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ANIMAL PRODUCTION

Effect of ageing and MAP on quality of striploin from cattle of Holstein-Friesian breed

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ABSTRACT. There have been determined the features of *m. longissimus lumborum* steaks from young cattle-for-fattening of Holstein-Friesian breed, Polish black-and-white variety. There were measured pH values, basic chemical composition and colour parameters. The meat was subjected to moist-ageing for 12 days and, next, stored in modified atmosphere for the following 10 days. The amount of heat loss in relation to the temperature of thermal processing was determined. Texture parameters were studied instrumentally and organoleptically. The studied muscles from young cattle-for-fattening characterised with proper and similar pH values. The average fat content was 4.37%. The surface colour of the studied dorsal muscle was relatively bright, the average value L*=37.97, and on the cross-section L*=32.97. The average value of the muscle surface's 'redness' was a*=18.98, whereas cross-section's a*=20.27. The amounts of heat leakages were rising along with the increase of temperature from 11.24 to 37.14%. Ageing and storing in MAP led to a significant decrease in the amounts of heat leakages. Ageing and storing in MAP had a significant influence on decreasing shear force and on increasing the organoleptic evaluation marks of the m. longissimus lumborum after thermal processing, which shows that the muscle may become culinary meat with features accepted by consumers.

Keywords: beef; moist ageing; texture, colour; sensory properties; MAP.

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Introduction

In Poland, for many years, there have been developed and implemented various programs aiming at improving the quality of culinary beef meat and increasing its consumption. Unfortunately, the consumption of beef, in the recent years, has decreased to the level of less than 2 kg per person, a year (Gutkowska, Batóg, & Sajdakowska, 2017). The demand for this kind of meat is limited, because on Polish market, there is available mainly meat from dairy cattle, of unstable, poor quality, and, what is more, at relatively high prices. Culinary beef, tender, juicy, of bright colour and high biological value, is possible to obtain from cattle breeds ranked among beef-type ones, but also from young dairy-cattle of Polish breeds on the condition of complying with the correct technological rigour and hygine at each stage of the meat production and also applying an appropriate method of *post mortem* ageing (Chizzolini, Zanardi, Dorigoni, & Ghidini, 1999; Kłoczko, 2000; Yu et al., 2008; Cierach, Borzyszkowski, & Niedźwiedź., 2009a; Cierach, Niedźwiedź, & Borzyszkowski, 2009b). High hygiene of cattle slaughtering creates the possibility of applying *post mortem* ageing in an increased temperature, in order to decrease the *rigor mortis* effect and accelerating the endogenous *post mortem* proteolysis. Beef ageing is conducted by means of the dry method – meat ages in carcasses, or in elements, not packed in specific temperature and air humidity, or by moist method, which is about carving elements, vacuum packaging, and storing. (Sitz, Calkins, Feuz, Umberger, & Eskridge, 2006; Smith et al., 2008; Frylinck, Strydom, Webb, & Du Toit, 2013; Pinto Neto, Beraquet, & Cardoso, 2013). There are many views and theories explaining, with higher or lower degree of probability, the mechanism of *post mortem* proteolysis taking place in animals' muscles. Beside classical theories of myofibrillar-cytoskeletal proteolysis, responsible for which is the calpain system and its inhibitor calpastatin, it is more and more commonly acknowledged that the shaping of meat's texture is dependent on multi-enzymatic mechanism involving proteasomes, caspases. More and more often, meat quality is associated with the process of apoptosis, so called programmed cell death, which takes place in the period between slaughter and *rigor mortis*. The process, controlled by caspases, results in an array of structural and biochemical changes, affecting meat's texture. Further degradation changes follow in sequential order. The rupture of myofibrillar proteins, involving calpains, facilitates the action of proteasomes, capable of further degrading the myofibrillar proteins (Kemp & Parr, 2012). Beneficial for the quality of beef meat is the limiting of *rigor mortis* and eliminating cold shortening, which can be achieved through electro-stimulation, specific hanging of carcasses, incision of dorsal vertebrae or controlling with temperature the *post mortem* ageing (Yu et al., 2008; Kim, Frandsen, & Rosenvold, 2011). The aim of the conducted studies was the characterization of features of beef meat from young bulls, of the most prevalent in Poland, Holstein-Friesian breed, black-and-white variety, produced on the basis of culinary meat production technology, directly after *post mortem* cooling and after ageing by means of 'moist' method in an increased temperature, and next, storing in modified atmosphere. It was assumed that the two combined methods of dealing with the post slaughter beef meat, that is moist ageing in an increased temperature, and next, directly after, storing meat in modified atmosphere, will result in a significant improvement of tenderness, juiciness, colour, and taste of beef, despite the raw material being obtained from dairy cattle.

Material and methods

Study material was *musculus longissimus lumborum* (loin's longest muscle), assuming that it can be representative material for the quality of culinary meat in the studied bovine carcasses. The longest loin's muscle (*m. longissimus lumborum*), (samples approx. of 2 kg), was taken from quarter-carcasses of young bulls, Holstein-Friesian breed, Polish black-and-white variety, 48h after slaughter. The age of cattle was 15-18 months. A part of the muscle (a third – approx. 700 g) was studied after extraction. The remaining part of the muscle (two thirds – approx. 1,400 g) was vacuum packaged and stored for 12 days at 12ºC. After conducting moist ageing, the sample was divided into two parts, one of which was tested, and the other was packaged in MAP system (70:15:15, O_2:CO_2:N_2) and stored for 10 days at 6°C, then also tested.

The pH values of the muscles were determined 48h after slaughter, using the Hanna Instruments pH meter (HI99161) with Hanna Instruments (FC232D) stiletto electrode. For calibration, there were used buffer solutions with pH of 4.01 and 7.01.

Basic composition was marked in the analyzer 'Food check' (22FC906080), calibrated for minced beef with a fat content of up to 10%. There were determined the contents of water, protein and fat.

The parameters of surface and cross-section's colours, in the system L*a*b*, were determined by the reflection method using the Konica-Minolta CR-400 colorimeter. On the basis of the marked colour parameters, a* ('redness') and b* ('yellowness'), there was calculated the colour saturation C* according to the formula: $C^* = (a^{*2} + b^{*2})^{0.5}$ (Clydesdale, 1978).

To determine the amount of heat leakage, the samples of meat, minced on a net with holes' diameter Ø 3 mm, weighing approx. 10 g, were put in plastic sacks with V-shaped zipper closing, and heated in the temperature 50, 60, 70, 80 or 90°C for 20 min. The amount of thermal leakage was calculated from the difference in mass, before and after the heat treatment of the cooled meat sample and expressed as a percentage (Pan & Singh, 2001).

The measurement of shear force was carried out using instrumental cutting test of meat samples, subjected to the prior heat treatment. The beef samples, at each stage of the study, were placed in cold water, which was then heated to 80°C, and subjected to heat treatment in this temperature for 45 min. After the heat treatment, samples were cooled down to the temperature of approx. 4°C. The measurement of shear force F_{max} (N) was performed using the device Instron 5965, equipped with the blade Warner-Bratzler (S5406A) moving at the speed of 120 mm minutes^{-1}. The samples to the measurement of the shear force value were cut along the muscles fibers in the cylinder shape with the cross-section diameter of 1.275 mm (Bourne, 1978; Lepetit & Culioli, 1994). There was conducted the organoleptic assessment of beef muscles, determining their tenderness on the scale from 1 to 9 points. The evaluation team comprised of 12 people.

The obtained results were subjected to statistical analysis. There were calculated the average values and values of variation coefficients. The normality of results distribution was examined using the Shapiro-Wilk test. The significance of the differences was calculated by Duncan group homogeneity test ($p \leq 0.05$). Statistical analysis was performed using the STATISTICA 12.5 software (StatSoft, Inc., 2011).

Results and discussion

The basic chemical composition of the examined muscles was characterised with an average content of water 74.27%, protein 21.52% and fat 4.37% (Table 1). The contents of protein and water showed low individual variability, whereas in the case of fat, there was marked a significantly greater variation. The average fat content was 4.37%, but the variation coefficient was high, around 35%. Fat in beef is a labile ingredient, due to high individual variability. It is the ingredient associated with the outer meat or the creating of marbling. Individuals of the same breed, fed and kept under identical conditions may show different marbling of meat. A similar content of water and protein, and lower by 2% content of fat, characterised the *longissimus thoracis* muscle studied by Fabre et al. (2018) in comparison with our results. Fat content was characterised by a significantly greater variability in relation to protein and water. Results obtained by Wajda, Daszkiewicz and Piotrowski (2004) confirm the highest variability in the case of the fat component. Due to the cross-breeding of the black-and-white breed with meat breeds, the authors obtained, however, higher variation in protein and water contents.

Table 1. Basic chemical composition of meat (n=12).

Parameter	X (average)	S (standard deviation)	V (variation coefficient), (%)
Water	74.27	1.53	2.06
Protein	21.52	0.39	1.81
Fat	4.37	1.52	34.78

The condition for obtaining meat of normal quality and durability is the post slaughter acidification to the pH level in the range of 5.4-5.9. Therefore, at the initial stage of the study, there was measured the pH value of the examined muscles. The average pH value of *m. longissimus lumborum* steaks was 5.63 (Table 2).

Table 2. The pH value of *m. longissimus lumborum* steaks, 48h p.m., after 12 days of ageing and 10 days in MAP (n=12).

Parameter	X (average)	S (standard deviation)	V (variation coefficient), (%)
pH/48h	5.63 A	0.11	1.95
pH/12	5.98 B	0.12	2.01
pH/10	5.90 B	0.14	2.37

A, B, C – different letters at the mean values in the columns indicate the statistical significance of the differences at p <0.05.

The variability of the obtained results was not much (V=1.95%), which proves balanced acidification in the whole mass of muscles, lack of significant individual differences resulting from the similar pace and extent of glycolytic changes. The obtained results prove the correct course of *post mortem* changes, in particular: the consumption of glycogen reserves, ATP decay and accumulation of lactic acid. The test material was free from quality deviations associated with the depletion of glycogen before slaughter. Incorrect acidification and defective meat occur most often as a result of *ante mortem* incorrect handling of animals, which also affects the tenderness of meat. Researchers drawing attention to these conditions include Florek, Litwińczuk, Skałecki and Ryszkowska–Siwko, (2007), Jelenikowa, Pipek and Staruch, (2008) and Cierach et al. (2009a). Many meat processing plants are considering or already using subsidies to prices for slaughter livestock, the meat of which, 24h *post mortem* reaches the pH value <5.9 as a result of the proper handling of the animals and guarantees obtaining meat without quality deviations. During meat ageing, there was observed a significant increase in the pH value to the level of 5.98 and a slight – statistically insignificant, along with the adopted confidence coefficient – the decrease of the value to 5.90, during storing in MAP (Table 2). The increase in the water holding capacity of meat after the disappearance of cold shortening is closely related to the degradation of myofibrillar protein, the loosening of actin-myosin complexes and the increase of meat's pH value during ageing. The increase in the water holding capacity of meat contributes to the improvement of meat's tenderness (Huff-Lonergan & Lonergan, 2005; Jelenikowa et al., 2008).

The colour of the examined dorsal muscle was characterised by the average surface's brightness, L*=37.97 and cross-section's, L*=32.97. The determined values had similar variability. The average value of muscle surface's 'redness' was a*=18.98, whereas cross-section's was greater by approx. 1.3 unit. The parameter of 'yellowness' b* of muscle surface was averagely b*=7.99. A slightly higher value of 'yellowness' was noted for the muscle cross-section. The calculated values of colour saturation C* were for the surface C*=20.59, and cross-section C*=22.13, along with similar individual variability, (Table 3 and 4). Dorsal muscle is located in the exposed part of carcass, hence cooling is evenly distributed, the pH changes between layers are not significantly differentiated and colour rings do not form as in the case of muscles located deeper in the carcass, e.g. leg muscles. Hence, such a small demonstrated variability of pH and colour parameters. The significant dependence of colour on the pH value of meat was noted by Abril et al. (2001). The parameters of meat colour underwent significant changes as a result of ageing process and storing in MAP. The surface of meat was characterised with a significantly lower brightness L*, and higher value of 'redness' a*. As a result, the saturation of colour significantly increased its value. A further increase in the chromatic values a* and b* during storage in MAP storage led to the increased saturation of colour C* by more than 2 units (Table 3). In the case of muscle cross-section, the scope of these changes was different. It is worth emphasizing that the value cross-section's 'redness' was significantly higher in comparison with the surface of meat. As a result of ageing, the a* value increased by more than 3 units, and while storing by further 4 units. These changes had a decisive influence on the increase in the colour saturation C* by more than 7 units (Table 4). Similar trends in the changes of colour parameters can be observed in the work of King, Shackelford, Kalchayanand and Wheeler, (2012).

Table 3. Surface colour parameters of *m. longissimus lumborum* steaks, 48h p.m., after 12 days of ageing and 10 days in MAP, (n=12).

Parameter	48h		After 12 days of ageing 15 min.$^{-1}$		After 10 days in MAP 15min.$^{-1}$	
	x	V(%)	x	V(%)	x	V(%)
L*	37.97 A	5.03	33.53 B	3.32	34.49 B	6.22
a*	18.98 A	10.33	20.64 B	7.41	22.65 C	9.90
b*	7.99 A	13.58	8.21 A	16.25	9.82 B	16.13
C*	20.59 A	11.17	22.21 B	9.59	24.69 C	12.41

A, B, C - different letters at average values in lines indicate the statistical significance of differences at p <0.05.

Table 4. The colour parameters of short-loin cross section 48h p.m., after 12 days of ageing and 10 days in MAP, (n=12).

Parameter	48h		After 12 days of ageing 15 min.$^{-1}$		After 10 days in MAP 15 min.$^{-1}$	
	x	V(%)	x	V(%)	x	V(%)
L*	32.97 A	7.05	30.53 B	6.92	31.00 B	12.43
a*	20.27 A	8.25	23.79 B	7.00	27.81 C	13.56
b*	8.90 A	19.21	10.16 B	11.35	10.66 B	14.73
C*	22.13 A	10.34	25.87 B	8.43	29.78 C	13.75

A, B, C different letters at average values in lines indicate the statistical significance of differences at p <0.05.

The amounts of heat leakages were greater along with the increasing of temperature from the level of 11.24% (50°C), to the level of 37.14% - for temperature 90°C. In the range of 60 - 70°C the increase in the size of the heat leakage was the highest, and slightly smaller in the temperature range of 70 - 80°C (Table 5). These were temperature ranges, in which there occurred intensive denaturation of myofibrillar proteins, hence their decreasing water binding capacity and increased heat leakage. The highest variability of the results was noted for the temperature of treatment 50 and 60°C, and then there was observed a significantly higher repeatability of results. Due to the ageing of meat in vacuum packages and further storage in modified atmosphere, there were obtained significant, statistically vital, decrease in the sizes of leakages. Along with the increase in the thermal treatment temperature, there was more intense the beneficial effect of smaller leakages. At the temperature 50 and 60°C, there was obtained the decrease in the leakages sizes by approx. 2-3%, and in the temperature 70, 80 and 90°C, by approx. 7-8% (Table 5). Vacuum ageing had a greater impact on the reduction of leakages than the storing of meat in MAP, which could be linked to the shaping of meat's pH values, higher after ageing than after storing in MAP (Table 2). The reduction of heat leakages, by approx. 4%, due to the conditioning of meat for 14 days was also obtained by Silva, Moura, Ramos, and Ramos (2017). The next 14 days of meat conditioning did not lead to significant reduction in the size of heat leakage (Silva et al., 2017). The size of heat leakages is influenced, beside time, temperature, meat's pH values, by denaturation changes of protein responsible for water binding and disintegrative changes within cytoskeletal proteins, causing the contraction of muscle cells, which results in the movement of water to extra-cellular spaces (Huff-Lonergan & Lonergan, 2005; Yancey, Wharton, & Apple, 2011; Kemp & Parr, 2012).

Table 5. The amount of heat leakage during the heating of *m. longissimus lumborum* steaks 48h p.m., after 12 days of ageing and 10 days of storing in MAP.

T (ºC)	48h		After 12 days of ageing 15 min.$^{-1}$		After 10 days of storing in MAP 15 min.$^{-1}$	
	x	V(%)	x	V(%)	x	V(%)
50	11.24 A	14.76	9.73 B	13.72	9.52 B	8.90
60	15.88 A	10.23	13.77 B	9.85	13.04 B	10.78
70	29.33 A	5.05	24.36 B	3.63	22.16 C	8.32
80	35.24 A	7.10	30.11 B	5.18	27.74 C	6.18
90	37.14 A	8.32	32.63 B	7.39	29.39 C	11.40

A, B, C - different letters at average values in lines indicate the statistical significance of differences at p <0.05.

As a result of the conducted shear force test, it was found that the initial, before ageing, average shear force of the *m. longissimus lumborum* samples was 49.77N (Table 6). Belew, Brooks, McKenna and Savell (2003) showed in their studies that the supporting muscles (e.g. *m. longissimus lumborum*) are often less tender than dynamic muscles (e.g. *m. semimembranosus*). In the case of studied *m. longissimus lumborum* steaks, there was obtained shear force at the level of F_{max}=49.77 N, which was reflected in the relatively low score for tenderness amounting to 4.52 pts (1-9 scale) in the organoleptic evaluation (Table 6). Quite different values of shear force were obtained by Palka and Kołczak (1998). The longest dorsal muscle of young bulls was characterised by almost twice as big shear force (86.7 N) in comparison with the results obtained in this experiment. The cited authors did not obtain confirmation in the sensory evaluation of the instrumental tests (Palka & Kołczak, 1998). Destefanis, Brugiapaglia, Barge and Dal Molin (2008) achieved high correlation of sensory evaluation test results with the ones obtained from the test of shear force by means of the Warner-Bratzler blade. These authors determined that the beef meat of shear force F >52.68 N is considered by consumers as hard and the one of F <42.87 as tender (Destefanis et al., 2008). After 12 days of ageing, there was achieved the decrease in the shear force from 49.77 to 37.17 N, and after next 10 days of storing in MAP the shear force was averagely 34.09 N (Table 6). Simultaneously, in the consumers' evaluation of tenderness, the score was successively higher. As a result, the final score was shaped at the level of 7.39, and F_{max}=34.09. Due to the conditioning of Brazilian beef for 28 days (*m. longissimus thoracis*), Silva et al. (2017), achieved the decrease in the shear force by approx. 50%, despite not applying increased temperature in the *post mortem* ageing process. These authors, applying two different methods of preparing samples to the shear test, achieved in both cases a high correlation coefficient with the sensory evaluation. In the conducted experiment, *m. longissimus lumborum* meat shall be considered as tender, all the more, there were examined samples with a bigger diameter than in the cited references. In turn, according to Belew et al. (2003), 'very tender' meat has shear force below 32 N, and 'hard' above 46 N. The classification applies, however, to meat from carcasses described by the American system of evaluation as 'Choice' or 'Select'. Conducting the classification of different beef muscles by sensory and instrumental evaluations Hildrum et al. (2009) expressed a view that the longest dorsal muscle should not be a point of reference to the evaluation of muscle profile of the whole carcass because other muscles show significant differences in tenderness.

Table 6. The evaluation of short loin's tenderness, 48h p.m., after 12 days of ageing and 10 days in MAP (n=12).

Parameter	48h		After 12 days of ageing 15 min.$^{-1}$		After 10 days in MAP 15 min.$^{-1}$	
	x	V(%)	x	V(%)	x	V(%)
F_{max} (N)	49.77 A	14.97	37.17 B	10.63	34.09 C	17.20
Points score (0-9)	4.52 A	17.44	6.17 B	18.74	7.39 C	21.16

A, B, C - different letters at average values in lines indicate the statistical significance of differences at p <0.05.

Summary

The evaluation of meat from young bulls of Holstein-Friesian breed, black-and-white variety characterised with beneficial chemical composition due to the low content of fat and high content of protein, correct colour with a high share of 'redness'. The obtained amounts of heat leakages were characteristic for beef with a low content of fat and applied thermal treatment. Due to the origin of young bulls of CB breed (dairy cattle), without the meat component, the obtained parameters of shear force test and the results of organoleptic tenderness test directly after slaughter should be considered as unfavourable. Due to the applied method, of associated ageing in an increased temperature in the lower pressure conditions, and next storing in modified atmosphere, there were obtained very good results in terms of improving the quality of beef, especially, the preferred by consumers, tenderness. The measured shear force values and organoleptic evaluation of *m. longissimus lumborum* steaks' tenderness after thermal treatment prove that they can be used as culinary meat. The obtained results in confrontation with the classification of meat tenderness shown in scientific sources allow to consider *m. longissimus lumborum* as a tender muscle, or medium tender. Such univocal comparison may be precise and credible by applying the same parameters of thermal treatment, identical shear force test parameters and other experimental conditions related mainly to the raw material.

Conclusion

1- *M. longissimus lumborum* steaks from slaughter dairy cattle (HF breed, BW variety) *post mortem*, was characterized with quality features which make the meat eligible for consumption, however, the preferred by consumers, tenderness, softness and delicacy must be considered as unfavourable.

2- The achieved improvement in the parameters of *m. longissimus lumborum* steaks' tenderness, showed in shear force tests and organoleptic evaluation, by more than 30%, as a result of applied technological treatment, moist ageing and MAP storage, allows to consider the muscle as tender, in confrontation with the classifications of beef tenderness in scientific sources.

3- The applied technology of moist ageing and storing in MAP may be used for the improving of the quality of beef from cattle-for-fattening, dairy or mixed types.

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