The effect of selected methods of heat treatment on the chemical composition, colour and texture parameters of longissimus dorsi muscle of wild boars

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ABSTRACT

The aim of this study was to analyse the impact of differentiation of cooking and baking temperatures on the chemical composition, colour, sensory evaluation, shear force and muscle texture parameters of the longissimus dorsal muscle of wild boars. It was shown that the increase in the final temperature during cooking and baking caused a decrease in the water content in the muscle, and as a result of the density of the tissue structure after the loss of this component, the fat content in the meat after heat treatment increases. Cooking at 80–90°C and baking at 150–175°C contributed to more favourable texture parameters such as hardness of cycles 1 and 2 and gumminess. In addition, it was found that the heat treatment affects the increase of the yellow colour and meat brightness, and at the same time the reduction of the $a^*$ parameter.

1. Introduction

Meat obtained from wild animals is a sought after and valued culinary raw material due to the unique taste, aroma and other sensory characteristics that distinguish them from the meat of farm animals. It is characterized by a higher content of wholesome proteins, vitamins, mineral salts, a favourable ratio of unsaturated to saturated fatty acids and lower in comparison to meat of farm animals, fat and cholesterol content, as well as a lower energy content of about 90–110 kcal/100 g (Hoffman & Wiklund, 2006; Hoffmann, 2008). Many factors can affect the nutrient content of meat, such as animal species, age and sex, and environmental factors (Greenfield et al., 2009; Lombardi-Bocciaia, Lanzi, & Aguzzi, 2005; Tomović, Petrović, Tomović, Kveřešan, & Džinić, 2011).

Heat treatment of meat is essential to obtain a tasty and safe product. What is more, it can affect the basic characteristics associated with consumer preferences, such as taste, delicacy, colour and appearance (Garcia-Segovia et al., 2007; Meinert, Andersen, Bredle, Bjergegaard, & Aslyng, 2007; Modzelewaska-Kapitula, Dąbrowska, Jankowska, Kwiatkowska, & Cierach, 2012).

Heat treatment can also lead to undesirable changes in meat quality, such as loss of nutritional value due to lipid oxidation and changes in several segments of the protein fraction (Rodriguez-Estrada, Penazzi, Caboni, Bertacco, & Lercker, 1997). Preservation and preparation of meat for consumption using high temperatures causes thermal denaturation of proteins which leads to specific changes in the microstructure of muscle fibres and connective tissue, and affects water absorption in meat (Tornberg, 2005). Fragility, apart from the juiciness and palatability, is a key quality attribute used in the food industry of fresh and processed products in order to assess quality and acceptability (Choe, Choi, Rhee, & Kim, 2015; Grujić, Vujadinović, & Tomović, 2014). The important role of texture as a decisive factor in the desirability of a product makes its control and forecasting an important issue for meat industry (Claus, 1995).

The aim of the work was to analyse the impact of differentiation of cooking and baking temperatures on the chemical composition, colour, sensory evaluation, shear force and muscle texture parameters of the longest dorsal muscle of wild boars.
2. Materials and methods

2.1. Materials

The research material were parts of the longest dorsal muscle taken from 15 carcasses of wild boars (aged 24 months and 40–56 kg in weight), shot in autumn in the Podkarpackie Province.

2.2. Sample preparation

Each collected muscle was divided into 5 parts (500 g ± 0.25 each), one of which was a control sample, while the remaining ones were subjected to heat treatment: cooking in a water bath (WB-436, Funke-Dr.N. Gerber Labortechnik GmbH, Germany) in two variants (I – at the temperature of 80–90°C, II – at 90–100°C) and baking in the electric oven (Model: C6444 Di, Amica, Poland) in two variants (I – at the temperature of 150–175°C, II – at the temperature of 175–200°C). Treatments were carried out to obtain a geometric temperature of 72°C. After cooling the meat samples the chemical composition and colour were marked and a texture profile analysis test was carried out.

2.3. Instrumental analysis

2.3.1. Chemical composition

Water content was determined in accordance with PN-ISO 1442-2000 standard.

Protein was determined with the Kjeldahl method where the determined value of nitrogen is recalculated to protein according to PN-A-04018: 1975 / Az3, 2002 Polish standard.

Fat content was determined with the Soxhlet method as per recommendation in the PN-ISO 1444: 2000 Polish standard.

2.3.2. Colour analysis

The colour determination was made on a fresh cross-section in raw muscle samples and after heat treatment. Instrumental colour measurement in the CIE L* a* b* system was carried out using the EnviSense electronic NR20XE colorimeter (light source D 65, 20 mm measuring head opening, white colour calibration: L* = 99.18, a* = –0.07, b* = 0.05). The measuring geometry of 45°/0° was used. During the measurement, the colorimeter was coupled with the computer in which the CQCS3 V2 software was installed. In this system L* is the brightness which is the spatial vector, while a* and b* are the coordinates of the trichromaticity, where the positive values a* – correspond to the colour of red, negative – the colour of green, positive b* – yellow, negative b* – blue.

2.3.3. Texture analysis

Profile texture analysis (TPA) was done with a Brookfield Texture Analyzer – CT3 – 25 equipped with a cylindrical probe of 38.1 mm in diameter and the length of 20 mm. A test of double compression of samples to 50% of their height was carried out. The texture was determined on raw muscle samples and after heat treatment (in triplicate) in the form of cubes with dimensions of 20 mm x 20 mm x 20 mm. The speed of the roller during the test was 2 mm/s, the pressure interval was 2 s. The following texture parameters were determined using the Texture Pro CT program: hardness 1, hardness 2, springiness, adhesiveness, resilience, gumminess and cohesiveness.

2.4. Shear force

The shear force was measured using a Warner-Bratzler gauge with a head speed of 100 mm·min⁻¹. The measurement was made on raw meat samples of a cross-section of 100 mm² and a length of 50 mm along the muscle fibres and after heat treatment. Samples prepared in this way were subjected to cutting during which the value of the pressure force (N x 10 mm⁻²) needed to make it was recorded.

2.5. Sensory evaluation

The sensory quality of heat treatment of the longest dorsal muscle was scaled using the method according to Barylkopikielna and Matuszewks (2009). In order to conduct the sensory assessment, the heat-treated samples were cooled to 20°C±2°C, cut into 1.5 cm thick slices, perpendicular to the run of meat fibres. They were placed in disposable plastic boxes that were covered with lids. All samples for evaluations were coded individually and given in random order. The sensory evaluation was carried out by a 10-person evaluation team tested in terms of sensitivity and sensory fitness according to ISO 8586-2:2008 and ISO 8587:2006. The evaluating persons had experience in assessing meat and meat products. A 5-point evaluation was applied with a defined value limit, including the following qualitative indices: odour (1-intensity and desirability the worst, 5-intensity and desirability the best), flavour (1-intensity and desirability the worst, 5-intensity and desirability the best), juiciness (1-very dry, 5-very juicy), tenderness (1-very hard, 5-very tender).

2.6. Statistical analysis

The obtained results were developed using the STATISTICA PL program ver. 12.5, using a one-way analysis of variance. Table 1–3 present the values of arithmetic means and standard deviations of the examined features. Significance of differences between groups was determined using the

| Specification | Raw meat | Meat cooked in temp. 80–90°C | Meat cooked in temp. 90–100°C | Meat cooked in temp. 150–175°C | Meat cooked in temp. 175–200°C |
|---------------|----------|-----------------------------|-----------------------------|---------------------------------|-------------------------------|
| Water [%]     | 73.98 ± 1.34⁸ | 70.09 ± 1.43b          | 69.15 ± 2.26⁸              | 67.36 ± 0.93c                 | 66.91 ± 1.43c                |
| Fat [%]       | 3.09 ± 1.93⁸ | 5.59 ± 2.5³              | 6.61 ± 3.01b              | 8.08 ± 2.22b                 | 8.72 ± 1.94b                |
| Protein [%]   | 21.43 ± 0.61 | 21.00 ± 0.63            | 20.70 ± 0.89             | 20.90 ± 0.60                 | 21.00 ± 0.60                |

Different letters at mean values in the row mean statistically significant differences at p ≤ 0.05.
Las letras diferentes en los valores medios en la fila indican diferencias estadisticamente significativas en p ≤ 0.05.
Tukey test for the significance level α ≤ 0.05. To determine the relationship between the studied features, the correlation coefficients of Pearson’s (r) line were calculated. Values of correlation coefficients were interpreted according to the following scale: r = 0.2 – unclear correlation, 0.2 – 0.4 clear but weak correlation, 0.4 – 0.7 moderate correlation, 0.7 – 0.9 significant correlation, r > 0.9 very strong correlation.

3. Results and discussion

The share and proportions of basic chemical components determine not only the nutritional value of meat, but also its consumer appeal. Data on the effect of heat treatment on the basic chemical composition of the longest dorsal muscle are presented in Table 1. As a result of the temperature, the protein constituting about 20% of meat undergoes a denaturation process which simultaneously increases the digestibility of this raw material. Heating of proteins changes the rheological properties of meat – under the influence of high temperatures there is a contraction of muscle fibres causing hardening and the transformation of collagen. The resultant of these two processes is hardness which is an important characteristic of meat quality (Borrelli et al., 2003). The analysis of own research shows that the heat treatment had no significant effect on the protein content.

The average protein content in raw meat was 21.43% ± 0.61. Under the influence of treatment such as cooking or baking at different temperatures, a slight decrease in this component was observed. The next analysed parameter of the chemical composition was water. It was observed that as the temperature of baking or cooking increased, the water content decreased in a statistically significant way (p ≤ 0.05). The composition and content of intramuscular fat is an important factor affecting meat quality and nutritional value (Hocquette et al., 2009). Due to the thickening of tissue structure after the loss of water, the fat content in the meat after heat treatment increases. The carried-out heat treatment caused significant changes in the percentage of fat content (Table 1). It was shown that in the case of cooked and roasted meat, the fat content increased with the increase of the treatment temperature. In studies carried out by various scientists, there was found a wide range in the fat content of fresh wild boar meat. Depending on the feed intake, the fat content in this raw material was determined at the level of 1.23–4.27% (Quaresma et al., 2011) and 3.5–5.2% (Zomborsky, Sentmihályi, Sarudi, Horn, & Sabó, 1996). In the professional literature, there is no data on current studies of the influence of heat treatment on the basic chemical composition of the longest dorsal muscle of wild boars. Cheng et al. (2005), examining the content of basic nutrients in pork ham subjected to various heat treatment methods showed slightly different values compared to the results of own research. The average fat content was found at 1.64–2.07%, which was significantly different from the amount of this ingredient marked in the longest dorsal muscle of wild boars. In addition, the cited authors determined protein content in pork ham at 21.58–24.56% and water content between 65.75% and 71.74%. Juárez et al. (2010) who analyzed buffaloes meat composition as affected by different cooking methods, showed that the heat treatment reduced moisture and increased protein and fat contents.

The colour of meat is one of the basic distinguishing features of its technological and culinary quality and is one of the most important differentiating factors in the consumer assessment of this raw material (Mancini & Hunt, 2005; Troy & Kerry, 2010; Valous, Mendoza, Sun, & Allen, 2009; Warris, Brown, & Pasčiak, 2006). Hoffman, Kritzinger, and Ferreira (2005) report that game is perceived as a raw material with a darker colour than meat from farm animals. The dark colour of this meat is a natural feature related to, among other things, an increased content of myoglobin in

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### Table 2

| Composition                  | Specification | Raw meat | Meat cooked in temp. 80–90°C | Meat cooked in temp. 90–100°C | Meat cooked in temp. 150–175°C | Meat cooked in temp. 175–200°C |
|-----------------------------|--------------|----------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| Amino acids content (%)     |              |          |                               |                               |                               |                               |
| Fat content (%)             |              |          |                               |                               |                               |                               |
| Protein content (%)         |              |          |                               |                               |                               |                               |

Different letters at mean values in the row mean statistically significant differences at p ≤ 0.05.

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### Table 3

| Specification                  | Raw meat | Meat cooked in temp. 80–90°C | Meat cooked in temp. 90–100°C | Meat cooked in temp. 150–175°C | Meat cooked in temp. 175–200°C |
|-------------------------------|----------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| Hardness 1 [N]                |          |                               |                               |                               |                               |
| Hardness 2 [N]                |          |                               |                               |                               |                               |
| Adhesiveness [µ]              |          |                               |                               |                               |                               |
| Resilience [-]                |          |                               |                               |                               |                               |
| Cohesiveness [-]              |          |                               |                               |                               |                               |
| Springiness [mm]              |          |                               |                               |                               |                               |
| Gumminess [N]                 |          |                               |                               |                               |                               |
| Shear force [N x 10 mm⁻²]     |          |                               |                               |                               |                               |

Different letters at mean values in the row mean statistically significant differences at p ≤ 0.05.

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Las letras diferentes en los valores medios en la fila indican diferencias estadísticamente significativas en p ≤ 0.05.
the muscles of wild animals as a consequence of their high physical activity. It may also be associated with a worse bleeding of carcasses of hunted animals compared to carcasses of slaughtered animals.

Table 2 provides data on the effect of heat treatment on the muscle colour parameters of the longest dorsal muscle of wild boars. There were statistically significant \( p \leq 0.05 \) differences in these features between fresh meat and the meat cooked or baked at different temperatures. The raw longest dorsal muscle of wild boars was characterized by lower brightness \( (L^*) \), as well as a higher value of red \( (a^*) \) and a smaller share of yellow colour \( (b^*) \) compared to the muscles subjected to heat treatment. In the professional literature, there is also no data on current studies of the influence of heat treatment on muscle colour parameters of the longest dorsal muscle of wild boars. Referring to the research carried out by Cheng et al. (2005) it can be noticed that the share of red in pork ham cooked in water bath at 82°C was on a similar level in comparison with own research and amounted to 9.86, while the share of yellow was lower and amounted to 5.25. In turn, in the studies of Yang, Jeong, Chong-Sam, and Hwang (2016) it was found that the proportion of red in steaks cooked at 60°C was higher, compared with steaks cooked at 82°C. Sen, Naveena, Muthukumar, and Vaidhiyanathan (2011) found, that increase in final core temperature of heating meat products intensifies the lightness \( L^* \) on the cross-section, and decreases the redness \( a^* \).

Segovia et al. (2007), who studied the effect of cooking method on mechanical properties, colour and structure of beef muscle, showed that the cooked steaks were generally lighter (higher \( L^* \)) and more yellow (higher \( b^* \)), whereas \( a^* \) (red colour) decreased as temperature and cooking time increases. Similar colour changes were observed by Yancey, Wharton, and Apple (2011).

Roldan, Antequera, Martin, Mayoral, and Ruiz (2013) and Sanchez Del Pulgar, Gazquez, and Ruiz-Carrascal (2012) observed higher \( L^* \) values at 60°C compared to 80°C when heating lamb loins or pork meat for prolonged times. According to Kwang-Ii et al. (2015) the colour after thermal treatment showed higher \( L^* \) and \( b^* \) values and lower \( a^* \) values compared with the raw beef, except for the pan-frying thermal treatment.

Texture is probably the most important quality factor associated with consumer satisfaction of eating meat products (Fletcher, 2002). The International Organization for Standardization (ISO) defines the texture as follows: “Texture is all the rheological and structural properties of a food product that can be perceived by a human using tactile, mechanical and, if possible, visual and auditory receptors”. Data on the effect of heat treatment on texture parameters of the longest dorsal muscle of wild boars are given in Table 3.

The lowest value of hardness of cycle 1 (56.81 N) was found in raw meat. Along with the increase in temperature in the case of cooking and baking, this parameter assumed higher and higher values. There were shown statistically significant \( p \leq 0.05 \) differences in hardness of cycle 1 between raw meat and cooked meat at 90–100°C and baked at 175–200°C, as well as between cooked meat at 80–90°C and 90–100°C and between meat baked at 150–175°C and 175–200°C. The highest hardness of cycle 2 was characteristic of meat baked at 175–200°C and meat cooked at 90–100°C. Differences in this parameter between raw meat and heat-treated meat and between meat cooked at different temperatures and baked at different temperatures were statistically significant \( p \leq 0.05 \). The next indicator of texture profile is springiness. It can be defined as the elasticity expressed in (mm) – it is the rate of return of the tested sample from the deformed state to the initial state. For this parameter, statistically significant differences were found between raw meat and heat-treated meat. It was observed that the value of springiness increased with increasing temperature. A similar relationship was found in the case of resilience and cohesion, and the differences were statistically significant. Analysing another texture parameter in these studies, statistically significant differences \( p \leq 0.05 \) were found regarding gumminess between raw meat and heat treated meat, as well as between cooked meat at 80–90°C and 90–100°C and between roasted meat at temperatures 150–175°C and 175–200°C. The highest gumminess was characteristic of meat baked at 175–200°C, while the lowest gumminess was characteristic of raw meat. Lower shear force values were found in raw meat. The values of this feature were increased in meat subjected to both cooking and roasting. Statistically significant differences \( p \leq 0.05 \) were demonstrated for the shear force between raw meat and cooked and roasted meat.

According to Prestat, Jensen, Mckeith, and Brewer (2002), regarding the influence of the thermal processing of pork, there was no difference between the shear force of deep fried pig sirloin roasted and fried oil.

Table 4 provides data on the effect of heat treatment on the muscle sensory evaluation of the longest dorsal muscle of wild boars. The odour of wild boar meat was not varied depending on the type of heat treatment. Statistically significant differences were found for the juiciness, tenderness and flavour between boiled meat and roasted meat. More favourable values of these features were obtained for roasted meat. Bejerholm and Aaslyng (2004) examining the influence of cooking technique and core temperature on the results of a sensory analysis of pork showed difference between samples with respect to odour and flavour. According Gil et al. (2017) who analysed the effect of thermal treatment on sensory evaluation of loin showed that the longer periods of both cooking and roasting influenced positively the development of odour and Juiciness of meat.
On the basis of the performed statistical analysis correlation coefficients between the chemical composition and texture parameters were calculated (Table 5). The analysis of correlation between protein, fat and water contents and texture features showed both positive and negative relationships. There was a statistically significant positive correlation dependence between water content and adhesiveness and resilience, as well as a negative relationship between fat content and adhesiveness in cooked meat at 90–100°C.

Analysing the correlation coefficients between the colour and the texture parameters of the longest dorsal muscle of wild boars (Table 6) it should be stated that there is a statistically significant correlation (p ≤ 0.05) between the value of a* and such texture features as hardness of cycles 1 and 2, adhesiveness, cohesiveness and gumminess in meat cooked at the temperature of 80–90°C and between this first feature and resilience and springiness in meat cooked at 90–100°C. It is believed that red is the most important colour parameter, but only in the case of raw meat. When the ability to reduce MMb (metmyoglobin) to OMb (oxymyoglobin) decreases, brown colour appears and the value of red parameter, but only in the case of raw meat. When the ability to reduce MMb (metmyoglobin) to OMb (oxymyoglobin) decreases, brown colour appears and the value of red parameter.

Table 6. Oceanográn of cooked and roasted longest dorsal muscle of wild boars (mean ± standard deviation).

| Specification | Meat cooked in temp. 80–90°C | Meat cooked in temp. 90–100°C | Meat cooked in temp. 150–175°C | Meat cooked in temp. 175–200°C |
|---------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| Odour [pkt]   | 2.88 ± 0.33                   | 2.90 ± 0.51                   | 2.50 ± 0.25                   | 2.55 ± 0.29                   |
|Juiciness [pkt]| 2.63 ± 0.43a                  | 2.67 ± 0.34a                  | 2.50 ± 0.58b                  | 2.90 ± 0.41b                  |
|Flavour [pkt]  | 2.75 ± 0.21a                  | 2.54 ± 0.25a                  | 3.13 ± 0.51b                  | 3.14 ± 0.49b                  |
|Tenderness     | 3.28 ± 0.49                   | 2.90 ± 0.51                   | 2.50 ± 0.25                   | 2.55 ± 0.29                   |

Different letters at mean values in the row mean statistically significant differences at p ≤ 0.05.

Las letras diferentes en valores medios en la fila indican diferencias estadísticamente significativas en p ≤ 0.05.

4. Conclusions

An increase in the final temperature during cooking and baking caused a decrease in the water content in the muscle, and as a result of the density of the tissue structure after the loss of this component, the fat content in the meat after heat treatment increases. The average protein content in the longest dorsal muscle subjected to different heat treatments was at a similar level. It was found that the heat treatment influences the increase of the yellow colour and brightness of the meat, and at the same time the reduction of the a* parameter. Cooking at 80–90°C and baking at 150–175°C contributed to more favourable texture parameters, such as hardness of cycle 1 and 2 and gumminess. A significant treatment accelerates the transformation of Mb (myoglobin), causing its denaturation and also the change of colour from red to brown (Ramirez et al., 2004). The parameter characterizing the saturation of yellow b* was significantly and statistically significantly correlated with the hardness of cycles 1 and 2, adhesiveness and gumminess in meat baked at the temperature of 150–175°C.

Table 5. Coefficients de correlación entre la composición química y los parámetros de textura del músculo dorsal más largo de los jabalíes.

| Specification | Meat cooked in temp. 80–90°C | Meat cooked in temp. 90–100°C | Meat cooked in temp. 150–175°C | Meat cooked in temp. 175–200°C |
|---------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| Hardness 1    | −0.198                        | 0.313                         | −0.202                        | −0.151                        |
| Hardness 2    | −0.242                        | 0.338                         | −0.199                        | −0.158                        |
| Adhesiveness  | 0.038                         | −0.026                        | −0.679                        | −0.422                        |
| Resilience    | 0.465                         | −0.591                        | 0.498                         | −0.367                        |
| Cohesiveness  | 0.054                         | −0.208                        | 0.138                         | 0.171                         |
| Springiness   | 0.075                         | −0.327                        | 0.217                         | −0.236                        |
| Gumminess     | −0.155                        | 0.211                         | −0.135                        | −0.155                        |

*Correlaciones significativas al p ≤ 0.05.
* Coeficientes de correlación significativos a p ≤ 0.05.

Table 4. Sensory evaluation of cooked and roasted longest dorsal muscle of wild boars (mean ± standard deviation).

| Specification | Meat cooked in temp. 80–90°C | Meat cooked in temp. 90–100°C | Meat cooked in temp. 150–175°C | Meat cooked in temp. 175–200°C |
|---------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| Odour [pkt]   | 2.88 ± 0.33                   | 2.90 ± 0.51                   | 2.50 ± 0.25                   | 2.55 ± 0.29                   |
|Juiciness [pkt]| 2.63 ± 0.43a                  | 2.67 ± 0.34a                  | 2.50 ± 0.58b                  | 2.90 ± 0.41b                  |
|Flavour [pkt]  | 2.75 ± 0.21a                  | 2.54 ± 0.25a                  | 3.13 ± 0.51b                  | 3.14 ± 0.49b                  |
|Tenderness     | 3.28 ± 0.49                   | 2.90 ± 0.51                   | 2.50 ± 0.25                   | 2.55 ± 0.29                   |

Different letters at mean values in the row mean statistically significant differences at p ≤ 0.05.

Las letras diferentes en valores medios en la fila indican diferencias estadísticamente significativas en p ≤ 0.05.
degree of correlation between the value of α° and the following texture parameters was observed: hardness of cycle 1 and 2, adhesiveness, cohesiveness and gumminess in meat cooked at 80–90°C.

**Disclosure statement**

No potential conflict of interest was reported by the authors.

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