUO ATŠILDYMO BŪDO

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Santrauka. Šio tyrimo tikslas buvo nustatyti fizinius ir cheminius pokyčius užšaldytos triušienos, atšildytos mikrobangų krosnelėje arba aplinkos ore. Tyrimų rezultatais nustatyta, kad *m. longissimus dorsi* mėginių, atšildytų mikrobangų krosnelėje ir aplinkos ore rūgštingumas buvo panašus, o spalva šviesesnė palyginti su atšaldytais mėginiais. Vandens rišlumo gebos vertė buvo aukštesnė, o natūralaus vandeningumo – žemesnė atšaldytuose *m. longissimus dorsi* mėginiuose nei mėginiuose, atšildytuose dviem minėtais būdais. Atšildytos mikrobangų krosnelėje triušienos kokybė ir tinkamumas perdirbti nesuprastėjo.
Raktažodžiai: triušiena, atšildymo būdas, technologinės savybės.

Introduction. Rabbit meat is known for its exceptional taste and nutritionally healthful properties. In the European Union rabbit meat is considered an attractive alternative to poultry, pork and beef, although it is much more expensive (Forrester-Anderson et al., 2006). Breeders and producers aim to monitor and improve the quality attributes of rabbit meat and rabbit meat products (Maj et al., 2008a). The quality of rabbit meat, usually defined differently by breeders, producers and consumers, is affected by four main groups of factors, i.e.: chemical composition (the content of protein, fat, carbohydrates, vitamins and minerals), technological properties (water-holding capacity, thermal loss, the content of collagen, fat and pigments), physical properties (free water content, pH, consistence and color brightness), sensory properties (tenderness, juiciness, taste) and dietary attributes (nutritional value and digestibility) (Łapa et al., 2006). The determination of the relationships between the above parameters may contribute to developing reliable reference methods for rabbit meat quality assessment (Łapa et al., 2006; Maj et al., 2008a).

Meat quality is influenced not only by processing, but also by deep-freeze storage conditions and thawing methods (Kondratowicz and Chwastowska, 2006). During freezing, the post slaughter aging process is largely inhibited while ice formation proceeds at a faster rate. Biological, physical and chemical reactions are slowed down, but not stopped, in deep-frozen meat (Kondratowicz et al., 2008). The key factors affecting the thawing process are relative airhumidity and effective thawing time dependent on the temperature of the thawing medium (Chwastowska and Kondratowicz, 2005). Both freezing and deep-freeze storage can lead to considerable changes in meat quality. Inappropriate freezing and thawing may significantly deteriorate the ultimate quality of meat. Meat used for industrial purposes is most often thawed naturally in the atmospheric air, under uncontrolled conditions. This process, may lead to considerable weight losses and alter the physicochemical properties of meat (Chwastowska and Kondratowicz, 2005; Kondratowicz et al., 2005). The increasing market share of deep-frozen meat products and the disadvantages of conventional thawing methods have prompted the authors to compare two thawing techniques, namely air thawing and microwave thawing.

The objective of this study was to determine the changes in the physicochemical properties of deep-frozen rabbit meat thawed in a microwave oven and in the atmospheric air.

Materials and methods. The experimental materials comprised 24 crossbred rabbits (New Zealand White x mothers in a type of Belgian giant breed) kept in wooden cages, on deep litter, in a small traditional farm. The experiment was performed over the spring and summer (since May to September) last year. Feeding and housing conditions were similar for all animalsthroughout the fattening period. Rabbits received farm-made diets containing no complete pellets, and they had free access to drinking water. The animals (sex ratio 1:1) were slaughtered at approximately 3.0 kg live weight. Stunning was followed by bleeding, skinning and evisceration. Muscular tissue acidity was measured in *m. longissimus dorsi* 45 min. and 24 hours post mortem. Carcasses were chilled at around 4°C for 24 hours. After that, they were cut to primal cuts. The samples of *m. longissimus dorsi* were packaged in HD-PE foil, and 16 of them were deep-frozen in the Bosch freezer (-28°C, 40% relative humidity), while the remaining 8 were stored at 4°C for 24 hours, until analyses. After 2 months of storage, deep-frozen samples were thawed in a microwave oven and in the atmospheric air. During microwave thawing, samples were placed in a TEC microwave oven and were exposed to electromagnetic waves, at a power of 260W for 40 min., and then at 120W for 30 min. Every 10 minutes, the power of electromagnetic waves was changed from 260W to 120W, to ensure equal heat distribution in the thawed meat. Thawing was continued until a temperature of around -1ºC at the geometrical centre of the muscle and around 15ºC in the outer layer had been reached. After 2 hours of temperature equalization, the temperature of the analyzed muscles oscillated around 4°C. Air thawing involved placing samples in a Polar-600 chilling chamber for 24 hours at air temperature 4°C and relative air humidity of around 45%.

The thawed and chilled samples of *m. longissimus dorsi* were subjected to quantitative and qualitative analyses. In order to prepare meat for laboratory analyses, the outer fatty and connective tissue was removed from the sample surface. Samples were ground three times in a laboratory grinder with a plate diameter of 1.5 mm, and the obtained mixed meat was battered. The samples were analyzed for the:

total weight loss in the processes of freezing, storage and thawing- by weighing the samples, to accuracy to 0.1g;

proximate composition of muscular tissue (the content of dry matter, total protein, fat and ash)- by the AOAC (1990);

meat acidity (after thawing) – based on the pH of water homogenates (meat to distilled water ratio of 1:1), using a Double Pore glass-combination electrode (Hamilton) and a 340i pH-meter manufactured by the WTW POL-EKO-APARATURA company;

colour brightness – based on the percentage of light reflection against the surface of minced meat samples, using a "Specol" spectrometer and an R45/O remission attachment, at a wavelength of 560 nm (with a magnesium oxide plate as a reference standard of whiteness);

colour– based on the values of L^*, a^*, b^* in the CIE LAB system (1978), by the reflectance method, using a MiniScan XE Plus spectrophotometer (HunterLab) ;

water-holding capacity – by the Grau-Hamm method (1953);

natural drip loss, as described by Honikel (1998);

thermal loss, as described by Janicki (1970).

Statistical analyses. Arithmetic means ($\bar{x}$) and standard deviations (s) were determined, and the significance of differences between the mean values of the analyzed parameters in experimental groups (subject to the applied thawing method) was estimated by Duncan's test, using STATISTICA ver. 9.0 PL software (StatSoft Inc. 2009).

Results and discussion. The technological quality parameters of rabbit meat are presented in Tables 1 and 2. Weight loss, which is a natural consequence of low-temperature preservation of meat, affects the chemical composition and water content-dependent technological properties of thawed meat (Kondratowicz and Matusevičius, 2003). The amount of thawing drip may be a measure of damage to muscular tissue structure in the freezing process, reflecting the effectiveness of different thawing methods (Kondratowicz et. al., 2008). As shown by data in Table 1, thawing methods had no significant effect on meat weight loss. However, total weight loss was lower (by 0.93%) in *m. longissimus dorsi* samples thawed in a microwave oven than in samples thawed in the air.

The proximate chemical composition of rabbit meat was determined based on the content of dry matter, total protein, fat and minerals in ash form (Table 1). Thawing methods had a significant effect on the dry matter content of *m. longissimus dorsi,* which was higher in air-thawed samples than in microwave-thawed samples. The highest dry matter content was noted in chilled muscles. Chilled muscles and muscles thawed by two different methods differed very significantly with respect to total protein concentrations. Thawing methods had no influence on total protein content which was 23.13% in microwave-thawed muscles and 23.24% in air-thawed muscles. Chilled muscles had the highest total protein content. The ash content in meat samples thawed in a microwave oven and in the air was similar, at 1.28%, which shows that it was not affected by thawing methods. The ash content of chilled muscles was by 0.23% lower, compared with deep-frozen and thawed samples.

Table 1. **Weight loss and the chemical composition of** *m. longissimus dorsi* **in rabbits**

Specification	Chilled muscles	Deep-frozen muscles – Thawing method: Microwave oven	Deep-frozen muscles – Thawing method: Atmospheric air
Weight loss (%)	-	8.98 ±1.50	9.91 ±2.13
Dry matter (%) content	24.65^{a} ±0.37	24.12^{b} ±0.39	24.57^{a} ±0.32
Total protein (%)	23.80^{A} ±0.43	23.13^{B} ±0.51	23.24^{B} ±0.18
Fat (%)	0.24 ±0.15	0.24 ±0.10	0.30 ±0.06
Ash (%)	1.05^{B} ±0.06	1.28^{A} ±0.02	1.28^{A} ±0.02

a, b – values with different superscript letters are significantly different at (p≤0.05)
A, B – values with different superscript letters are significantly different at (p≤0.01)

The technological properties of thawed rabbit meat investigated in this study were acidity, colour, water-holding capacity, natural drip loss and thermal loss. Acidity measurements provide information about the rate of post mortem glycolysis which affects the quality, processing suitability and shelf-life of meat. The reaction of muscular tissue at slaughter is close to neutral. Immediately after slaughter the pH of muscles decreases due to acidification. Ultimate pH (pH_u) is the main indicator of meat quality and durability (Kondratowicz and Matusevičius, 2003; Bielański, 2004). The values of pH_1 measured 45 min. post mortem are indicative of a good quality of chilled muscles and deep-frozen muscles thawed by the analyzed methods (Table 2). Chilled muscles were characterized by slightly lower pH_1 (6.26). Similar values of pH_1 measured 45 min. post mortem were reported by Zając (1999) and Maj et. al. (2008b). The acidity of good-quality rabbit meat, measured immediately post mortem, should range from pH 6.1 to 6.9 (Zając, 1999; Bielański, 2004). The values of pH_{24}, determined 24 hours post mortem, were comparable in experimental groups and were typical of RFN meat (pH_{24} 5.7- 5.8) (Bielański, 2004). According to Bielański (2004), the pH of meat should decrease to 5.8 after 24 hours of chilling, as a result of glycolysis. No statistically significant differences in ultimate pH (pH_u) were noted between the analyzed muscles.

Table 2. **Physicochemical properties of** *m. longissimus dorsi* **in rabbits**

Specification	Chilled muscles	Deep-frozen muscles – Thawing method: Microwave oven	Deep-frozen muscles – Thawing method: Atmospheric Air
pH_1	6.26^{b} ±0.22	6.53^{a} ±0.14	6.50^{a} ±0.23
pH_{24}	5.72 ±0.09	5.70 ±0.05	5.68 ±0.05
pHu	5.82 ±0.04	5.79 ±0.05	5.79 ±0.05
Colour brightness (%)	29.00 ±3.34	29.25 ±3.15	31.75 ±1.91
Colour*(CIELAB):*			
L*- lightness	57.38^{b} ±1.81	60.80^{a} ±2.54	57.85^{b} ±2.68
a*- redness	6.21^{a} ±1.82	4.39^{b} ±0.92	5.15 ±1.16
b*- yellowness	11.71^{B} ±0.41	13.74^{A} ±0.67	14.06^{A} ±0.29
Water-holding capacity-Grau and Hamm method (cm^2)	3.62^{B} ±0.96	5.29^{A} ±0.37	5.36^{A} ±0.47
Drip loss (%)	0.70^{b} ±0.27	1.58^{a} ±1.22	1.83^{a} ±0.59
Thermal loss (%)	28.59 ±1.25	28.35 ±1.97	27.87 ±2.16

a, b – values with different superscript letters are significantly different at (p≤0.05)
A, B – values with different superscript letters are significantly different at (p≤0.01)

Meat colour is one of the key selection criteria for consumers making their purchase decisions and important indicator of the processing suitability of meat. Consumers use colour as an indicator of meat freshness or even eating quality (Ngapo et al., 2004; Mancini and Hunt, 2005). Meat colour is affected by the total content and qualitative composition of heme pigments, as well as by the transformations they undergo during storage. Another important consideration is water-holding capacity. Other factors influencing meat quality are acidity and fat content (Kondratowicz and Matusevičius, 2003; Maj et al., 2008a, b). According to Maj et al. (2008a, b), development of meat paleness is a result of its high acidity. The data given in Table 2 show that thawing methods had no significant impact on the colour brightness of muscle samples. Microwave-thawed and chilled muscles were marked by a lower percentage of light reflection (29.25% and 29.00% respectively), i.e. by a darker colour, in comparison with air-thawed samples (31.75%). The average colour values in the CIE LAB system show that the analyzed rabbit meat was relatively light, with a low contribution of redness (a*) and a high contribution of yellowness. This is natural, as rabbit meat has low myoglobin content. Analyses of colour parameters revealed that colour lightness was affected by thawing techniques. The average values of the L* component (lightness) of meat colour were higher in microwave-thawed samples than in air-thawed and chilled samples (60.80 vs. 57.85 and 57.38 respectively). Redness (a*) had a higher share of colour in chilled samples of *m. longissimus dorsi* (6.21) than in microwave-thawed muscles (4.39). A highly significant difference was also noted between chilled muscles and deep-frozen muscles thawed by two different methods with regard to yellowness (b*). The lowest contribution of the yellow components was observed in chilled muscles (11.71) and highest in air thawed (14.06). Maj et al. (2008a) demonstrated that an increase in color brightness is accompanied by a decrease in colour intensity and redness (a*), thus leading to paleness of rabbit meat. Łapa et al. (2006) reported that a decrease in the pH_{45} of rabbit meat was accompanied by an increase in the contribution of the yellow components (b*) and by changes in the remaining parameters of colour and lightness.

Another important functional property of meat is water-holding capacity, in particular water absorption and retention by the protein structures of muscular tissue as well as water retention during heat processing (Huff-Lonergan and Lonergan, 2005; Micklander et al., 2005). The water-holding capacity of meat is dependent primarily on pH- which is a measure of post mortem changes, followed by the time of deep-freeze storage and many other factors (Honikel, 2004). Water-holding capacity is also determined by the state of muscle protein fractions. Myofibrillar proteins play a key role in the development of hydration-related properties of meat. Ice formation in deep-frozen meat is accompanied by an increase in pH and salt concentrations, thus supporting water retention (Huff-Lonergan and Lonergan, 2005). In the present study, described of functional attribute of rabbit meat, qualifying on natural drip and forced drip losses, and thermal losses. Highly significant differences in water-holding capacity were noted between chilled muscles and muscles thawed by the two analyzed methods (Table 2). The applied thawing techniques had no effect on the water-holding capacity of meat, which was at a similar level in microwave-thawed muscles (5.29 cm^2) and in air-thawed muscles (5.36 cm^2). Chilled muscles were characterized by lower values (3.62 cm^2) of water absorbability due to their greater ability to retain own and added water. Chilled and thawed muscles differed with respect to natural drip loss. The lowest drip loss was noted in chilled LD muscles (0.70%), while the highest – in air-thawed muscles (1.83%). The thawing methods had no statistical significant influence on thermal loss, which was highest in chilled samples (28.59%) and lowest in air-thawed samples (27.87%). Total weight loss during thawing and heat treatment significantly influences the sensory properties of meat, in particular palatability and juiciness. As indicated by the present results, the juiciness and other sensory attributes of rabbit meat deteriorate as drip loss increases. Total weight loss, measured as the amount of drip during thermal processing, is substantially higher in meat with low water-holding capacity, and the final product is less juicy (Bielański, 2004).

Conclusions

The following conclusions can be drawn from the results of the present study which investigated the effect of thawing methods on changes in the physicochemical properties of deep-frozen rabbit meat:

1. The total weight loss was at a similar level in *m. longissimus dorsi* samples thawed in a microwave oven and in the atmospheric air, yet the weight reduction was slightly less when using microwave oven (0.93 %).
2. In the group of deep-frozen muscles, air-thawed samples had a higher dry matter content than microwave-thawed samples. Furthermore, more significant differences between the mean values of total protein in the chilled muscles (23.80%) and in the samples thawed by two different methods (23.13% and 23.24% respectively) were found.
3. *M. longissimus dorsi* samples thawed by the two analyzed methods were characterized by similar acidity for pH_1, pH_{24}, ultimate pH, contribution of the red (a*) and yellow (b*) colour components, water-holding capacity and thermal losses.
4. The values of water-holding capacity and natural drip loss were lower in chilled *m. longissimus dorsi* samples (3.62 cm^2 and 0.70% respectively), than in samples thawed by two different techniques, and this fact was proved statistically.
5. Microwave thawing did not deteriorate the quality and processing suitability of rabbit meat. The properties of microwave-thawed muscles were comparable with those of fresh meat.

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