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INFLUENCE OF SLAUGHTER SEASON OF CALVES AND AGEING TIME ON MEAT QUALITY

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The objective of the work was to evaluate the effect of slaughter season of calves (spring, summer, and autumn) and ageing time (during 7 days *post mortem*) on veal quality. The research material was made by random samples of *m. longissimus lumborum* (MLL) from 58 carcasses of calves slaughtered in spring (n=20), summer (n=20), and autumn (n=18) season. The slaughter quality of carcass, the chemical composition, and physicochemical properties of meat during 7 days *post mortem* were determined. The differences for hot and cold carcass weight and dressing percentage in the compared seasons were observed. The influence ($p \leq 0.01$) of ageing time on all traits of MLL was observed. The slaughter season of calves also influenced meat quality, with the exception of electrical conductivity, drip and cooking loss. Interactions of the assessed factors for meat pH and its colour (yellowness) as well as for the TBARS value and cooking loss were confirmed. The best physicochemical traits showed meat from summer season (the highest content of protein, and the lowest of intramuscular fat ($p<0.05$), the lowest TBARS value as well as shear force and work values). The certain improvement of water holding capacity, and tenderness at 7 days *post mortem* in comparison with 48 h was observed for meat from all seasons.

INTRODUCTION

Requirements of the EU consumers regarding veal quality seem quite differentiated, subject to geographical and regional aspects. According to the opinion poll made in the EU, the most important quality traits of veal meat appear to be tenderness and palatability, while its colour is of minor importance. Alike, veal meat consumption ranges from very high in the Mediterranean countries like Italy, France, Spain to rather low in Ireland, Finland, Sweden and virtually insignificant in Great Britain [Tyszkiewicz, 2005a,b]. The current average beef consumption in Poland is very low as it is over 2.5 kg per capita annually, in that insignificant veal meat share (about 0.25 kg) [Świetlik, 2005]. Peculiar consumers' demands determine that meat of pale colour, mild taste and fine texture is sought-after. The veal meat quality is depended on numerous factors and the essential are a breed, dietary treatment and maintenance system, animal handling as well as post-slaughter changes rate. However, details of the season (or month) impact on veal quality are more fragmentary [Ngapo & Gariépy, 2006].

In retail conditions, colour is a critical sensory characteristics of beef as it is experienced by consumers before tenderness or flavour and tends to be used as an indicator of perceived quality and freshness [Carpenter *et al*., 2001]. Therefore colour is probably the single greatest appearance factor that determines whether meat is purchased.

In the meat tenderness formation a special part play enzymic processes, which occur in muscle and result from an interaction between sequence groups of enzymes. A special function among them is served by proteolytic enzymes. They determine the rate of proteins metabolism throughout animal's life, and after slaughter define the dynamics of changes influencing meat tenderness. The main effect of beef ageing is the improvement of tenderness and palatability of meat, which after suitable thermal preparation will more satisfy consumers expectation. For practical reason, an ageing time of beef originating from properly fattened animals should not be less than 7 till 10 days at a temperature of 1-2°C. A temperature and post-slaughter storage life influence substantially the *post mortem* changes rate and, in a consequence, beef meat tenderness development [Purchas *et al*., 1999]. The contribution of the myofibrillar component to the overall tenderness of beef is greater than that of the connective tissue. This conclusion applies primarily to meat taken from young animals, which are composed of muscles of lower connective tissue content [Harris & Shorthose, 1988].

The objective of the work was to evaluate the effect of slaughter season of calves (spring, summer, and autumn) and ageing time (during 7 days *post mortem*) on veal quality.

MATERIALS AND METHODS

The experiments comprised material of 58 calves purchased from private breeders from the central-eastern part of Poland. The animals were assigned to three treatment groups due to season of slaughter, *i.e.* spring (n=20), summer (n=20), and autumn period (n=18). Due to a low number

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of calving in the winter season, this period was passed in analysis over. After at least 24 h – pre slaughter rest, the animals were weighed prior to slaughter. The stunning and slaughter processing of the calves were conducted in compliance with the technology obligatory in the meat industry and under supervision of veterinary inspection.

Carcass body weight before (hot) and after chilling (cold) and the weight of kidneys and kidney fat were determined. Values of hot and cold dressing percentage were calculated. During the technological partition of carcass (after chilling for 24 h at a temperature of 2°C, and relative moisture of 85%) the samples of *musculus longissimus lumborum* (MLL) were cut out, and then divided into 3 sections of the same length, weighed and vacuum packed in the PA/PE foil bags. The bags were cold stored at 4°C until analysed.

Conventional methods were applied to determine the proximate chemical composition, *i.e.* water content with the drying method (103°C) according to the Polish Standard [PN-ISO 1442:2000]; ash by incineration (550°C) after the Polish Standard [PN-ISO 936:2000]; crude protein content (N x 6.25) with Kjeldahl method by Büchi B-324 apparatus according to the Polish Standard [PN-75/A-04018:1975]; intramuscular fat level (IMF) by Soxhlet lipid extraction method using Büchi -B-811 equipment and n-hexane as a solvent after the Polish Standard [PN-ISO 1444:2000]. The degree of protein hydration (Feder's number) was calculated as a proportion of water to protein content. Calorific value (energy) of meat (100 g) was calculated on the grounds of the content of crude protein and intramuscular fat. The computations were based on the physiological (Atwater) energy equivalents (for protein 4.0 kcal=16.76 kJ, while for fat 9.0 kcal=37.66 kJ).

The content of total haematin pigments was determined with the method of Hornsey [1956] a using Varian Cary 300 Bio spectrophotometer at 640 nm, and the haem iron content was calculated with the factor 8.82. Lipid oxidation was assayed by measuring 2-thiobarbituric acid reactive substances (TBARS), according to the method of Witte *et al.* [1970] using a Varian Cary 300 Bio spectrophotometer at 530 nm, at day 2, 3 and 7 of ageing and was expressed as milligram of malonaldehyde (MA) produced per kilogram of muscle.

The PQM I-KOMBI INTEK GmbH apparatus was employed to determine meat pH and specific electrical conductivity – EC (mS/cm), taking the measurements 45 min, and 2, 3, and 7 days following the slaughter.

The colour of fresh cut meat surface following 30 min blooming time (samples were stored in contact with air at 4°C) was measured immediately after the meat had been removed from the vacuum bag using a Minolta CR-310 portable chromameter (illumination D65, geometry 0 projection angle and 50 mm measure area). The measurements were taken on days 2, 3, and 7. Values were given in the colour space CIE [CIE, 1976], where L* – lightness; a* – redness; b* – yellowness. A result for a sample was computed as an arithmetic mean from two replications on the muscle surface.

Water holding capacity (WHC) at 2, 3 and 7 days *post mortem*, was determined using three different methods. Drip loss (DL) was calculated by subtracting the weight of sample after a storage period (24 h) at chill temperature (4°C) from the initial weight, multiplying by 100 and then dividing by the initial weight. Similarly, the cooking loss (CL) was calculated as weight (grams) lost from a raw sample after thermal treatment (in the water bath at 70°C for 60 min), and expressed as a percentage of the initial sample weight. Filter paper press method [Grau & Hamm, 1953], was expressed as the ratio M/T × 100 (%), where M is the area (cm^2) of the meat and T is the total area (cm^2) [Hofmann *et al*., 1982].Measurements of meat area were determined on scanned pictures using image analysis software MultiScan Base ver. 14.

Shear force – SF (N) and work – W/N (J) measurements were carried out using a 1-column table-top Zwick/Roell Proline B0.5 machine and a Warner-Bratzler device (V-blade), after thermal treatment of the samples at 3 and 7 days *post mortem*. From each meat sample a minimum of five blocks (10×10×50 mm) were tested perpendicular to the fibres.

The data obtained were analysed statistically using the STATISTICA data analysis software system ver. 6 [StatSoft, 2003]. On the ground of one-way analysis of variance the influence of season on slaughter quality of calves and chemical composition of veal was estimated. In order to study the season and ageing time effects and their interactions on veal quality the two-way analysis of variance was employed. Fisher LSD test was used to Post-hoc comparisons.

RESULTS AND DISSCUSION

Differences were observed for hot and cold carcass weight and dressing percentage in the seasons compared (Table 1). At the not significant different slaughter weight of calves, the highest values of these traits were stated in spring, and the lowest in autumn season. The average weight of kidney, kidney fat and its percentage was similar in the compared seasons. Specht *et al.* [1994] obtained dressing percentage of light calves at 55% and heavy ones at 59%; whereas the percentage of kidney fat at 0.6% and 2.5%, respectively.

The chemical composition mainly determined the nutritive value of meat and its processing and culinary usefulness. It was demonstrated that meat from the summer season had the highest content of water ($p<0.01$) and protein ($p<0.05$),

TABLE 1. Parameters of carcass slaughter value in relation to slaughter season of calves (mean±standard error).

Specification	Season		
	Spring (n=20)	Summer (n=20)	Autumn (n=18)
Body weight at slaughter (kg)	74.63±2.72	70.38±3.03	66.94±2.78
Hot carcass weight (kg)	44.96^{B}±1.82	41.43^{AB}±1.64	38.48^{A}±1.29
Cold carcass weight (kg)	43.98^{B}±1.67	40.42^{AB}±1.57	37.53^{A}±1.31
Hot dressing percentage (%)	60.24^{b}±0.63	58.88^{ab}±0.61	57.58^{a}±0.72
Cold dressing percentage (%)	58.93^{b}±0.52	57.46^{ab}±0.58	56.16^{a}±0.69
Kidneys weight (kg)	0.32±0.02	0.31±0.02	0.31±0.01
Kidney fat weight (kg)	0.66±0.13	0.59±0.09	0.44±0.06
Kidney fat percentage (%)	0.84±0.14	0.80±0.12	0.66±0.09

Means marked with different letters differ significantly: a,b – $p<0.05$; A,B – $p<0.01$.

and at the same time the lowest amount of intramuscular fat ($p<0.05$), ash and haem iron ($p<0.01$), (Table 2). In spite of the differences in water and protein content, the degree of protein hydration (Feder's number) was similar, and found in the range accepted for skeletal muscles, *i.e.* 3.3--3.8. The meat of calves slaughtered in the autumn showed the lowest content of protein and the highest amount of intramuscular fat, whereas meat of calves from the spring season demonstrated the highest level of ash and haem iron.

The energy value of meat is determined by the content of basic chemical constituents, primarily fat. Despite differences in protein and fat content, the meat of calves had a similar energy value in the compared seasons. Lombradi--Boccia *et al.* [2002] reported that beef from young slaughter cattle was a significant source of elements in the diet, in particular of zinc, copper and haem iron, which were characterised by high bio-availability. The research results obtained in the present study showed that veal contained the haem iron at the level of 50% stated in beef from young animals [Florek *et al.,* 2007], and its energy value was similar to chicken or rabbit meat [Salvini *et al.*, 1998].

The pH value is one of the most critical parameters of meat quality evaluation. Lawrie [1985] reported that the internal factors such as a species, race, type of muscle and individual variation influenced the rate and size of pH fall just like the external factors such as temperature of environment and extent of stress. The lowest pH at 45 min and 2 days after slaughter were found in calf meat from the summer, and the highest in that from the spring season (Figure 1). At 3 and 7 days *post mortem* the meat pH was similar in the compared seasons, however, lower meat pH values were observed in the spring, but higher in the autumn season. The initial pH decline is caused by glycogen degradation and accumulation of lactic acid, and proved the appropriate run of the meat acidification process. The later pH rise, arising from the progressing alkalization caused by the release of basic products of protein breakdown throughout the post-slaughter endogenous changes (ageing). This tendency was also observed in our studies at 7 days *post mortem*.

TABLE 2. The chemical composition, Feder number and energy value of *m. longissimus lumborum* in relation to slaughter season of calves (mean±standard error).

Specification	Season		
	Spring N=20	Summer N=20	Autumn N=18
Chemical composition (g/kg)			
Water	741.0^{A}±1.9	762.1^{B}±1.6	757.5^{B}±2.3
Protein (N×6.25)	213.3^{ab}±4.5	225.0^{b}±4.9	208.3^{a}±2.9
Intramuscular fat	7.9^{b}±0.5	5.8^{a}±0.3	14.0^{c}±1.6
Ash	12.8^{B}±0.4	8.7^{A}±0.8	9.9^{A}±0.7
Haem iron (mg/kg)	10.3^{B}±0.7	8.1^{A}±0.4	9.1^{AB}±0.5
Feder number	3.5±0.1	3.4±0.1	3.6±0.1
Energy value (kJ/100g)	387.2±8.6	398.9±8.4	401.8±6.6

Means marked with different letters differ significantly: a,b – $p<0.05$; A,B – $p<0.01$.

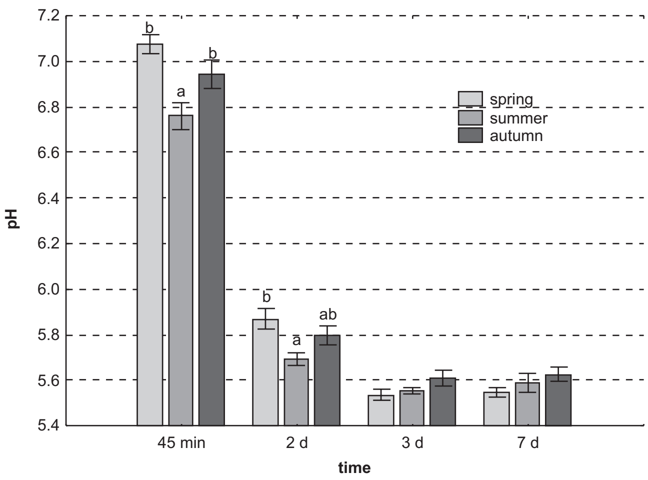

FIGURE 1. pH changes of *m. longissimus lumborum* in relation to slaughter season of calves and *post mortem* time (mean±standard error).
Means with the same letter within the same time do not differ significantly ($p<0.05$).

The electrical conductivity (EC) is a direct measurement of muscle juice drip [Pliquett *et al.*, 1990]. It is the consequence of cellular membranes weakening in the muscle tissue after slaughter and maintenance of water by miofilaments that make the fluids translocate within the intra- and intercellular space [Honikel, 1993]. The meat from autumn season showed the highest value of electrical conductivity at 45 min after slaughter. However, in the following three measurements the meat from this season was characterised by the lowest values of EC (Figure 2). The present studies revealed an electrical conductivity decrease in muscles within the first 2 days after slaughter, and then its successive rise up to 7 days *post mortem*. Similar results were also obtained for young slaughter cattle by Byrne *et al.* [2000], and Florek & Litwińczuk [2001].

The consumers recognize veal meat freshness and tenderness on the grounds of meat colour, hence this trait is a major

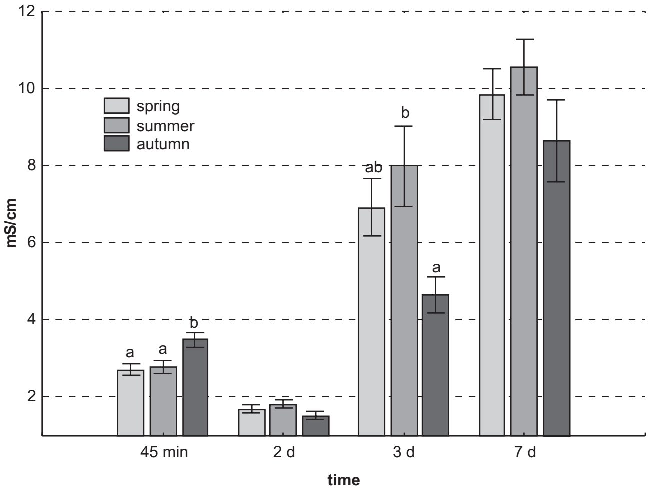

FIGURE 2. Electrical conductivity (mS/cm) changes of *m. longissimus lumborum* in relation to slaughter season of calves and *post mortem* time (mean±standard error).
Means with the same letter within the same time do not differ significantly ($p<0.05$).

criterion for the carcass classification and trade value of this meat. A light colour of veal is caused by a low pigment concentration in the muscle tissue of growing calves administered a diet with a low iron content, similarly to animals fed milk or milk-replacers. Colour being a consumer search attribute for fresh veal meat proves to vary in different countries, *e.g.* in France, Italy and Poland white or pale pink meat colour is preferred, whereas in Belgium, Portugal, Spain, Sweden, Germany and Denmark veal meat of dark colour is commercially acceptable [Tyszkiewicz, 2005a,b].

Studying the parameters of meat colour in relation to the season (Table 3), there was noted the lowest haematin pigment content in MLL from the summer season, along with the highest L* value, and generally the highest proportion of yellowness (b*). The redness (a*) of MLL in principle did not differ between seasons, with the exception of measurement at 7 days *post mortem*. Aporta *et al.* [1996] evaluating changes of CIE L*a*b* parameters of veal meat colour during following days after slaughter, found the L* value for the *longissimus dorsi* muscle oscillating between 37.2 to 39.2, whereas the a* value – from 15.4 up to 17.3. The research results obtained in the present study showed an increase in the values of CIE L*a*b* colour parameters in the following measurements at days 3 and 7 compared to day 2 *post mortem*. Alike, Oliete *et al.* [2006] found that extending the vacuum storage time of *m. longissimus thoracis* (1^{st}, 7^{th} and 14^{th} d) was related to a rise of the a* and b* parameters, showing that meat become more red and yellow. Also Pommier *et al.* [1990] observed greater lightness of *m. longissimus dorsi* (MLD) at 144 h than 48 h after slaughter. In turn, Mandell *et al.* [2001] reported the higher value of lightness of both *m. longissimus dorsi* and *m. semimembranosus* on days 7 and 14 than on day 2 *post mortem*. Guignot *et al.* [1992] confirmed a strong correlation between a pigment content and most of the colour parameters of MLD assessed instrumentally.

TABLE 3. The haem pigments content, colour parameters and TBARS value of *m. longissimus lumborum* in relation to slaughter season of calves and *post mortem* time (mean±standard error).

Specification	Season		
	Spring N=20	Summer N=20	Autumn N=18
Haem pigments (mg/kg)	$116.28^{B}\pm7.02$	$91.64^{A}\pm4.43$	$103.36^{AB}\pm6.18$
2 days *post mortem*			
CIE			
L*	39.35±0.95	42.11±0.96	41.24±1.60
a*	18.96±0.50	18.15±0.49	18.98±0.61
b*	$2.34^{a}\pm0.15$	$3.03^{b}\pm0.23$	$2.92^{ab}\pm0.31$
TBARS (mg MA/kg)	0.36±0.05	0.29±0.03	0.32±0.05
3 days *post mortem*			
CIE			
L*	43.45±0.86	45.90±0.96	44.08±1.59
a*	18.87±0.43	18.93±0.45	17.93±0.78
b*	$3.38^{A}\pm0.15$	$4.15^{B}\pm0.26$	$2.77^{A}\pm0.21$
TBARS (mg MA/kg)	$0.41^{b}\pm0.04$	$0.31^{a}\pm0.03$	$0.34^{a}\pm0.03$
7 days *post mortem*			
CIE			
L*	45.34±0.96	46.80±1.06	45.35±1.29
a*	$21.46^{b}\pm0.54$	$19.49^{a}\pm0.50$	$19.31^{a}\pm0.82$
b*	$6.03^{B}\pm0.19$	$5.51^{B}\pm0.30$	$4.18^{A}\pm0.19$
TBARS (mg MA/kg)	$0.45^{b}\pm0.06$	$0.37^{a}\pm0.03$	$0.40^{ab}\pm0.04$

Means marked with different letters differ significantly: a,b – $p<0.05$; A,B – $p<0.01$.

Veal meat colour depends on the haem pigment content of the muscle and meat pH [Guignot *et al.*, 1992; Klont *et al.*, 1999]; a low haematin and ultimate pH content lead to paler meat. Indeed, a brighter colour of meat from calves slaughtered in the summer season was accompanied with a lower content of haem pigments (about over 10%), (Table 3). The bright-red colour of meat is due to the oxygenated form of myoglobin (oxymyoglobin), whereas the oxidized form (metmyoglobin) is responsible for browning [Insausti *et al.*, 1999]. Lipid oxidation is directly related to the formation of metmyoglobin during meat display [Insausti *et al.*, 2001].

The lowest oxidative stability of intramuscular fat expressed as TBARS value showed meat from calves slaughtered in the spring season in all measurements as compared to the other seasons. Rhee *et al.* [1996] suggested that the difference in haem pigments content, which is associated with catalase activity, could be responsible for the difference in oxidative stability of meat. In turn, Min *et al.* [2008] reported that ferrylmyoglobin and/or haematin, rather than free ionic iron or fatty acid composition, could be primarily responsible for higher TBARS values in raw beef loin during storage.

McKenna *et al.* [2005] noted that redness (a*) was negatively correlated with lipid oxidation measured by TBARS values. Faustman & Cassens [1990] reported a strong relationship between lipid and myoglobin oxidation. Muscle redness has been used extensively as an index of discoloration in displayed beef [O'Sullivan *et al.*, 2002; Yang *et al.*, 2002]. The decrease in redness a* values may result from the gradual formation of metmyoglobin on the meat surface, as they are negatively correlated [Insausti *et al.*, 1999]. In the present study, the meat from the summer season had lower haem pigments content and showed greater oxidative stability, although the TBARS value was always well below the threshold value for rancidity of 1–2 mg/kg of meat [Watts, 1962].

According to Insausti *et al.* [1999], meat with a higher pigment content is more oxidative, and thus its colour is less stable. O'Grady *et al.* [2001] suggested that increased oxidation of oxymyoglobin occurred at lower pH values. The results of this research also showed that meat from the spring season had the highest redness (a*) and TBARS values at 7 days *post mortem*.

Loss value of fresh beef is dependent on age, sex, diet, pre-slaughter stress, slaughter method, time and storage temperature as well as meat characteristics like, pH, content of intramuscular water and fat [Lawrie, 1991]. The lowest drip loss at 3 and 7 days *post mortem* (Table 4) was observed in meat from the autumn season, probably as a result of the highest meat pH (Figure 1) and the lowest value of electrical conductivity (Figure 2).

The certain improvement was observed in water holding capacity measured as M/T ratio at 7 days *post mortem*

TABLE 4. Water holding capacity and tenderness of *m. longissimus lumborum* in relation to slaughter season of calves and *post mortem* time (mean±standard error).

Specification	Season		
	Spring N=20	Summer N=20	Autumn N=18
3 days *post mortem*			
Drip loss (%)	1.13±0.08	1.10±0.15	0.94±0.07
Cooking loss (%)	27.98±0.83	28.47±0.74	30.14±1.10
M/T (%)	43.78ᴮ±0.96	38.08ᴬ±1.25	34.37ᴬ±0.85
Shear force (N)	86.48ᴬᴮ±5.80	69.52ᴬ±6.78	97.83ᴮ±9.64
Work (J)	0.34ᴬᴮ±0.02	0.25ᴬ±0.02	0.36ᴮ±0.03
7 days *post mortem*			
Drip loss (%)	2.45±0.23	2.11±0.16	1.81±0.36
Cooking loss (%)	27.78ᴮ±0.66	23.74ᴬ±1.53	24.74ᴬᴮ±1.21
M/T (%)	49.70ᵇ±2.42	42.82ᵃ±1.43	45.96ᵃᵇ±2.76
Shear force (N)	47.27ᵃᵇ±6.18	39.96ᵃ±4.16	56.63ᵇ±8.17
Work (J)	0.16ᴬ±0.03	0.16ᴬ±0.02	0.31ᴮ±0.06

Means marked with different letters differ significantly: a,b – p<0.05; A,B – p<0.01. M/T – Ratio=meat area/total area × 100.

TABLE 5. The influence of slaughter season and ageing time on *m. longissimus lumborum* quality.

Trait	Influence		
	Slaughter season (S)	Ageing time (A)	Interaction (S×A)
pH	**	**	**
Electrical conductivity(mS/cm)	ns	**	ns
CIE			
L*	*	**	ns
a*	*	**	ns
b*	**	**	**
TBARS (mg MA/kg)	*	**	*
Drip loss (%)	ns	**	ns
Cooking loss (%)	ns	**	*
M/T (%)	**	**	ns
Shear force (N)	**	**	ns
Work (J)	**	**	ns

* – p≤0.05; ** – p≤0.01, M/T – Ratio=meat area/total area × 100.

in comparison with day 3. The greater M/T ratio is an indicator of water holding capacity (WHC), which indicates the ability of meat to retain inherent water, thus representing an essential quality parameter for both the industry and the consumer.

The quantity of cooking loss at 3 days after slaughter was similar in the compared seasons. The higher cooking loss at 7 days *post mortem* showed meat from spring, whereas the lowest one – that from the summer season (Table 4).

The calf meat from the summer season at 3 and 7 days following slaughter had the best tenderness (the lowest shear force and work values), (Table 4). The most tough meat was stated in the autumn season. However, a certain improvement of meat tenderness (decrease of shear force) was determined for all seasons after 7 days of the conditioning period. Destefanis *et al.* [2008] have compared beef tenderness assessed by consumers with Warner-Bratzler shear force measured instrumentally, and determined the threshold to classify tender beef at the level of 42.9 N. Likewise, in an earlier study Shackelford *et al.* [1991] claimed that the W-B threshold value for retail beef was 45.1 N.

The ageing time was observed to influence (p≤0.01) all traits of MLL (Table 5). The slaughter season of the calves also affected meat quality, with the exception of electrical conductivity, drip and cooking loss. The interactions of the assessed factors for meat pH and its colour (yellowness) as well as for TBARS value and cooking loss were confirmed.

CONCLUSIONS

The slaughter season of calves influenced carcass weight, dressing percentage, and meat quality, with the exception of electrical conductivity, drip and cooking loss. However, the ageing time was observed to influence (p≤0.01) all traits of *m. longissimus lumborum*. The interactions of the assessed factors for meat pH and its colour (yellowness) as well as for TBARS value and cooking loss were confirmed. The most favourable physicochemical traits showed meat from the summer season, *i.e.* the highest content of protein, and the lowest of intramuscular fat (p<0.05), the highest oxidative stability (the lowest TBARS value), and tenderness (the lowest shear force and work). The certain improvement of water holding capacity (measured as M/T ratio) and tenderness was observed for meat from all seasons on day 7 *post mortem* in comparison with day 3.

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REFERENCES

1. Aporta J., Hernandez B., Sanudo C., Veal colour assessment with three wavelengths. Meat Sci., 1996, 44, 113–123.
2. Byrne C.E., Troy D.J., Buckley D.J., *Postmortem* changes in muscle electrical properties of bovine M. longissimus dorsi and their relationship to meat quality attributes and pH fall. Meat Sci., 2000, 54, 23–34.
3. Carpenter C.E., Cornforth D.P., Whittier D., Consumer preferences for beef colour and packaging did not affect eating satisfaction. Meat Sci., 2001, 57, 359–363.
4. CIE, Colorimetry. 1976, 2nd ed. Commission International de l'Eclairage. Vienna.
5. Destefanis G., Brugiapaglia A., Barge M.T., Dal Molin E., Relationship between beef consumer tenderness perception and Warner–Bratzler shear force. Meat Sci., 2008, 78, 153–156.
6. Faustman C., Cassens R.G., The biochemical basis for discoloration in fresh meat: A review. J. Muscle Foods, 1990, 1, 217–243.
7. Florek M., Litwińczuk Z., Comparison of physicochemical quality of young bull meat classified into three commercial classes EUROP. Pol. J. Food Nutr. Sci., 2001, 10/51, 3 (S), 205–208.

8. Florek M., Litwińczuk Z., Kędzierska-Matysek M., Grodzicki T., Skałecki P., Meat nutritive value from *musculus longissimus lumborum* and *musculus semitendinosus* of young slaughter cattle. Med. Wet., 2007, 63, 242–246 (in Polish).
9. Grau R., Hamm R., Eine einfache Methode zur Bestimmung der Wasserbindung im Muskel. Naturwissenschaften, 1953, 40, 29 (in German).
10. Guignot F., Quilichini F., Renerre M., Lacourt A., Monin G., Relationship between muscle type and some traits influencing veal colour. J. Sci. Food Agric., 1992, 58, 523–529.
11. Harris P.V., Shorthose W.R., Meat texture. 1988, *in*: Developments in Meat Science (ed. R. Lawrie.). Elsevier UK, London. pp. 245–296.
12. Hofmann K., Hamm R., Blüchel E., Neues uber die Bestimmung der Wasserbindung des Fleisches mit Hilfe der Filterpapierpreßmethode. Fleischwirtschaft, 1982, 62, 87–92 (in German).
13. Honikel K.O., Beziehungen zwischen fruh postmortem merkmalen bei schweinfleisch. Mitteilungsblatt der Bundesanstalt fur Fleischforschung Kulmbach, 1993, 32, 170 (in German).
14. Hornsey H.C., The colour of cooked cured pork I. Estimation of the nitrioxidehaem pigments. J. Sci. Food Agric., 1956, 7, 534–540.
15. Insausti K., Beriain M.J., Purroy A., Alberti P., Lizaso L., Hernandez B., Colour stability of beef from different Spanish native cattle breeds stored under vacuum and modified atmosphere. Meat Sci., 1999, 53, 241–249.
16. Insausti K., Beriain M.J., Purroy A., Alberti P., Gorraiz C., Alzueta M.J., Shelf life of beef from local Spanish cattle breeds stored under modified atmosphere. Meat Sci., 2001, 57, 273–281.
17. Klont R.E., Barnier V.M.H., Smulders F.J.M., Van Dijk A., Hoving-Bolink A.H., Eikelenboom G., *Post-mortem* variation in pH, temperature, and colour profiles of veal carcasses in relation to breed, blood haemoglobin content, and carcass characteristics. Meat Sci., 1999, 53, 195–202.
18. Lawrie R.A., Chemical and biological constitution of muscle. 1985, *in*: Meat Science, 4th ed., (ed. R.A. Lawrie). Oxford, Pergamon Press, pp. 43–73.
19. Lawrie R.A., Meat Science. 1991, 5th ed., Pergamon Press, Oxford. p. 239.
20. Lombradi-Boccia G., Martinez-Dominguez B., Aguzzi A., Total, heme, non-heme iron in raw and cooked meats. J. Food Sci., 2002, 67, 1738–1741.
21. Mandell I.B., Maclaurin T., Buttenhan S., Effects of carcass weight class and *post-mortem* aging on carcass characteristics and sensory attributes in grain fed veal. J. Food Sci., 2001, 66, 762–769.
22. Mckenna D.R., Mies P.D., Baird B.E., Pfeiffer K.D., Ellebracht J.W., Savell J.W., Biochemical and physical factors affecting discoloration characteristics of 19 bovine muscles. Meat Sci., 2005, 70, 665–682.
23. Min B., Nam K.C., Cordray J., Ahn D.U., Endogenous factors affecting oxidative stability of beef loin, pork loin, and chicken breast and thigh meats. J. Food Sci., 2008, 73, C439–C446.
24. Ngapo T.M., Gariépy C., Factors affecting the meat quality of veal. J. Sci. Food Agric., 2006, 86, 1412–1431.
25. O'Grady M.N., Monohan F.J., Mooney M.T., Oxymyoglobin in bovine muscle system as affected by oxidizing lipids, vitamin E and metmyoglobin reductase activity. J. Muscle Foods, 2001, 12, 19–35.
26. Oliete B., Carballo J.A., Varela A., Moreno T., Monserrat L., Sanchez L., Effect of weaning status and storage time under vacuum upon physical characteristics of meat of the Rubia Gallega breed. Meat Sci., 2006, 73, 102–108.
27. O'Sullivan A., O'Sullivan K., Galvin K., Moloney A.P., Troy D.J., Kerry J.P., Grass silage *versus* maize silage effects on retail packaged beef quality. J. Anim. Sci., 2002, 80, 1556–1563.
28. Pliquett F., Pliquett U., Robekamp W., Beurteilung der reifung des M. long. dorsi und M. semitendinosus durch impulsimpedanzenmessungen. Fleischwirtschaft, 1990, 70, 1468–1470 (in German).
29. Polish Standard PN-A-04018:1975. Agricultural food products – Determination of nitrogen by Kjeldahl method and expressing as protein (in Polish).
30. Polish Standard PN-ISO 1442:2000. Meat and meat products – Determination of moisture content (reference method) (in Polish).
31. Polish Standard PN-ISO 1444:2000. Meat and meat products – Determination of free fat content (in Polish).
32. Polish Standard PN-ISO 936:2000. Meat and meat products – Determination of total ash (in Polish).
33. Pommier S.A., Lachance B., Vinet C., Evolution of the reflectance of veal pectoralis major muscle over time postmortem and relationship with the reflectance of other muscles. Can. Inst. Food Sc. Technol. J., 1990, 23, 198–202.
34. Purchas R.W., Yan X., Hartley D.G., The influence of a period of ageing on the relationship between ultimate pH and shear values of beef m. longissimus thoracis. Meat Sci., 1999, 51, 135–141.
35. Rhee K.S., Anderson L.M., Sams A.R., Lipid oxidation potential of beef, chicken, and pork. J. Food Sci., 1996, 61, 8–12.
36. Salvini S., Parpinel M., Gnagnarella P., Maisonneuve P., Turrini A., Banca dati di composizione degli alimenti per studi epidemiologici in Italia. Instituto Europeo di Oncologia, Milano, Italy, 1998, p. 958.
37. Specht S.M., Faustman C., Bendel R.B., Malkus L.A., Kinsman D.M., Sison C., Carcass composition of "bob" and "specialfed" veal and its prediction. J. Anim. Sci., 1994, 72, 2635–2641.
38. Shackleford S.D., Morgan J.B., Cross H.R., Savell J.W., Identification of threshold levels for Warner-Bratzler shear force in beef top loin steaks. J. Muscle Foods, 1991, 2, 289.
39. StatSoft, Inc., STATISTICA, 2003, data analysis software system, version 6, [www.statsoft.com].
40. Świetlik K., Meat consumption and its conditioning in year 2004. Gosp. Mięs., 2005, 7, 16–25 (in Polish).
41. Tyszkiewicz S., The opinions of consumers of European Union on calf meat quality and conditioning of its production. Przem. Spoż., 2005a, 12, 12–19 (in Polish).
42. Tyszkiewicz S., Calf meat in European Union. Production. Consumption. Legislation. Gosp. Mięs., 2005b, 12, 40–44 (in Polish).
43. Watts B.M., Meat products. 1962, *in:* Symposium on Food: Lipid and their Oxidation (eds. A. Day, R.P.R. Simhulber). AVI Publ. Co., Westport, CT. pp. 202–219.
44. Witte V.C., Krause G.F., Bailey M.E., A New extraction method for determining 2-thiobarbituric acid values of pork and beef during storage. J. Food Sci., 1970, 35, 582–585.
45. Yang A., Lanari M.C., Brewster M., Tume R.K., Lipid stability and meat colour of beef from pasture- and grain-fed cattle with or without vitamin E supplement. Meat Sci., 2002, 60, 41–50.

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