Nauka Przyroda Technologie

2016
Tom 10
Zeszyt 4
#43

ISSN 1897-7820 http://www.npt.up-poznan.net DOI: http://dx.doi.org/10.17306/J.NPT.2016.4.43

Dział: Nauki o Żywności i Żywieniu

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CHANGES IN GLYCOLYSIS PROCESS IN BULLS' MEAT CARCASSES SUBJECTED TO DIFFERENT TENDERIZATION TREATMENTS

PRZEBIEG PRZEMIAN GLIKOLITYCZNYCH W MIĘSIE TUSZ BUHAJÓW PODDANYCH RÓŻNYM ZABIEGOM TENDERYZACJI

Summary

Background. Electrical stimulation and conditioning of carcasses are carried out to improve the quality of meat. The aim of the study was to evaluate the effect of these treatments on the glycolysis process and tenderness of beef.

Material and methods. The longest lumbar muscles (*m. longissimus lumborum*) were the experimental material. They were divided into four groups by tenderization treatments: ES – high voltage electrical stimulation, KD – conditioning for 18 h at a temperature of 12–15°C, ES+KD – electrical stimulation and conditioning, in conjunction, K – standard cooled carcasses. Glycolysis was evaluated on the basis of the pH value, the content of glycogen and lactic acid after 45 min, and 3, 14, 17, 21, and 28 days *post mortem*. Tenderness was measured on the 3rd, 14th, 17th, 21st and 28th day based on shear force evaluations.

Results. At 45 min after slaughter the value of pH of the muscles was decreasing at the highest rate in the case of ES and ES+KD. Meat of those carcasses displayed the best tenderness after 3 and 14 days, especially when compared to K samples ($p \leq 0.05$).

Conclusions. Among the evaluated meat tenderization treatments, ES had the greatest impact on improving meat tenderness. The conjunction of ES and KD did not cause significant changes in the process of glycolysis and meat tenderization.

Key words: beef, glycolysis, electrical stimulation, conditioning, tenderness

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Introduction

Meat quality is influenced via numerous factors connected with animals rearing conditions, as well as postmortem treatments, which are applied on carcasses, influencing the biochemical processes of the muscle tissue (Domaradzki et al., 2016). To the group of these practices belong both electrical stimulation and carcasses conditioning. Electrical stimulation brings about an increase in the rate of glycolysis and an increase of muscle acidification (Adeyemi and Sazili, 2014; Mombeni et al., 2013; Rhee and Kim, 2001). The course of glycolysis shows a significant influence on forming the quality of meat (Pospiech et al., 2011), especially on its tenderness (Hwang and Thompson, 2001; Kim et al., 2013; White et al., 2006). The aim of the research was an evaluation of the impact of various tenderization treatments on the course of glycolysis and bovine meat tenderness.

Material and methods

The experimental material were the longest lumbar muscles (*m. longissimus lumborum*), derived from eight bulls of Holstein Friesian breed, slaughtered in standard abattoir conditions. Standard quality muscles (RFN, Red Firm Normal) were taken which were evaluated on the basis of the pH value – measured 45 min and 48 h after the slaughter and the IMP/ATP ratio. They were divided into four groups by tenderization treatments. ES and K groups of muscles came from one individual. After the slaughter the left carcass was subjected to electrical stimulation (ES), and the right one was cooled (K). The samples of ES+KD and KD groups also came from one individual: the left carcass was subjected to electrical stimulation and next to conditioning (ES+KD). The right one was only conditioned for 18 h at 12–15°C (KD). The cooled muscles were cut out 48 h after slaughter.

Glycolytic changes were assessed after 45 min and 3, 14, 17, 21, 28 days *post mortem*. The measurement of pH value in muscles was done applying a portable pH meter of Handylab 2 type (PN-ISO 2917:2001, 2001). The content of glycogen (GL) was assessed according to Dalrymple and Hamm's (1973) enzymatic method, and lactic acid (KM) applying Bergmeyer's (1974) method. Meat tenderness was measured on the 3rd, 14th, 17th, 21st and 28th day based on shear force evaluations by help of a TA.XT.plus texture meter with a Warner-Bratzler's countershaft. The meat slices of 2.3 cm thickness were thermally processed in a convection-vapour oven produced by Rational company (model SCC 61E) till 72°C were reached in the geometric center of the sample. Shearing force indispensable for cutting was expressed in newtons per 1 cm^2.

Statistical analysis was conducted using the Statistica 10 program. The calculations of mean values and standard deviation were conducted. The results of the experiments were subjected to monofactorial analysis of variance taking into account the effect of time and type of tenderization treatment. Significance of differences between means was defined by help of Fisher's LSD test.

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Results and discussion

pH meat value was a reflection of the glycolysis process in the muscles of the carcasses in focus and the ratio of their quality (Lee et al., 2002). During the storage, pH value decreased in all the groups but the fastest decrease was observed in the muscles of the electrostimulated carcasses (Table 1). ES and ES+KD muscles, 45 min after slaughter showed a significantly lower ($p \leq 0.05$) pH value compared to K and KD carcasses' muscles (Table 1). ES brought about an increase in the rate of muscles' acidification, especially in a short time after slaughter, which is confirmed by the research of Mombeni et al. (2013), as well as Rosenvold et al. (2008). King et al. (2004) indicate that pH value is, on average, lower by 0.4 of a unit than in the control carcasses which results from electrical stimulation. In these experiments the difference between pH value of the muscles coming from ES, ES+KD carcasses and those from K, KD reached 0.37 of a unit.

Table 1. Changes in the pH value in the muscles during storage
Tabela 1. Zmiany wartości pH w mięśniach w czasie przechowywania

Time after slaughter Czas od uboju	ES	KD	ES+KD	K
45 min	$6.32^{Ac} \pm 0.13$	$6.75^{Bb} \pm 0.23$	$6.38^{Ab} \pm 0.09$	$6.69^{Bb} \pm 0.27$
48 h	$5.56^{b} \pm 0.06$	$5.54^{a} \pm 0.04$	$5.55^{a} \pm 0.08$	$5.57^{a} \pm 0.06$
3 days – 3 dni	$5.41^{a} \pm 0.06$	$5.37^{a} \pm 0.017$	$5.41^{a} \pm 0.20$	$5.45^{a} \pm 0.10$
14 days – 14 dni	$5.52^{ab} \pm 0.04$	$5.47^{a} \pm 0.10$	$5.48^{a} \pm 0.05$	$5.53^{a} \pm 0.04$
17 days – 17 dni	$5.53^{ab} \pm 0.07$	$5.48^{a} \pm 0.08$	$5.50^{a} \pm 0.08$	$5.53^{a} \pm 0.04$
21 days – 21 dni	$5.52^{ab} \pm 0.05$	$5.51^{a} \pm 0.11$	$5.49^{a} \pm 0.06$	$5.54^{a} \pm 0.05$
28 days – 28 dni	$5.56^{b} \pm 0.12$	$5.55^{a} \pm 0.22$	$5.54^{a} \pm 0.17$	$5.58^{a} \pm 0.16$

Values in rows marked with various capital letters differ statistically significantly at the level of $p \leq 0.05$, values in columns marked with various small letters differ statistically significantly at the level of $p \leq 0.05$.

Wartości w wierszach oznaczone różnymi dużymi literami różnią się statystycznie istotnie na poziomie $p \leq 0,05$, wartości w kolumnach oznaczone różnymi małymi literami różnią się statystycznie istotnie na poziomie $p \leq 0,05$.

The GL amount in postmortem muscles was connected with the process of glycolysis (Neath et al., 2007). Its content was decreasing during the storage time (Table 2) and was the highest after 45 min compared to the other times of the experiment ($p \leq 0.05$). Changes in GL content were also observed 3 days after slaughter. Despite the absence of a meaningful differentiation, the lowest GL content after 45 min of storage was noted in ES and ES+KD muscles (Table 2). The result of the anaerobic glycolysis was KM appearance (Choe et al., 2008) and that is why an increase of its amount in muscles was observed during the storage time (Table 3). An impact of ES and KD on its increase was found. After 45 min and 3 days the highest content of KM was found in ES and ES+KD muscles compared to K (Table 3).

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Table 2. Changes in the amount of glycogen in muscles during storage (mmol/kg)
Tabela 2. Zmiany zawartości glikogenu w mięśniach w czasie przechowywania (mmol/kg)

Time after slaughter Czas od uboju	ES	KD	ES+KD	K
45 min	33.34^{c} ±9.89	38.35^{c} ±8.59	30.34^{c} ±4.70	38.02^{b} ±15.74
3 days – 3 dni	18.08^{b} ±4.53	14.99^{b} ±3.86	15.37^{b} ±5.58	17.16^{a} ±5.03
14 days – 14 dni	7.26^{a} ±0.57	6.02^{a} ±1.95	5.79^{a} ±2.05	8.13^{a} ±2.18
17 days – 17 dni	8.95^{a} ±2.73	7.47^{a} ±3.64	6.53^{a} ±3.30	8.84^{a} ±2.74
21 days – 21 dni	8.21^{a} ±4.17	6.84^{a} ±3.62	7.01^{a} ±3.92	7.47^{a} ±4.07
28 days – 28 dni	8.11^{a} ±4.34	5.92^{a} ±4.04	6.54^{a} ±4.67	7.14^{a} ±4.06

Values in columns marked with various small letters differ statistically significantly at the level of $p \leq 0.05$.
Wartości w kolumnach oznaczone różnymi małymi literami różnią się statystycznie istotnie na poziomie $p \leq 0,05$.

Table 3. Changes in the amount of lactic acid in muscles during storage (mmol/kg)
Tabela 3. Zmiany zawartości kwasu mlekowego w mięśniach w czasie przechowywania (mmol/kg)

Time after slaughter Czas od uboju	ES	KD	ES+KD	K
45 min	59.53^{ABb} ±12.46	51.21^{ABb} ±23.09	68.13^{Bb} ±12.89	40.44^{Ab} ±8.74
3 days – 3 dni	92.62^{a} ±5.40	91.34^{a} ±9,16	94.34^{a} ±7.78	85.53^{a} ±10.41
14 days – 14 dni	90.02^{a} ±3.81	93.05^{a} ±9.75	82.24^{ab} ±20.54	82.59^{a} ±8.81
17 days – 17 dni	92.20^{AB} ±6.98	96.94^{Ba} ±8.33	84.36^{Aab} ±11.98	88.72^{ABa} ±5.02
21 days – 21 dni	93.17^{ABa} ±3.38	93.62^{ABa} ±4.26	97.38^{Ba} ±9.15	86.30^{Aa} ±7.90
28 days – 28 dni	93.77^{a} ±6.86	93.47^{a} ±7.58	93.64^{a} ±8.78	94.26^{a} ±7.06

Values in rows marked with various capital letters differ statistically significantly at the level of $p \leq 0.05$, values in columns marked with various small letters differ statistically significantly at the level of $p \leq 0.05$.
Wartości w wierszach oznaczone różnymi dużymi literami różnią się statystycznie istotnie na poziomie $p \leq 0,05$, wartości w kolumnach oznaczone różnymi małymi literami różnią się statystycznie istotnie na poziomie $p \leq 0,05$.

Attention should be paid to the fact that the value of shear force of meat was factually the highest ($p \leq 0.05$) on the 3rd day in group K (97.08 N/cm^2) compared to ES and ES+KD carcasses muscles (respectively: 52.70 N/cm^2 and 54.93 N/cm^2) (Table 4). Research of numerous authors (Hwang and Thompson, 2001; Mombeni et al., 2013; Rhee and Kim, 2001; Rosenvold et al., 2008; Simmons et al., 2008) confirm ES of carcasses meaningfully influenced the meat's tenderness.

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Table 4. Changes in the tenderness (evaluated by the shear force) of beef meat during storage (N/cm^2)
Tabela 4. Zmiany kruchości (mierzonej siłą cięcia) wołowiny w czasie przechowywania (N/cm^2)

Time after slaughter Czas od uboju	ES	KD	ES+KD	K
3 days – 3 dni	$52.70^{bA} \pm 15.15$	$79.08^{bAB} \pm 31.34$	$54.93^{bA} \pm 25.52$	$97.08^{bB} \pm 20.69$
14 days – 14 dni	$31.53^{aA} \pm 3.70$	$46.41^{aBC} \pm 2.20$	$36.56^{abAB} \pm 13.90$	$53.31^{aC} \pm 7.43$
17 days – 17 dni	$32.47^{aA} \pm 4.12$	$44.23^{aAB} \pm 9.19$	$32.27^{abA} \pm 13.36$	$56.14^{aB} \pm 9.70$
21 days – 21 dni	$28.42^{aA} \pm 1.34$	$44.17^{aB} \pm 15.27$	$29.11^{aA} \pm 6.17$	$47.86^{aB} \pm 10.78$
28 days – 28 dni	$30.95^{a} \pm 4.72$	$45.03^{a} \pm 22.54$	$32.81^{ab} \pm 9.17$	$48.30^{a} \pm 16.71$

Values in rows marked with various capital letters differ statistically significantly at the level of $p \leq 0.05$, values in columns marked with various small letters differ statistically significantly at the level of $p \leq 0.05$.

Wartości w wierszach oznaczone różnymi dużymi literami różnią się statystycznie istotnie na poziomie $p \leq 0,05$, wartości w kolumnach oznaczone różnymi małymi literami różnią się statystycznie istotnie na poziomie $p \leq 0,05$.

ES and ES+KD treatments significantly influenced the speed of glycolysis and tenderness of meat tissue (Tables 3 and 4). The research carried out by Hollung et al. (2007), Hwang and Thompson (2001), as well as Simmons et al. (2008) indicates a simultaneous influence of the ES and KD treatment of cattle carcasses on the course of glycolysis and improvement of meat tenderness. It is worth stressing though that the changes concerning KD treatment conducted independently are slower compared to the situation when it is combined with ES.

Conclusions

1. ES carcasses treatment accelerated the process of glycolysis. 45 min after the slaughter, significantly lower pH value of ES and ES+KD muscles was observed, compared to non-electrostimulated carcass.

2. After a 3-day storage, muscles from ES and ES+KD exposed carcasses were characterized by a significantly lower ($p \leq 0.05$) shear force value, compared to the control ones. The above proves that the ES treatment is most efficient in speeding up glycolysis and significantly influences the improvement of meat tenderness.

References

Adeyemi, K. D., Sazili, A. Q. (2014). Efficacy of carcass electrical stimulation in meat quality enhancement: a review. Asian-Australas. J. Anim. Sci., 27, 3, 447–456. DOI: https://doi.org/10.5713/ajas.2013.13463

Bergmeyer, H. U. (1974). Methods of enzymatic analysis. New York: Academic Press.

Copiters, W., van Zeveren, A., van de Weghe, A., Peelman, L., Bouquet, Y. (1992). Direct genotyping of stress susceptibility and resistance in pigs by means of a DNA test. Vlaams Diergeneeskd. Tijdschr., 61, 68–72.

Choe, J. H., Choi, Y. M., Lee, S. H., Shin, H. G., Ryu, Y. C., Hong, K. C., Kim, B. C. (2008). The relation between glycogen, lactate content and muscle fiber type composition, and their influence on postmortem glycolytic rate and pork quality. Meat Sci., 80, 2, 355–362. DOI: 10.1016/j.meatsci.2007.12.019

Dalrymple, R. H., Hamm, R. (1973). A method for the extraction of glycogen and metabolites from a single muscle sample. Int. J. Food Sci. Technol., 8, 4, 439–444. DOI: 10.1111/j.1365-2621.1973.tb01730.x

Domaradzki, P., Florek, M., Litwińczuk, A. (2016). Czynniki kształtujące jakość mięsa wołowego. Wiad. Zootech., 54, 2, 160–170.

Hollung, K., Veiseth, E., Frøystein, T., Aass, L., Langsrud, Ø., Hildrum, K. I. (2007). Variation in the response to manipulation of *post-mortem* glycolysis in beef muscles by low-voltage electrical stimulation and conditioning temperature. Meat Sci., 77, 3, 372–383. DOI: 10.1016/j.meatsci.2007.03.029

Hwang, I. H., Thompson, J. M. (2001). The effect of time and type of electrical stimulation on the calpain system and meat tenderness in beef longissimus dorsi muscle. Meat Sci., 58, 135–144.

Kim, Y. H. B., Lonergan, S. M., Grubbs, J. K., Cruzen, S. M., Fritchen, A. N., della Malva, A., Marino, R., Huff-Lonergan, E. (2013). Effect of low voltage electrical stimulation on protein and quality changes in bovine muscles during postmortem aging. Meat Sci., 94, 3, 289–296. DOI: 10.1016/j.meatsci.2013.02.013

King, D. A., Voges, K. L., Hale, D. S., Waldron, D. F., Taylor, C. A., Savell, J. W. (2004). High voltage electrical stimulation enhances muscle tenderness, increases aging response, and improves muscle color from cabrito carcasses. Meat Sci., 68, 4, 529–535. DOI: 10.1016/j.meatsci.2004.05.003

Lee, J., Cho, S., Kim, J., Park, B., Hwang, I., Choe, H. (2002). Comparison of carcasses and meat quality of purebred, F_1 and three-way crossbred pigs. In: Meat, nutrition, development: 48th International Congress of Meat Science and Technology, Rome, 25–30 August, 2002: congress proceedings, vol. 1 (pp. 340–341). Rome: FAO.

Mombeni, E. G., Mombeini, M. G., Figueiredo, L. Ch., Siqueira, L. S. J., Dias, D. T. (2013). Effects of high voltage electrical stimulation on the rate of pH decline, meat quality and color stability in chilled beef carcasses. Asian Pac. J. Trop. Biomed., 3, 9, 716–719. DOI: 10.1016/S2221-1691(13)60144-6

Neath, K. E., Del Barrio, A. N., Lapitan, R. M., Herrera, J. R. V., Cruz, L. C., Fujihara, T., Muroya, S., Chikuni, K., Hirabayashi, M., Kanai, Y. (2007). Difference in tenderness and pH decline between water buffalo meat and beef during postmortem aging. Meat Sci., 75, 3, 499–505. DOI: 10.1016/j.meatsci.2006.08.016

PN-ISO 2917:2001. (2001). Mięso i przetwory mięsne – Pomiar pH – Metoda odwoławcza. Warszawa: PKN.

Pospiech, E., Iwanowska, A., Montowska, M. (2011). Jakość surowca mięsnego i jej uwarunkowania. In: A. Pisula, E. Pospiech (eds.), Mięso – podstawy nauki i technologii (pp. 231–249). Warszawa: Wyd. SGGW.

Rhee, M. S., Kim, B. C. (2001). Effect of low voltage electrical stimulation and temperature conditioning on postmortem changes in glycolysis and calpains activities of Korean native cattle (Hanwoo). Meat Sci., 58, 3, 231–237.

Rosenvold, K., North, M., Devine, C., Micklander, E., Hansen, P., Dobbie, P., Wells, R. (2008). The protective effect of electrical stimulation and wrapping on beef tenderness at high *pre rigor* temperatures. Meat Sci., 79, 2, 299–306. DOI: 10.1016/j.meatsci.2007.10.002

Iwańska, E., Mikołajczak, B., Grześ, B., Żywica, R., Banach, K., Iwanowska, A., Pospiech, E. (2016). Changes in glycolysis process in bulls' meat carcasses subjected to different tenderization treatments. Nauka Przyr. Technol., 10, 4, #43. DOI: http://dx.doi.org/10.17306/J.NPT.2016.4.43

Simmons, N. J., Daly, C. C., Cummings, T. L., Morgan, S. K., Johnson, N. V., Lombard, A. (2008). Reassessing the principles of electrical stimulation. Meat Sci., 80, 1, 110–122. DOI: 10.1016/j.meatsci.2008.05.006

White, A., O'Sullivan, A., Troy, D. J., O'Neill, E. E. (2006). Manipulation of the pre-rigor glycolytic behaviour of bovine *M. longissimus dorsi* in order to identify causes of inconsistencies in tenderness. Meat Sci., 73, 1, 151–156. DOI: 10.1016/j.meatsci.2005.11.022

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Streszczenie

Wstęp. Zabiegi elektrostymulacji i kondycjonowania tusz wykonuje się w celu poprawy jakości mięsa. Celem badań była ocena wpływu tych zabiegów na przebieg procesu glikolizy i kruszenia mięsa wołowego.

Materiał i metody. Materiałem doświadczalnym były mięśnie najdłuższe lędźwi (*m. longissimus lumborum*). Dzielono je na cztery grupy według zabiegów tenderyzacyjnych: ES – elektrostymulacja wysokonapięciowa, KD – kondycjonowanie przez 18 h w temperaturze 12–15°C, ES+KD – elektrostymulacja i kondycjonowanie łącznie, K – tusze chłodzone standardowo. Glikolizę oceniano na podstawie wartości pH, ilości glikogenu i kwasu mlekowego po 45 min oraz 3, 14, 17, 21 i 28 dniach *post mortem*. Kruchość mięsa oceniano w 3., 14., 17., 21. i 28. dniu na podstawie wartości siły cięcia.

Wyniki. W czasie 45 min po uboju wartość pH badanych mięśni malała najszybciej w przypadku tusz ES i ES+KD. Mięso z nich cechowało się najlepszą kruchością już po 3 i 14 dniach, szczególnie w porównaniu z próbami K ($p \leq 0,05$).

Wnioski. Spośród zabiegów tenderyzacji mięsa największy wpływ na polepszenie kruchości mięsa miała ES. Połączenie ES i KD nie spowodowało istotnych zmian w przebiegu glikolizy i kruszenia mięsa.

Słowa kluczowe: wołowina, glikoliza, elektrostymulacja, kondycjonowanie, kruchość

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Accepted for publication – Zaakceptowano do opublikowania:
26.10.2016

For citation – Do cytowania:
Iwańska, E., Mikołajczak, B., Grześ, B., Żywica, R., Banach, K., Iwanowska, A., Pospiech, E. (2016). Changes in glycolysis process in bulls' meat carcasses subjected to different tenderization treatments. Nauka Przyr. Technol., 10, 4, #43. DOI: http://dx.doi.org/10.17306/J.NPT.2016.4.43