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EFFECT OF VACUUM AGEING ON INSTRUMENTAL AND SENSORY TEXTURAL PROPERTIES OF MEAT FROM UHRUSKA LAMBS*

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Abstract

The objective of the present research was to assess the instrumental and sensory textural attributes of lamb meat depending on the cold storage ageing under vacuum. The research material included two skeletal muscles, i.e. *semimembranosus* (SM) and *rectus femoris* (RF) from carcasses of Uhruska lambs. The age of animals ranged from 120 to 135 days. The ageing and muscle influenced significantly shear force and shear energy. However, significantly lower shear force and higher score of tenderness were observed on 7 vs. 2 days of ageing only for SM. The evaluated factors (ageing and muscle) affected slightly and not significantly the parameters of texture profile analysis. The muscle samples after the 7-day ageing showed higher hardness and chewiness. Significant correlation of sensory tenderness with instrumental shear and energy force and springiness was confirmed. The obtained results indicated that vacuum-packed lamb meat during cold storage for 7 days following slaughter develops the sensory attributes, especially tenderness.

Key words: lamb, texture, tenderness, ageing

In Poland over 90% of slaughter sheep are lambs (Klepacki and Rokicki, 2005), i.e. animals of both sexes, aged from 1 to 10 months (Liśkiewicz et al., 2012) with live weight between 13 and 35 kg. Due to their low adiposity of carcass, rams are slaughtered at body weight over 36 kg as well (Liśkiewicz et al., 2013). Generally, rams are not castrated because even the heaviest animals are still young, which virtually eliminates any risk of "male smell" in muscle tissue. In the European Union, lamb meat is considered dietetic and a delicacy (Montossi et al., 2013). However,

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with an increase in animal age and body weight at slaughter, meat quality parameters deteriorate indicating progressive adiposity of carcass and decreasing meat tenderness (Rokicki, 2007).

Mutton and lamb are very valuable food products, however, due to the specific flavor and taste have low consumer acceptance in Poland (Borys and Pisulewski, 2001). The domestic demand for sheep meat has been weak, hence nearly the entire domestic lamb production is exported, mainly to Italy (light lambs) and Germany (heavy lambs) (Liśkiewicz et al., 2012). The average annual consumption of sheep meat per capita in the EU is 4 kg, while in Poland is only 40 grams. Iceland holds the world record for lamb consumption with 20 kg/person/year (Borek-Daruk, 2011). Many “registered” sheep products in the EU are labelled Protected Designation of Origin (PDO). Due to the small global production share (approximately 4%) the sheep meat products remain niche, and in the vast majority, they are produced by traditional methods. Therefore, their successful marketing should rely on product diversity and specificity resulting from different production systems used (Baruk et al., 2014). There are two groups of sheep meat consumers, i.e. from urban and rural areas (Mc Cormik et al., 2000). Both groups have different preferences for sheep meat attributes, especially lamb, specificity of its preparation, taste and tenderness (Borzuta and Strzelecki, 2001). Refrigeration is the most common method for extending the shelf life of meat. Furthermore, an extended storage life is desirable because it facilitates the distribution of meat. For trading chilled (unfrozen) lamb, the meat products are typically vacuum-packed immediately after the deboning process. Additional time linked to delivering to markets allows further development of meat tenderness (Kim et al., 2012).

The results obtained within the development project – Lamb production in year-round cycle and development on domestic market – Lamb from Lublin region (No 12-0113-10), clearly indicate the need for considering consumer expectations on improving quality values of culinary lamb in the national production technology. Consumers should be also provided with the information about proper handling of purchased meat (temperature and storage time) and appropriate culinary treatment tailored to the properties of retail cuts of meat (conditions, temperature and culinary treatment time) (Baruk et al., 2014).

The objective of the present research was to assess the instrumental and sensory textural attributes of lamb meat depending on the cold storage period of lamb ageing under vacuum.

Material and methods

The research material included two skeletal muscles, i.e. *semimembranosus* (SM) and *rectus femoris* (RF) from 20 carcasses of entire Uhruska lambs aged 120–135 days and slaughtered during spring of 2013. The sex ratio was 1:1, and slaughter body weight of rams averaged 34.45±3.87 kg, while ewes 32.75±3.23 kg.

The stunning and slaughter processing of the lambs were conducted in compliance with the technology obligatory in the meat industry and under the supervision of veterinary inspection. After carcass chilling (24 h at 2ºC, and relative moisture 85%), the lamb legs were dissected into muscle samples (of similar weight), then vacuum packed in PA/PE foil bags and labelled with slaughter number and sex. The bags were cold stored at 4ºC prior to analysis on 2 and 7 d postmortem.

Cooking loss (CL) after 2 and 7 d postmortem was expressed as a percentage of the sample weight (about 120 g) before (initial) and after heat treatment (cooked). The samples after the cooking in the water bath at 70ºC for 60 min were cooled for 30 min in running tap water and stored at 4°C until analysed. After cooking, the meat samples underwent sensory evaluation and texture analyses.

Sensory assessment was carried out according to PN-ISO4121:1998 by a panel of 8 people selected from the staff and students from the University of Life Sciences in Lublin, subject to passing the general sensory aptitude test. Sensory evaluation included 3 characteristics of cooked meat samples (tenderness, juiciness and palatability) and was based on a 5-point hedonic scale (1 – unacceptable, 2 – poor, 3 – satisfactory, 4 – good, 5 – very good). For tenderness, a severity coefficient of 0.5 was accepted, for juiciness – 0.3 and palatability – 0.2 (sum of severity coefficients=1). The results of individual evaluations were multiplied by appropriate coefficients and the total values were calculated.

The texture studies of cooked meat samples were performed with a Zwick/Roell Proline BDO-FB0.5TS (Zwick GmbH & Co, Ulm, Germany) machine using devices for shearing test (W-B SF) and texture profile analysis (TPA) as well as the TestXpert®II software. The crosshead was fitted with a 500 N load cell. For the shear force test, the Zwick/Roell machine was fitted with a single V-blade cell. From each meat sample, a minimum of six stripes (10×10×50 mm) of 1 cm^2 area were cut perpendicularly to the fibre direction, at a crosshead speed of 100 mm min^{-1}. As for the TPA, the Zwick/Roell Proline machine was fitted with a 70 mm diameter compression plate. The cubic samples of meat (20×20×20 mm) were compressed to 50% of their original height at a speed of 100 mm×min^{-1} during each bite. A double-bite compression cycle was carried out with a rest period of 3 s between bites. Hardness (N), springiness (mm) and chewiness (N×mm) were measured. For each meat sample the test was repeated in triplicate.

Statistical analysis was conducted using SAS Enterprise Guide 6.1 software (SAS, 2013). Due to the nonsignificant sex impact on the evaluated parameters, this factor has been omitted in the statistical analysis. The general linear model (GLM) procedure was used. For drip loss, instrumental measurements and sensory traits the model included 2 muscles (SM and RF), time of ageing (2 d and 7 d) and their interactions (SM 2d, SM 7d, RF 2d, RF 7d) as fixed effects. Least squares means for all traits of interest were separated by Tukey's test ($P<0.05$ and $P<0.01$). Pearson's correlation coefficients between instrumental and sensory textural properties were calculated.

Results

Table 1 summarizes the cooking loss from the evaluated muscles on 2 and 7 d of ageing under vacuum. Only significant impact of a muscle on the cooking loss was presented. The lower cooking loss was established in the RF muscle compared with the SM and significant difference (P<0.05) was observed 2 days postmortem.

Table 1. Least squares means for cooking loss, shear force test and TPA analysis of *semimembranosus* (SM) and *rectus femoris* (RF) muscles according to ageing time

Parameters	Ageing				sed	P-value		
	2 d		7 d					
	Muscle					A	M	A × M
	SM	RF	SM	RF				
Cooking loss %	23.79 b	18.36 a	23.42 b	20.28 ab	1.59	0.635	0.014	0.420
W-B SF								
Shear force N	75.93 B	39.35 A	31.05 A	29.83 A	3.33	0.000	0.000	0.000
Shear energy J	0.28 B	0.12 A	0.17 AB	0.10 A	0.02	0.001	0.000	0.024
TPA								
Hardness	44.18 ab	42.10 a	63.02 b	55.40 ab	3.99	0.039	0.513	0.708
Springiness	0.58	0.54	0.55	0.55	0.02	0.755	0.437	0.484
Chewiness	9.55	9.04	11.56	12.52	1.37	0.082	0.933	0.621

Distinct letters in the row indicate significant differences according to Tukey's test: a, b – P<0.05.

Probability of significant effects ageing (A), muscle (M), and their interaction (A × M).

sed – standard error of the difference.

The statistical analysis confirmed significant (P<0.01) impact of muscle and ageing time on the assessed parameters of the shear force test. Besides, the interaction between these factors was noted (Table 1). Lower values of shear force and energy on 2 and 7 d postmortem were determined in the RF muscle. There was found a positive effect of ageing time under vacuum on both muscles manifested by the reduction of shear force (P<0.01) and shear energy, however, the difference was confirmed statistically only for shear force in the SM muscle. In the case of this muscle, shear force on 7 d postmortem reached 40.9% of the initial force (determined 2 d postmortem), whereas for the RF – 75.8%. Besides, a similar relationship was observed in the case of shear energy, here the decrease was 60.7% in the SM muscle and 83.3% in the RF muscle.

Table 1 presents the results of the texture profile analysis (TPA) for the evaluated muscles depending on ageing time. No significant effect of both muscle and ageing time on the assessed parameters was observed. There was only confirmed the significant (P<0.05) impact of ageing (2 vs. 7 d) on hardness increasing. Despite evident differences in the mean values, the lack of significant effect of ageing on meat chewiness is likely to result from high variability of these parameters as demonstrated by standard deviation.

The results of sensory evaluation of muscle samples at different ageing time are presented in Table 2. Significant effect of ageing on tenderness (P<0.05), palatability (P<0.01) and overall value (P<0.05) was confirmed, as well as the impact of muscle (P<0.01) on tenderness and overall value. As regards these traits, an interaction was also noted.

Table 2. Least square means for sensory traits of *semimembranosus* (SM) and *rectus femoris* (RF) muscles according to ageing time

Parameters	Ageing				sed	P-value		
	2		7					
	Muscle					A	M	A × M
	SM	RF	SM	RF				
Tenderness	3.28 A	4.50 B	4.14 B	4.44 B	0.16	0.020	0.000	0.009
Juiciness	3.72	4.14	4.04	4.17	0.16	0.294	0.109	0.391
Palatability	3.82 a	3.97 ab	4.18 b	4.30 b	0.12	0.009	0.283	0.892
Overall value	3.52 a	4.29 b	4.12 b	4.33 b	0.13	0.024	0.001	0.049

Distinct letters in the row indicate significant differences according to Tukey's test: a, b – P<0.05; A, B – P<0.01.

Probability of significant effects ageing (A), muscle (M), and their interaction (A × M).

sed – standard error of the difference.

Table 3. Significant correlations between instrumental measurements and sensory scores

Parameters	Shear force (N)	Shear energy (J)	Springiness (mm)	Springiness (mm)
	SM			RF
Tenderness (pts)	–0.79**	–0.83**	–0.56*	–0.58*
Overall score (pts)	–0.71**	–0.77**		

* – P<0.05; ** – P<0.01.

Generally, beneficial effect of ageing was determined solely for the SM muscle, i.e. on tenderness, palatability and overall value. Significantly higher mean ratings for these traits on day 7 compared to day 2 postmortem have confirmed the finding. It should be highlighted that the RF muscle obtained higher scores for tenderness and overall value as compared to the SM.

To establish a potential correlation between the sensory ratings for tenderness, juiciness, palatability and overall value and the instrumental textural properties obtained in the shear force test together with the texture profile analysis for each muscle, the Pearson`s simple correlations were calculated. The paper discusses only the most important and significant correlations (Table 3). Statistical analysis for the RF muscle showed the only significant (P<0.05) and negative correlation between sensory tenderness and springiness measured instrumentally. A slightly lower correlation (P<0.05) of these parameters was also confirmed for the SM muscle and importantly, there was also determined a significant (P<0.01) and negative correlation between tenderness and overall score with instrumental shear force and shear energy. The complementarity of these two procedures for texture assessment was confirmed by the obtained correlation. The muscles which were characterized by lower shear force and shear energy had higher tenderness scores.

Discussion

Decreased water absorption causes increased meat losses during storage or heat treatment. Abdullah and Qudsieh (2009) found no effect of ageing (7 days) on cooking loss in three muscles (*semitendinosus*, *semimembranosus* and *biceps femoris*) from Awassi lamb. Yanar and Yetim (2001) revealed the reduction of cooking loss by the *semimembranosus* muscle from 29.9% on day 1 of ageing to 26.8% after 7 days. Moreover, according to Pospiech et al. (2003) tenderness is related positively with hydration and water binding capacity of muscle proteins. In the present study, such relationships were not established (Tables 1 and 3).

The most common objective measurements for meat textural parameters have been performed by measuring devices improved upon Warner-Bratzler shear machine (Wheeler et al., 1997), and the results are compared to the sensory or consumer evaluation (Boleman et al., 1997; Destefanis et al., 2008; Shackelford et al., 1995). It is assumed that hardness measurements made by the Warner-Bratzler shear test characterize both muscle components, i.e. myofibrillar and connective tissue, whereas the compression test mainly reflects the properties of connective tissue (Lepetit and Culioli, 1994). Tschirhart-Hoelscher et al. (2006) characterized the quality features of 18 muscles of slaughter lambs whose hot carcass weight ranged from 30.5 to 32.7 kg. After 7 days of vacuum ageing, the authors estimated W-B shear force value for *rectus femoris* (26.9 N) which was close to this obtained in the present study, while higher for the *semimembranosus* muscle (42.6 N). Taking into consideration different systems of beef tenderness classification (Belew et al., 2003; Destefanis et al., 2008; Shackelford et al., 1991) both evaluated muscles after 7 days of vacuum ageing should be considered tender or very tender.

The longer ageing time positively influences the tenderness of lamb (Devine and Graafhuis, 1995; Jaime et al., 1992). According to Boleman et al. (2004) ageing time required to maximize tenderness of lamb appears to be muscle dependent. The W-B shear force values for the *m. longissimus lumborum* and *m. semimembranosus* declined incrementally with increasing ageing time whereas the *m. semitendinosus* showed no decrease in shear force until after 10 days of ageing. Abdullah and Qudsieh (2009) analysed meat quality of Awassi rams aged 90–175 days and showed significant (P<0.01) impact of ageing period (24 h vs. 7 days) that reduced shear force of the *semimembranosus* muscle by approximately 15% (from 40.8 N to 35.0 N), and the *biceps femoris* muscle by approximately 19% (from 29.7 N to 24.2 N). Miranda-de la Lama et al. (2009) studied impact of ageing period (0, 7 and 28 days) on quality of *longissimus dorsi* in Aragonesa rams slaughtered at the age of 100 days. Interestingly, the lowest shear force and hardness were observed 7 days postmortem, in comparison to day 0 (–13% and –15%, respectively) and 28 (–20% for both parameters). Roldán et al. (2013) revealed that after the heat treatment at 70°C for 6 hours the springiness of *longissimus dorsi* of lambs was higher (0.65 cm), yet hardness, chewiness and shear force twice as low compared to the present research results (16.83, 8.07, 5.21 and 35.01 N, respectively). In the present study a trend (P>0.05) towards higher muscle chewiness (after the heat treatment) following vacuum ageing was also observed.

Tenderness, juiciness, flavour, odour and overall liking are all important quality determinants of sensory contentment of meat. This satisfaction is a key driver strongly influencing the demand of lamb, and the consumer decisions of purchase and willingness to pay more for a product (Pethick et al., 2006). Cloete et al. (2012) comparing meat of different breeds of lambs, did not show significant impact of gender on the sensory parameters (tenderness, juiciness, palatability). However, significantly higher shear force of meat was determined for ram in comparison to ewe.

Increasing shear force has been associated with lower tenderness, flavour, juiciness and overall liking scores (Hopkins et al., 2006). Similarly, Ekiz et al. (2009) revealed that meat samples of different lamb breeds having a lower Warner Bratzler shear force value were more tender (P<0.01). Similarly, Pannier et al. (2013) observed that shear force at 5 days of ageing for both loin and topside samples of Australian lamb had a negative relationship (P<0.01) with the sensory scores. It is well known and agreed that if shear force increases, meat tenderness decreases, and hence the sensory quality scores decrease, which was also observed in the present study. Moreover, several other studies in lamb have reported lower sensory scores when shear force increased (Hopkins et al., 2006) and this association occurred not only with tenderness scores, but also with overall liking, juiciness and flavour. Mechanistically it is difficult to explain why shear force would be associated with juiciness and flavour (Hopkins et al., 2013).

Conclusions

This study showed a positive effect of ageing time (7 days) of vacuum packed and cooled *semimembranosus* muscle from Uhruska lamb on shear force and shear energy. Such changes (insignificant) were observed also for *rectus femoris* muscle. However, the evaluated factors (ageing and muscle) affected slightly and nonsignificantly the instrumental parameters of profile texture analysis. In addition, the significant correlations of sensory tenderness with instrumental shear and energy force and springiness were confirmed. Summing up, the obtained results indicated that vacuum-packed lamb meat and cold storage for 7 days following slaughter develops the sensory attributes, especially tenderness, highly appreciated by consumers.

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