POLISH JOURNAL OF FOOD AND NUTRITION SCIENCES
Pol. J. Food Nutr. Sci. 2005, Vol. 14/55, No 1, pp. 17–26

WATER RETENTION, SHEAR FORCE AND TEXTURE PARAMETERS OF CATTLE *PSOAS* AND *SEMITENDINOSUS* MUSCLES UNFROZEN AND FROZEN DURING POST-MORTEM AGEING

Tadeusz Kołczak, Krystyna Palka, Jerzy Łącki

Animal Products Technology Department, University of Agriculture, Kraków

Key words: cattle, *Psoas* and *Semitendinosus* muscle, water retention, shear force, texture, ageing, freezing

The cooking losses, shear force values and Texture Profile Analysis (TPA) parameters of *psoas major* and *minor* (PM) and *semitendinosus* (ST) muscles of calves, heifers and cows were evaluated. The muscles were roasted at 170°C in an electric oven to an internal temperature of 78°C after 1, 3, 6, 9 and 12 days of post-mortem ageing at 4°C. After the same time of cold ageing, the muscles were frozen to -18°C and stored at this temperature for 1 month. They were then thawed and analysed after roasting under the same conditions. The thawing losses were also determined. The thawing and cooking losses were the highest in cow muscles and the lowest in calf muscles. Changes in the water retention of muscles during post-mortem ageing were low, the lowest were observed after the first day post-mortem. The shear force values were higher for ST than for PM muscles. During post-mortem ageing of meat, shear force values decreased, faster in PM than in ST muscles. The rate of tenderization of calf muscles was higher than that of heifer muscles, whereas heifer muscles were tenderised faster than cow muscles. Shear force values of frozen/thawed and roasted muscles were higher in comparison with unfrozen ones. The cow muscles and ST muscles had higher values of hardness, springiness, cohesiveness, resilience and chewiness than calf muscles and PM muscles, respectively. There were no significant changes in TPA parameters during post-mortem ageing of the analysed muscles.

INTRODUCTION

The culinary traits of meat are determined by colour, texture, juiciness and flavour. From the consumer's point of view, tenderness is one of the most important [Baryłko-Pikielna, 1995].

The inter- and intracellular components of meat have a major influence on its texture and tenderness [Lepetit & Culioli, 1994; Calkins *et al.*, 1981; Swatland, 1985; Crouse *et al.*, 1991].

The quantity and distribution of intramuscular water also plays an important role [Currie & Wolfe, 1980; Offer *et al.*, 1984].

The texture and tenderness of meat decline with physiological maturity of animals. These changes are closely connected with the quantity and properties of intramuscular connective tissue. As an animal matures, the quantity of intramuscular connective tissue decreases and its structure becomes more compact and the tenderness decreases [Kołczak *et al.*, 1992]. On the other hand, during post-mortem ageing, the structure of fibrous intramuscular elements becomes looser because of the catabolic degradation of the cytoskeletal, regulatory and myofibrillar muscle proteins. These changes are known as the tenderization process [Koohmaraie, 1996; Takahashi, 1996; Tornberg, 1996]. During post-mortem ageing, changes in intramuscular connective tissue also occur, which cause an increase in the solubility of its main constituent collagen [Feidt *et al.*, 1996, Kołczak *et al.*, 2003a]. The results of research carried out on calf, heifer and cow muscles have indicated that during post-mortem ageing, changes in ultrastructure of muscle fibres [Kołczak *et al.*, 2003c], in degradation of myofibrillar and cytoskeletal proteins [Kołczak *et al.*, 2003b] and also in intramuscular collagen solubility [Kołczak *et al.*, 2003a] are more rapid and intensive in muscles of younger animals. The processes of post-mortem ageing and accompanying changes in water retention, texture and quality traits may progress at different rates in cattle muscles with different degrees of somatic maturity.

The aim of this study was to determine the changes in water retention, shear force values, and Texture Profile Analysis (TPA) parameters of *psoas major* and *minor* (PM) and *semitendinosus* (ST) muscles of calves, heifers and cows roasted over 12 days of post-mortem ageing. The influence of freezing on muscle texture and cooking losses was also determined.

MATERIAL AND METHODS

The PM and ST muscles were taken from both half-carcasses of female calves (3 moths old), the left carcasses of heifers (18 months old) and cows (around 8 years old) 24 h after standard slaughtering and cooling. In each of the examined groups, analyses were carried out on muscles

Author's address for correspondence: Tadeusz Kołczak, Department of Animal Products Technology, University of Agriculture, Al. 29-Listopada 52, 31-425 Kraków, Poland; tel.: (48 12) 662 50 58; fax: (48 12) 662 52 80; e-mail: rrkolcza@cyf-kr.edu.pl

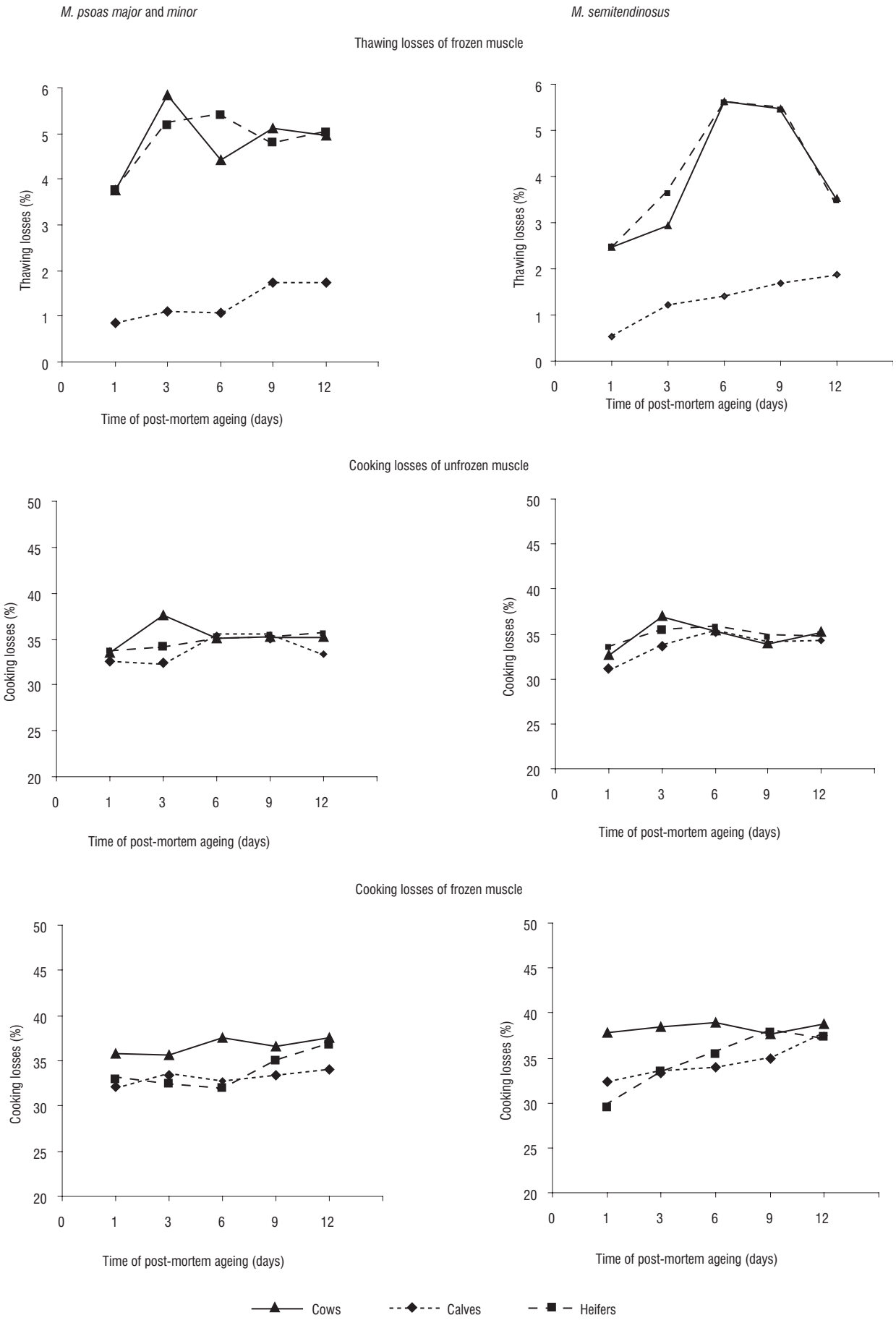

FIGURE 1. Thawing and cooking losses of *psoas major* and *minor* and *semitendinosus* muscles of calves, heifers and cows during 12 days of ageing at 4°C (mean values).

taken from three carcasses. Each of the muscles was divided into 5 parts, perpendicularly to the direction of the fibres, which were vacuum-sealed and stored at 4°C. On the 1st, 3rd, 6th, 9th and 12th day of cold storage, successive samples were taken and divided into 2 pieces. One of them was roasted, cooled to room temperature, dried with filter paper, weighed, and measured for shear force and TPA parameters. A second meat sample was packed in a foil bag, vacuum-sealed, frozen and stored at -18°C for 1 month, thawed at the room temperature, dried with filter paper, weighed, roasted, cooled to room temperature, dried with filter paper, weighed and measured for shear force and TPA parameters.

Thawing losses were calculated from differences in the weight of unfrozen and thawed pieces. Muscle samples of about 150 g were packed into aluminium foil and roasted at 170°C in an electric oven to an internal temperature of 78°C, cooled down to 20°C at ambient temperature and surface-dried with filter paper. Cooking losses were calculated by the difference between the sample weight before and after roasting. Shear force was determined using seven cylindrical samples of 14 mm diameter and 15 mm length cuts. The measurements were carried out for sample cut perpendicularly to the direction of the muscle fibres using a TA-XT2 texture analyser and Warner-Bratzler knife with a triangular cut-out. The TPA analyses were conducted as described by Breene [1975] using a TA-XT2 texture analyser with a 50 mm diameter cylindrical probe with the following settings: probe contact area 154 mm^2, probe travel rate before testing 5 mm/s, and during and after testing 2 mm/s, final strain 70%, time interval between first and second stroke 3 s. In the TPA tests, seven samples (14 mm diameter and 10 mm length, cut lengthwise to the fibres) were analysed. The following TPA parameters were determined: hardness, springiness, cohesiveness, resilience and chewiness.

The data were evaluated statistically using Statistica for Windows 5 software.

RESULTS AND DISCUSSION

Water retention in meat was estimated by measurements of thawing losses and cooking losses during roasting of raw and frozen/thawed muscle samples. The average results are shown in Figure 1, and the results of the statistical analysis are summarized in Table 1.

Independent of the age of cattle and time of post-mortem ageing of meat, the thawing losses were significantly higher for PM than for ST muscle. Thawing losses were lower for calf muscles than for heifer and cow muscles. The time of post-mortem ageing significantly influenced the thawing losses, the lowest losses were observed in meat frozen 24 h after slaughter. In calf muscles, thawing losses were small and increased with the time of post-mortem ageing of meat before freezing. However, in heifer and cow muscles thawing losses were highest after 3–6 days (PM) and 6–9 days (ST) of post-mortem ageing.

While freezing of meat at -18°C, the free water immobilized in larger capillary spaces of meat is frozen [Calvelo, 1981]. In the previous study [Kołczak *et al.*, 2003c], it was found that post-mortem ageing in heifer and cow muscles increased the spaces mainly between the sarcolemma and myofibril mass, whereas in calf muscles the degradation of cytoskeletal proteins stabilizing the structure of myofibrils was more intensive. A much higher increase in solubility of intramuscular collagen in calf muscles than in heifer and cow muscles during post-mortem ageing of meat was also observed [Kołczak *et al.*, 2000a]. During post-mortem ageing, an increase in the capacity of capillary spaces of smaller diameter in calf muscles may be larger than in heifer and cow muscles. The higher quantity of immobilized water in capillary spaces may be the reason for higher water retention and lower thawing losses of calf muscles compared with heifer and cow muscles. The increase in water retention during the thawing of heifer and cow meat frozen on the 12th day of post-mortem ageing may be explained by the intensive degradation processes of intracellular fibre structures which result in the larger capacity of capillary spaces of meat at this time of ageing.

TABLE 1. Mean squares of deviations from the analysis of variance of thawing losses and cooking losses of cattle muscles in relation to muscle type, animal maturity and post-mortem ageing.

Source of variance	Degrees of freedom	Thawing losses	Cooking losses of unfrozen muscles	Cooking losses of frozen muscles
Muscle type - A	1	8.0222^{XX}	13.3094	22.7306
Cattle maturity – B	2	97.5855^{XX}	27.6841^{X}	134.5650^{XX}
Post-mortem ageing – C	4	9.7276^{XX}	56.5151^{XX}	39.1711^{XX}
Interactions:				
A x B	2	2.3251^{XX}	7.8733	5.4333
A x C	4	3.5479^{XX}	17.4254^{X}	5.6296
B x C	8	1.3603^{XX}	15.9445^{X}	14.6642
A x B x C	8	0.9011^{XX}	2.8188	5.8934
Error	60	0.2693	6.4211	8.0462

^{X} – $p < 0.05$ ^{XX} – $p < 0.01$

The cooking losses during the roasting of meat to internal temperature of 78°C depend on the structure and properties of myofibrillar and connective tissue proteins and the quantity of intramuscular fat [Palka, 1999; 2000a, b, c; 2003; Palka & Daun, 1999].

The quantities of cooking losses for unfrozen meat of cows were higher than for meat of heifers, and the lowest losses were observed during roasting of calf meat. The cooking losses were significantly lower during roasting of unfrozen meat on day 1 and 12 of post-mortem ageing than on days 3–9 of ageing. The quantity of bound water (unfrozen at -40°C) in cattle muscles decreases during post-mortem ageing [Kołczak, unpublished data]. The high water holding capacity of meat proteins on day 1 after slaughtering, as well as the intensive degradation processes of fibrillar proteins (intra- and intercellular) resulting in a larger capacity of capillary space in meat after day 12 of ageing could explain the above results.

The cooking losses during roasting of previously frozen/thawed meat were significantly higher than those of unfrozen meat at the same intervals of post-mortem ageing time. The cooking losses of heifer and cow muscles were higher than those of calf muscles and also were higher in ST than PM muscles. There was a tendency towards increased cooking losses in frozen/thawed meat with an increased time of post-

TABLE 2. Mean squares of deviations from the analysis of variance of shear force and TPA parameters of cattle muscles in relation to muscle type, animal maturity, post-mortem ageing and freezing of muscle.

Source of variance	Degrees of freedom	Shear force	TPA parameters				
			hardness	springiness	cohesiveness	resilience	chewiness
Muscle type - A	1	49.8227^{XX}	502.9510^{XX}	0.0408^{XX}	0.2168^{XX}	0.1463^{XX}	106.1222^{XX}
Cattle maturity - B	2	59.3461^{XX}	184.0729^{XX}	0.0064^{XX}	0.0023^{XX}	0.0195^{XX}	25.0746^{XX}
Post-mortem ageing - C	4	49.8530^{XX}	2.0556^{X}	0.0004	0.0004	0.0001	0.1239
Freezing of muscle - D	1	18.2405^{XX}	30.0860^{XX}	0.0001	0.0216^{XX}	0.0001	0.3270
Interactions:							
A x B	2	4.4267^{XX}	1.8447^{XX}	0.0028	0.0058^{XX}	0.0095^{XX}	4.7404^{XX}
A x C	4	0.7568^{XX}	0.4118	0.0010	0.0004	0.0003	0.1853
B x C	8	0.1580	2.0197^{X}	0.0024^{X}	0.0009	0.0002	0.5846^{XX}
A x D	1	0.0001	1.2245	0.0001	0.0020^{X}	0.0011^{X}	0.8949^{XX}
B x D	2	3.3471^{XX}	15.8925^{XX}	0.0001	0.0017^{XX}	0.0001	0.8469^{XX}
C x D	4	0.4002^{X}	0.3450	0.0008	0.0001	0.0001	0.0229
A x B x C	8	0.0936	0.2467	0.0007	0.0002	0.0001	0.0560
A x B x D	2	0.2243	0.8772	0.0016	0.0005	0.0007^{X}	0.3115
A x C x D	4	0.0364	0.2784	0.0003	0.0004	0.0002	0.2565
B x C x D	8	0.0421	0.8851	0.0015	0.0001	0.0002	0.0966
A x B x C x D	8	0.0751	0.3462	0.0014	0.0002	0.0001	0.0760
Error	120	0.1437	0.8045	0.0011	0.0005	0.0002	0.1177

^{X} – $p < 0.05$ ^{XX} – $p < 0.01$

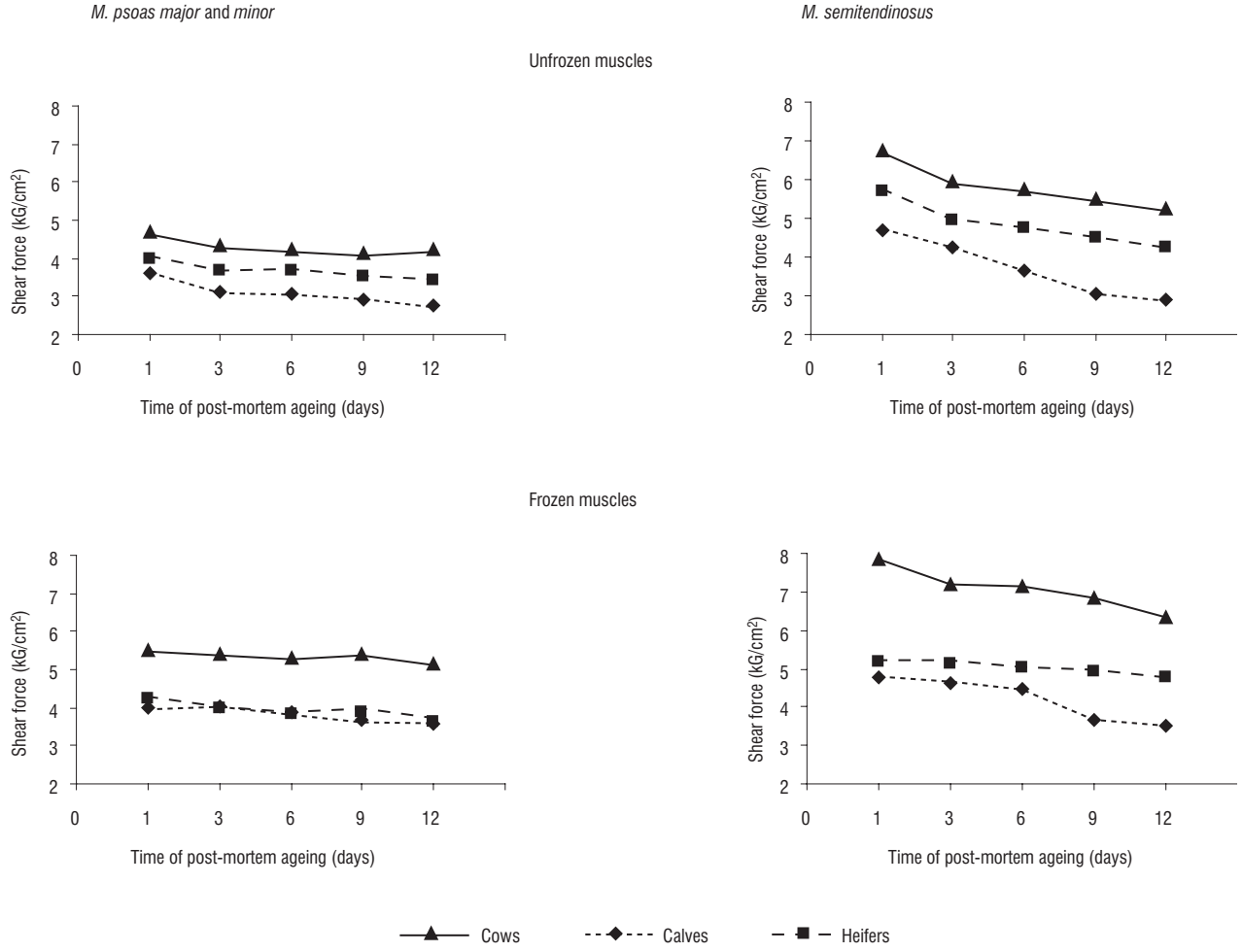

FIGURE 2. Shear force of roasted unfrozen and frozen *psoas major* and *minor* and *semitendinosus* muscles of calves, heifer and cows during post-mortem ageing at 4°C (mean values).

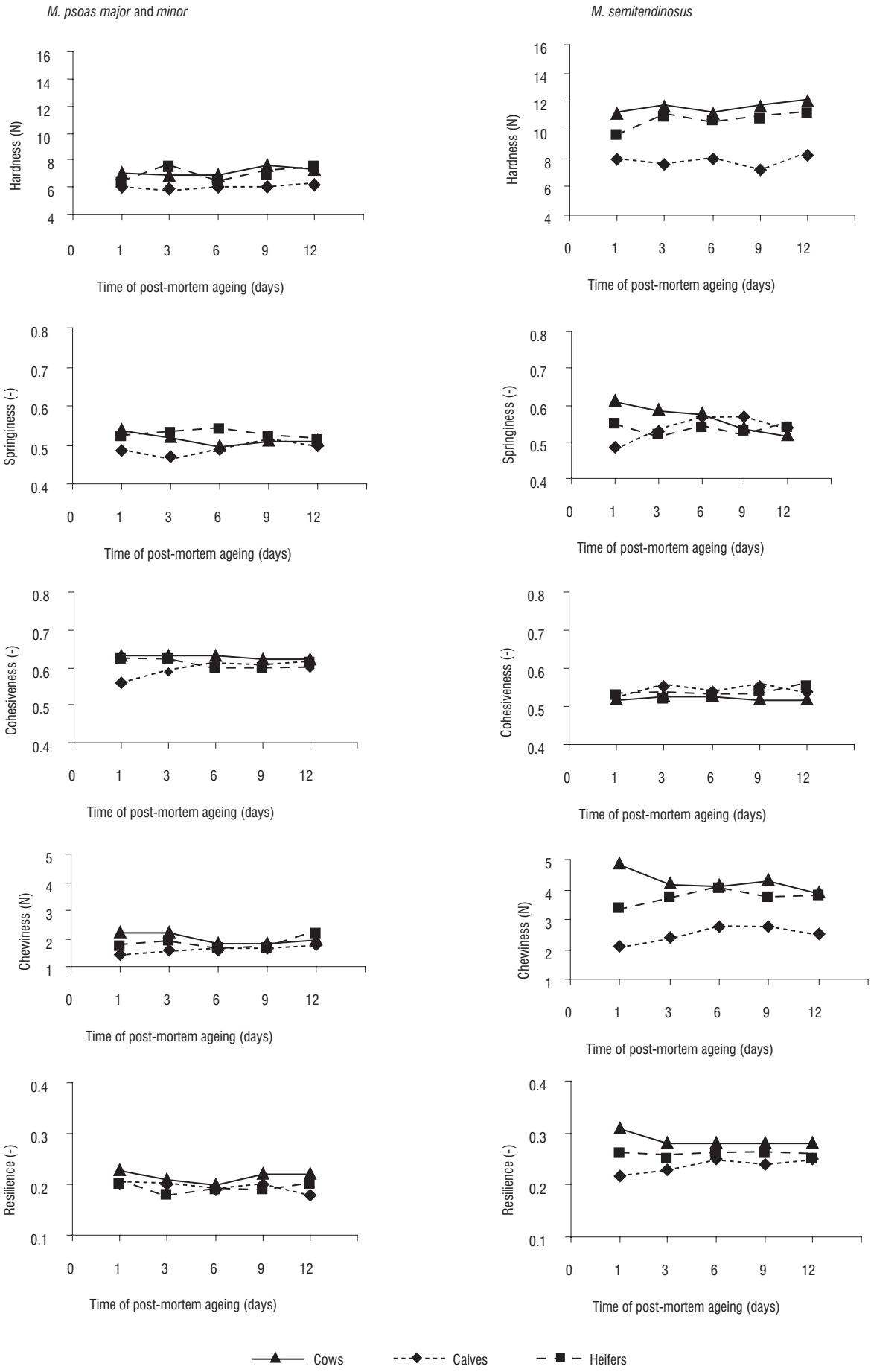

FIGURE 3. Changes in TPA parameters of roasted unfrozen *psoas major* and *minor* and *semitendinosus* muscles of calves, heifers and cows during post-mortem ageing at 4°C (mean values).

-mortem ageing of meat before freezing, however, the changes were not statistically significant.

During heating, meat proteins lose water-holding capacity because of their thermal denaturation [Terpsidis *et al.*, 1987; Palka, 2000a, b, c]. The protein denaturation and changes in their functional properties are the main reasons for leak formation during the heating of meat. The observed differences in cooking losses, depending on the age of the animal and the type of muscle, may be connected with a higher quantity of intramuscular fat in the meat of older animals and with a higher quantity of intramuscular collagen in ST than in PM muscles [Aberle *et al.*, 2001; Kołczak *et al.*, 1992; Lawrie, 1998].

During the freezing and thawing of meat, its proteins, mainly myofibrillar proteins, may undergo denaturation as a result of dehydratation. They lose over time, the ability to hold and retain water [Calvelo, 1981]. The freezing denaturation of meat proteins may be the reason for higher cooking losses in frozen/thawed meat.

The changes in shear force values of meat are shown in Figure 2, and the results of the statistical evaluation of the influence of the analysed factors are summarised in Table 2. Independent of the age of cattle and the time of post-mortem ageing, the shear force values were lower for PM than for ST muscles and increased with the somatic maturity of cattle. These results confirm the results of many authors [Dransfield, 1994; Kołczak *et al.*, 1992; Koohmaraie, 1996; Takahashi, 1996; Tornberg, 1996].

During post-mortem ageing, the shear force values of meat of the analysed cattle groups decreased. Similar results indicated that tenderization of meat occurred during post-mortem ageing, as it was reported by other authors [Huff-Lonergan *et al.*, 1995; Palka, 2003; Taylor *et al.*, 1995].

The decrease in shear force during 12 days of cold ageing was lower for PM than for ST muscles. It means that the PM muscles of calves, heifers and cows reach better tenderness in a shorter period of cold ageing than respective ST muscles. The shear force values of ST muscles decreased considerably during 12 days of ageing, the relative decrease was much higher in the ST muscles of calves than the ST muscles of heifers and cows.

The results indicate that the rate of calf muscle tenderising is much higher than that of heifer muscles, whereas heifer muscles are tenderised faster than cow muscles. The tenderness of ST muscles of heifers and cows on day 12 of cold storage was still lower than the tenderness of PM muscles of the same animals on the 1st day post-mortem. Calf ST muscles reached tenderness close to that of PM muscles on the 6th day of cold storage.

The reasons for the differences in the rate of post-mortem tenderization of PM and ST muscles, as well as the muscles of cattle of different ages may be the range and rates of degradation processes of cytoskeletal and the regulating proteins of muscle fibres as well as the different intensity of changes in intramuscular collagen [Kołczak *et al.*, 2003a, b, c]. From a practical point of view, these results indicate that under normal conditions of cold storage, the PM muscles of cattle carcasses do not require long term ageing. However, the ST muscles of cattle carcasses should be aged for a longer time. Calf carcasses require shorter ageing time than bovine or cow carcasses.

The shear force values of roasted muscles, previously frozen and thawed, were significantly higher than those of the muscles unfrozen before roasting. The differences were particularly evident for cow muscles. The changes of shear force values, depending on muscle type and time of post-mortem ageing, were similar to unfrozen muscles. The results show that regardless of the anatomical origin of meat or period of post-rigor ageing, freezing meat by the method used in this study changes the tenderness of frozen meat for the worse. The larger undesirable changes in the tenderness of frozen cow muscles in comparison to frozen muscles of younger cattle may be connected with larger thawing losses observed during the defrosting of cow muscles.

The results of the analysed TPA parameters of roasted unfrozen muscles are presented in Figure 3, and the TPA parameters of frozen and thawed muscles before roasting are presented in Figure 4. The results of a statistical evaluation of the examined factors are summarized in Table 2.

Hardness is the force necessary to obtain a stated deformation in the meat sample. The values of hardness of ST muscles were higher than PM muscles in all cattle groups, probably because of the higher quantity of intramuscular connective tissue in ST muscle. Cow muscles were the hardest, heifer muscles were average and calf muscles were the softest. The reasons for the differences in hardness, depending on the age of the cattle, may be connected with the structure of intramuscular collagen, which as an animal ages becomes more compact and resistant to heating [Bailey & Light, 1989]. The differences in the hardness of muscles during ageing were small, however, the hardness of muscles at 24 h after slaughter was lower than over longer periods of cold storage. The results indicate that the effects of changes occurring in meat structure and the degradation processes of meat proteins during post-mortem ageing on this TPA parameter are small. The hardness values of muscles roasted after freezing/thawing were slightly lower compared to unfrozen muscles.

Springiness is the rate of return of a meat sample from a deformed to a starting state after removal of the pressing force. The values of springiness of ST were higher than PM muscles, and significantly lower for calf muscles than for heifer and cow muscles. The analysed time of post-mortem ageing and freezing/thawing of meat before roasting did not influence this parameter of texture.

Cohesiveness is the force of internal bonds stabilizing the meat structure. The values of cohesiveness for ST were higher than for PM muscles, and were significantly higher for heifer and cow muscles than for calf muscles. No significant influence of time of post-mortem ageing on cohesiveness of roasted meat was observed. Meat frozen/thawed before roasting had lower cohesiveness than unfrozen meat.

Resilience is the immediate springiness of meat samples. The values of resilience for ST muscles were higher than for PM muscles, and were significantly higher for cow muscles than for heifer and calf muscles. The time of post-mortem ageing and freezing/thawing of muscles before roasting did not significantly influence the resilience.

Chewiness is the energy necessary to grind a meat sample. The values of chewiness were significantly higher for ST than PM muscles, the highest for cow muscles and the lowest for calf muscles. The time of ageing and freezing/thawing of meat before roasting had no significant effect on chewiness.

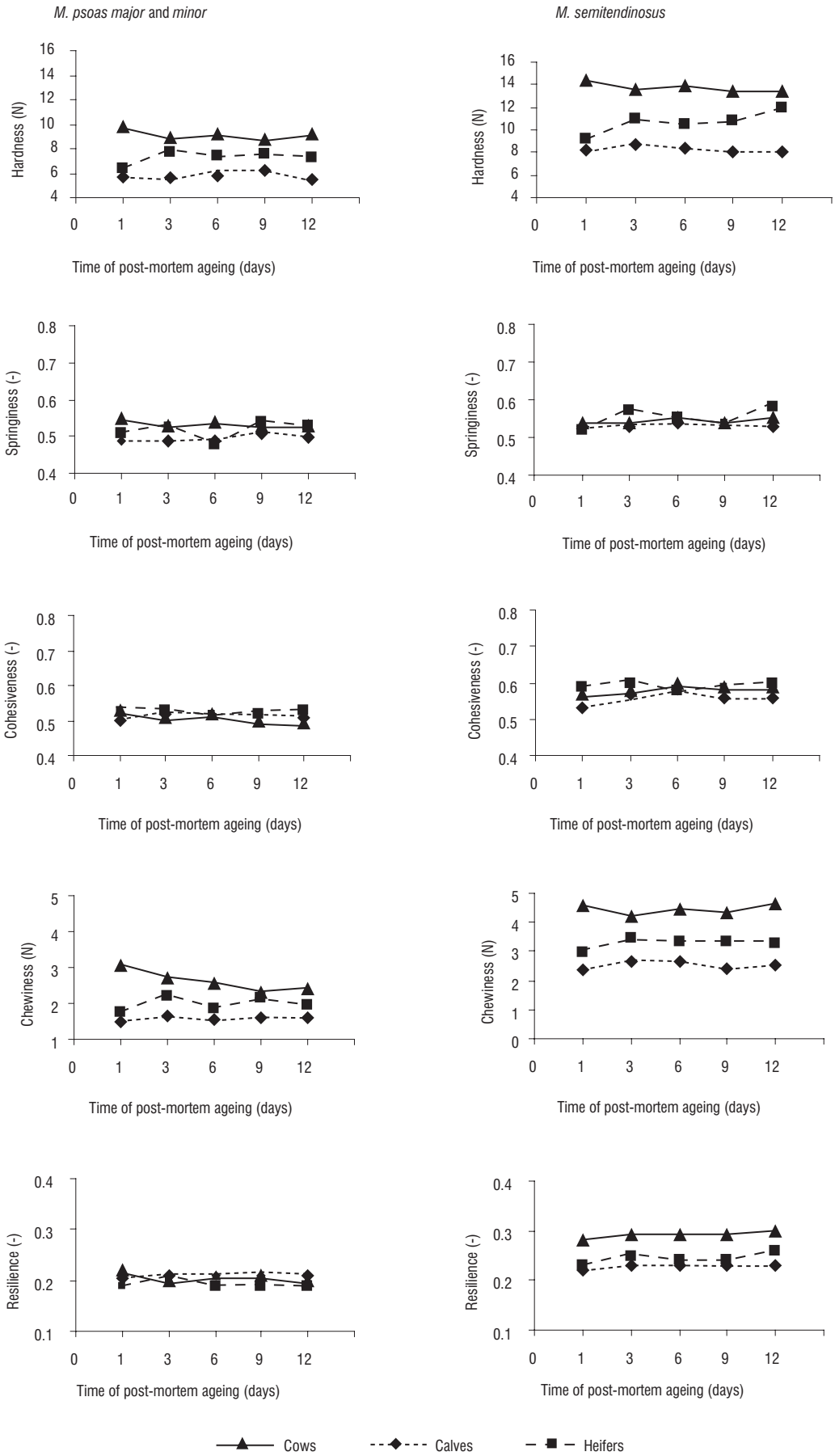

FIGURE 4. Changes in TPA parameters of roasted frozen *psoas major* and *minor* and *semitendinosus* muscles of calves, heifers and cows during during post-mortem ageing at 4°C (mean values).

The differences in the texture parameters of roasted meat, depending on the age of the animal and the anatomical location of muscles, may be connected with the tissue composition of meat, especially with the share of connective tissue. The changes in muscle structure and intracellular proteins as well as in the properties of connective tissue, which are observed over 12 days of post-mortem cold ageing, do not significantly influence the TPA parameters of roasted meat.

CONCLUSIONS

1. The thawing losses of calf muscles are lower than those of heifer and cow muscles, and are higher for *psoas* than for *semitendinosus* muscles.

2. The cooking losses during roasting of meat from older cattle are higher compared to meat from cattle of lower somatic maturity.

3. The *psoas* muscles reach better tenderness after a shorter post-mortem ageing period of meat than *semitendinosus*, which require a longer ageing period.

4. During post-mortem cold storage, the rate of calf muscles tenderising is higher than that of heifer muscles, but heifer muscles tenderise faster than cow muscles.

5. The tenderness of meat frozen/thawed before roasting is usually worse than unfrozen, regardless of post-mortem freezing period.

6. The cow and *semitendinosus* muscles have higher values of TPA parameters (hardness, springiness, cohesiveness, resilience and chewiness) in comparison to calf and *psoas* muscles, respectively. The post-mortem ageing do not influence significantly the TPA parameters of cattle meat.

REFERENCES

1. Aberle E.D., Forrest J.C., Gerrard D.E., Mills E.W., Principles of Meat Science. 2001, Kendall/Hunt Publ. Comp., Iowa, USA.
2. Baryłko-Pikielna N., Safety and nutritious value of food: Opinions of consumers and research workers. Przem. Spoż., 1995, 49, 111–112 (in Polish).
3. Bailey A.J., Light N.D., Connective Tissue in Meat and Meat Products. 1989, Elsevier Appl. Sci., London, 1989.
4. Breene W.M., Application of texture profile analysis to instrumental food texture evaluation. J. Texture Stud., 1975, 6, 53–82.
5. Calkins C.R., Dutson T.R., Smith G.C., Carpenter Z.L., Davis G.W., Relationship of fiber type composition to marbling and tenderness of bovine muscle. J. Food Sci., 1981, 46, 708–715.
6. Calvelo A., Recent studies on meat freezing 1981, *in*: Developments in Meat Science-2 (ed. R. Lawrie). Appl. Sci. Publ., London, pp. 125–158.
7. Crouse J.D., Koohmaraie M., Seideman S.C., The relationship of muscle fibre size to tenderness of beef. Meat Sci., 1991, 30, 295–302.
8. Currie R.W., Wolfe F.H., Rigor related changes in mechanical properties and extracellular space in beef muscle. Meat Sci., 1980, 4, 123–143.
9. Dransfield E., Optimisation of tenderization, ageing and tenderness. Meat Sci., 1994, 36, 105–121.
10. Feidt C., Petit A., Bruas-Requier F., Brun-Bullut J., Release of free amino acids during ageing in bovine meat. Meat Sci., 1996, 44, 19–25.
11. Huff-Lonergan E., Parrish F.C. Jr, Robson R.M., Effects of post-mortem aging, time, animal age, and sex on degradation of titin and nebulin in bovine *longissimus* muscle. J. Anim. Sci., 1995, 73, 1064–1073.
12. Kołczak T., Palka K., Zarzycki A., The effect of intramuscular collagen on tenderness and other sensory characteristics of bovine muscles. Acta Agraria et Silvestria, seria Zootechnica, 1992, 30, 75–85 (in Polish).
13. Kołczak T., Palka K., Łącki J., Changes in collagen solubility of bovine *psoas major* and *minor* and *semitendinosus* muscle roasted during cold storage. Pol. J. Food Nutr. Sci., 2003a, 12/53, 3, 57–62.
14. Kołczak T., Pospiech E., Palka K., Łącki J., Changes of myofibrillar and centrifugal drip proteins and shear force of *psoas major* and *minor* and *semitendinosus* muscles of calves, heifers and cows during post-mortem ageing. Meat Sci., 2003b, 64, 69–75.
15. Kołczak T., Pospiech E., Palka K., Łącki J., Changes in structure of *psoas major* and *minor* and *semitendinosus* muscles of calves, heifers and cows during post-mortem ageing. Meat Sci., 2003c, 64, 77–83.
16. Koohmaraie M., Biochemical factors regulating the toughening and tenderization processes of meat. Meat Sci., 1996, 43 S, 193–201.
17. Lawrie R., Meat Science. 1998, Woodheat Publ. Ltd., London, p. 352.
18. Lepetit J., Culioli J., Mechanical properties of meat. Meat Sci., 1994, 36, 203–237.
19. Offer G., Restall D., Trinick J., Water-holding in meat. 1984, *in*: Recent Advances in Chemistry of Meat (ed. A.J. Bailey). The Royal Society of Chemistry, London, pp. 71–86.
20. Palka K., Changes in intramuscular connective tissue and collagen solubility of bovine *m. semitendinosus* during retorting. Meat Sci., 1999, 53, 189–194.
21. Palka K., Roasting-induced changes in intramuscular connective tissue and tenderness of bovine *m. semitendinosus* muscle. Pol. J. Food Nutr. Sci., 2000a, 9/50, 3, 39–44.
22. Palka K., Roasting-induced changes in texture and fibre microstructure of bovine *m. semitendinosus* muscle. Pol. J. Food Nutr. Sci., 2000b, 9/50, 2, 41–45.
23. Palka K., Changes in the microstructure and texture of bovine muscles during post mortem ageing and heating. Zesz. Nauk. AR Kraków, 2000c, z. 270, pp. 1–117 (in Polish).
24. Palka K., The influence of post-mortem ageing and roasting on the microstructure, texture and collagen solubility of bovine *semitendinosus* muscle. Meat Sci., 2003, 64, 191–198.
25. Palka K., Daun H., Changes in texture, cooking losses and myofibrillar structure of bovine *m. semitendinosus* during heating. Meat Sci., 1999, 51, 237–243.
26. Swatland H.J., Early research on the fibrous microstructure of meat. Food Microstucture, 1985, 4, 73–82.
27. Takahashi K., Structural weakening of skeletal muscle tissue during post-mortem ageing of meat. The non-enzymatic mechanism of meat tenderization. Meat Sci., 1996, 43 S, 67–80.
28. Taylor R.G., Geesing G.H., Thompson V.F., Koohmara-

ie M., Goll D.E., Is Z-disck degradation responsible for postmortem tenderization? J. Anim. Sci., 1995, 73, 1351–1358.
29. Terpsidis K.H., Rentios A.T., Papavasilion P.V., Tsagavakis A.N., Heat dependable myofibril shrinkage and associated water losses. 33rd Eur. Meet. Meat Res. Work., Helsinki, 1987, 6, 24, 443.
30. Tornberg E., Biophysical aspects of meat tenderness. Meat Sci., 1996, 43 S, 175–191.

Received June 2003. Revision received August 2003 and accepted January 2004.

RETENCJA WODY, SIŁA CIĘCIA I PARAMETRY TEKSTURY MIĘŚNI BYDLĘCYCH *PSOAS* ORAZ *SEMITENDINOSUS* NIE MROŻONYCH I ZAMRAŻANYCH PODCZAS DOJRZEWANIA CHŁODNICZEGO

Tadeusz Kołczak, Krystyna Palka, Jerzy Łącki

Katedra Przetwórstwa Produktów Zwierzęcych, Akademia Rolnicza, Kraków

Badano wielkość wycieku cieplnego, wartość siły cięcia oraz parametry tekstury (TPA) mięśni *psoas major* i *minor* (PM) oraz *semitendinosus* (ST) cieląt, jałówek i krów, pieczonych do temperatury wewnętrznej 78°C w 1, 3, 6, 9 i 12 dniu dojrzewania poubojowego w 4°C. Ponadto w wymienionych okresach dojrzewania chłodniczego mięśnie zamrażano do -18°C, przechowywano w stanie zamrożonym przez 1 miesiąc i po rozmrożeniu pieczono i oznaczano wielkość wycieku cieplnego, siłę cięcia oraz parametry TPA. Określano również wielkość wycieku rozmrożeniowego. Wielkość wycieków rozmrożeniowego i cieplnego była największa w mięśniach krów a najmniejsza w mięśniach cieląt. Zmiany w retencji wody w mięśniach podczas dojrzewania chłodniczego były niewielkie, najmniejszy wyciek rozmrożeniowy i najmniejszą wielkość wycieku cieplnego obserwowano w mięśniach w 1 dniu po uboju (rys. 1, tab. 1). Wartość siły cięcia była wyższa w przypadku mięśnia ST niż mięśnia PM. Podczas dojrzewania chłodniczego wartości siły cięcia mięśni malały. Mięśnie PM osiągały niższą wartość siły cięcia w krótszym czasie dojrzewania chłodniczego niż mięśnie ST. Wartości siły cięcia mięśni mrożonych były wyższe niż mięśni nie mrożonych (rys. 2, tab. 2). Mięśnie krów oraz mięśnie ST charakteryzowały się większą twardością, sprężystością, spójnością i odbojnością oraz gorszą żujnością niż mięśnie cieląt i mięśnie PM. Nie obserwowano istotnych zmian w wymienionych parametrach tekstury mięśni podczas ich poubojowego dojrzewania chłodniczego (rys. 3, rys. 4, tab. 2).