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Quality of lamb *musculus Semimembranosus* meat in relation to cold storage duration

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Abstract

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The aim of the present study was to analyse the chemical composition and technological properties of lamb meat musculus Semimembranosus (SM) by the 24[th] h post-slaughter and after 7 days of cold storage at 0–4°C. The meat was obtained from Bulgarian Synthetic Dairy Population lambs (I group, control), and F1 crosses of BDSP with Ile-de-France (II group) and Mouton Charollais (III group) breeds. The slaughter live weight of animals was 22–23 kg. The tenderness of SM from crosses with Ile-de-France was statistically significantly higher compared to that of control group ($P \leq 0.01$), after 24-hour storage at 0–4°C. The fat content of SM from group III was by 12.39% lower than that of control lambs ($P \leq 0.05$). The pH values of SM were lower 24 h after slaughter compared to those after 7 days of cold storage in the three groups of animals ($P \leq 0.05$). The water holding capacity by the 24th post-slaughter hour in crosses with Ile-de-France and Mouton Charollais was better than that on the 7[th] day of cold storage ($P \leq 0.05$). Also, the water absorption capacity in distilled water and saline after 24 h of cold storage exceeded the values measured on the 7th day of storage in the three studied groups ($P \leq 0.05$). Cooking loss percentages on the 24[th] hour post-slaughter were higher in control lambs ($P \leq 0.01$) and in group III ($P \leq 0.05$), compared to values after 7 days of cold storage. Seven days after slaughter, the SM tenderness was better than that on the 24[th] hour in control lambs ($P \leq 0.01$) and crosses with Mouton Charollais ($P \leq 0.05$).

Keywords: chilled lamb meat quality; m. *Semimembranosus;* meat breeds

Introduction

At both national and global scale, crossbreeding with rams from meat-type sheep breeds is used for improvement of the quality and increase in yields of industrially produced lamb for consumption (Ružić-Muslić et al., 2012; Jandasek et al., 2014). In Bulgaria, the Ile-de-France (IF) and Mouton Charollais (MC) are the most commonly spread specialised meat-type sheep breeds. They are selected for slaughter carcass and meat quality. Meat-type breeds are outlined with very good carcass muscling and excellent meat quality traits.

In Bulgaria, the quality grading of sheep slaughter carcasses is done according to the stipulation of Ordinance 20 of 14 May 2004. The Ordinance states that sheep carcasses are graded according to carcass conformation and fatness. Carcass conformation, on its part, is associated to the shape and profile of muscles together with intermuscular and subcutaneous fat, versus the skeleton size. Carcass conformation is evaluated by determination of the degree of development of carcass profiles and in particular, the thigh, the back and the shoulder. *Musculus Semimembranosus* (SM) is one of three muscles located caudally to the hip bone and on the caudal femoral surface. The muscle is strong and considerably developed, so it is presumed to have an influence on lamb thigh meat yield.

An increasing number of people leading a busy and dynamic life, tend to buy meat for consumption in larger amounts – for the whole week, which is then stored under refrigerated conditions. The refrigerated storage of meat, however, has advantages and disadvantages. Buying a larger amount of meat for the week will save time for shopping, but on the other hand, changes in its quality are observed during storage. The more important technological properties of meat, determining its quality, are the pH, color, water-holding capacity (WHC) and tenderness.

The pH values are indicative for the freshness of meat. They vary both among the animal species and among the different muscles. For instance, the pH of SM meat ranges from 5.20 to about 5.40 (Uğurlu et al., 2017), and according to other researchers even attains 5.55 (de Moris et al., 2023). The increase of meat pH above 6.00–6.20 indicates spoilage, therefore the meat is not fit for consumption.

Meat water holding capacity is the ability of muscle proteins to hold inherent water under the influence of external forces – pressing, cutting, mincing etc. (Abdullah et al., 2013; Bhattacharya et al., 2016). Fresh meat quality largely depends on WHC value, which is technologically and economically important not only for food processing industry but also for consumers purchasing the product (Cheng & Sun, 2008, Prevolnik et al., 2010). It is reported that as storage duration increases, meat WHC decreases due to loss of inherent water (Kristensen & Purslow, 2001, Farouk et al., 2012). High water loss has an impact on meat quality, mostly on its juiciness and tenderness. Also, valuable proteins, vitamins and minerals are lost with water.

Meat tenderness is perhaps one of the most important meat quality traits (Muhtar et al., 2018; Alvarez et al., 2019). It is proved that this parameter is improved (meat becomes more tender) proportionally to meat storage duration (Silva et al.,1999).

The literature overview showed that studies on slaughter carcass and SM quality in crosses of Merino ewes with Ile-de-France rams have been carried out (Ribarski et al., 2005; Slavov et al., 2005a; Slavov et al., 2005b). In Bulgaria, there are neither studies on SM quality in crosses of dairy sheep breeds with Ile-de-France or Mouton Charollais rams, nor investigations on changes in SM meat technological properties in relation to refrigerated storage duration. The lack of such studies has motivated the present experiments.

The aim of the present study was to analyse the chemical composition of m. *Semimembranosus* (SM) from Bulgarian Synthetic Dairy Population lambs and crosses with Ile-de-France and Mouton Charollais breeds by post-slaughter hour 24 at 0–4°C and technological properties of the muscle after 24 hours and 7 days of cold storage.

Materials and Methods

The experiments were performed in the sheep farm of the Agricultural Institute, Stara Zagora, Bulgaria. A total of 27 lambs were studied, distributed into 3 groups – 9 BDSP lambs (first group, control), 9 F1 "BDSP×IF" crosses (second group, experimental) and 9 F1 BDSP×MC crosses (third group, experimental), according to the principle of initial body weight, sex and type of lambing. All lambs were reared in group boxes supplied with feeders and drinkers. They were fed ad libitum (+ 5 to 10% residue) a ratio compliant with their age and met all requirements from nutrients and biologically active substances. The ration included concentrate and alfalfa hay. All animals had free access to tap water.

For slaughter analysis, three male twin lambs from each group were slaughtered in a licensed slaughterhouse in the Stara Zagora region at 22–23 kg body weight. The animals were transported to the slaughterhouse early in the morning with the licensed vehicle. From slaughter carcasses, samples from SM. Meat samples were transported from the slaughterhouse to the laboratory of the Meat and Meat Products Unit (Faculty of Agriculture, Trakia University, Stara Zagora, Bulgaria) for analysis on post-slaughter hour 24 and post-slaughter day 7, stored at 0–4°C. The samples were analysed for determination of their chemical composition and technological properties.

Meat pH was measured on Testo 205 pH meter. The WHC of meat was evaluated by the classical pressing method of Grau & Hamm (1953). The water absorption capacity of meat (WAC) was determined by the method proposed by Kyosev & Danchev (1979). Cooking loss was determined by roasting a meat sample at 150°C for 20 min in a convection oven. Cooking loss percentage was calculated as the difference in sample weight prior to and after roasting. Meat tenderness was determined with DSD VEB Feinmess penetrometer (Dresden, Germany) and reported in penetrant egrees – °P. The water content of meat was determined by drying in a dryer at 105° C as per BSS 15437:1982. The protein content of meat was determined as per BSS 9374:1982. Fat content was determined by Soxhlet extraction as per BSS 8549:1992. Mineral content was determined by the method described in ISO 936:1998 based on ashing a meat sample in a muffle furnace.

The results were statistically processed with descriptive statistics and paired samples t-test.

Results and Discussion

The results from analysis of chemical composition of lamb SM meat by the 24th hour post-slaughter are presented in Table 1. The highest average moisture content of 76.69% was found in BDSP lambs whereas crosses with IF and MC demonstrated lower but similar percentages – 75.76% and 75.54% respectively. Abdullah & Qudsieh (2009) also reported comparable values for SM meat moisture, yet in Awassi lambs with slaughter weight of 20 kg.

The protein content of SM was the highest in group III – 20.26%, followed by group II група with 20.01%, and control group – 18.73%. Slavov et al. (2005b) reported lower protein SM content (19.64%) in ¼ blood crosses with the IF breed (Northeastern Merino x IF). Chemical composition parameters did not show any between-group statistically significant differences except for fat SM content that differed considerably between control and BDSP x MC lambs, being by 12.39% higher in the former compared to the latter group ($P \leq 0.05$).

Table 2 presents the data about technological properties of SM in lambs from the three groups 24 h post-slaughter. The lowers pH_{24} average value of the studied muscle was in control lambs – 5.14, whereas in both groups II and III, it was 5.25. The differences among the groups were not consistent. In Herik lamb meat, Uğurlu et al. (2017) reported average pH_{24} of SM of 5.24. Morais et al. (2023) found higher pH_{24} values (over 5.54) in 3/4 cross ((Border Leicester/Merino ewes) × Dorset ram) and Santa Inês lambs.

As meat WHC was concerned, the moisture losses of SM meat in lambs from groups I and II were higher (20.40% and 20.87%) than those measured in group III (14.19%), but the differences were insignificant. Table 2 showed that WAC in distilled water was comparable in the three groups, also without consistent differences: 12.23%, 12.41% and 12.34% for groups I, II and III, respectively. The WAC in saline was varied within a narrow range without statistically significant differences.

The highest SM tenderness, corresponding to most tender meat, was observed in BDSP x IF crosses – 377.00°P, followed by BDSP x MC crosses – 334.80°P and finally, BDSP control lambs – 329.40°P. The SM meat of crosses with IF was statistically significantly more tender than that of BDSP by 14.45% ($P \leq 0.01$). The observed tendency towards more tender meat in crosses of BDSP with meat-type breeds was reported in previous studies of ours (Ivanov et al., 2017; Ivanov, 2019). This allowed assuming that the crossbreeding with Ile-de-France rams improved meat tenderness in BDSP crosses.

The data related to SM technological properties after 7-day cold storage at 4°C are listed in Table 3. The refrigerated storage for 7 days resulted in lowest meat pH in BDSP lambs – 5.27, whereas in crosses with IF and MC breeds

Table 1. Chemical composition of m. SM meat samples by the 24th hour post-slaughter in light slaughter carcasses

Parameters	Animal groups						Significance
	I group – a		II group – b		III group – c		
	n	$\bar{X}\pm SD$	n	$\bar{X}\pm SD$	n	$\bar{X}\pm SD$	
Moisture, %	3	76.69±0.40	3	75.76±0.01	3	75.54±0.12	NS
Dry matter, %	3	23.31±0.40	3	24.24±0.10	3	24.46±0.12	NS
Protein, %	3	18.73±0.42	3	20.01±0.26	3	20.26±0.24	NS
Fat, %	3	3.31±0.07	3	2.97±0.12	3	2.90±0.10	a:c*
Minerals, %	3	1.28±0.05	3	1.26±0.05	3	1.30±0.05	NS

n – number of animals, * – $p \leq 0.05$, NS – Not Significant

Table 2. Technological properties of m. SM meat samples from light slaughter carcasses by the 24th hour post-slaughter

Parameters	Animal groups						Significance
	I group BDSP – a		II group BDSP x IF – b		III group BDSP x MC – c		
	n*	$\bar{X}\pm SD$	n*	$\bar{X}\pm SD$	n*	$\bar{X}\pm SD$	
pH	3	5.14±0.03	3	5.25±0.06	3	5.25±0.01	NS
WHC, %	3	20.40±5.19	3	20.87±3.13	3	14.19±2.12	NS
WAC – distilled water, %	3	12.23±2.17	3	12.41±2.06	3	12.34±2.35	NS
WAC – saline, %	3	15.86±2.24	3	14.00±0.29	3	19.86±3.41	NS
Tenderness, °P	6	329.40±10.86	6	377.00±22.86	6	334.80±29.35	a:b **
Cooking loss, %	3	31.46±2.50	3	36.23±1.22	3	32.05±0.50	NS

n* – number of animals, ** – $p \leq 0.01$, * – $p \leq 0.05$, NS – Not Significant

Table 3. Technological properties of m. SM meat samples from light slaughter carcasses after 7 days of cold storage at 0–4°C

Parameters	Animal groups						Significance
	I group BDSP – a		II group BDSP x IF – b		III group BDSP x MC – c		
	n*	X̄±SD	n*	X̄±SD	n*	X̄±SD	
pH	3	5.27±0.06	3	5.42±0.03	3	5.33±0.02	a:b *
WHC, %	3	26.70±1,71	3	30.86±3,78	3	30.00±4,18	NS
WAC – distilled water, %	3	4.60±1.01	3	5.09±0.23	3	3.70±0.57	NS
WAC – saline, %	3	5.87±0.26	3	7.01±0.71	3	5.87±0.62	NS
Tenderness, °P	6	390.40± 13.81	6	396.20± 6.10	6	397.00± 4.80	NS
Cooking loss, %	3	37.15±1.58	3	38.80±4.10	3	37.00±1.97	NS

n* – number of animals, NS – Not Significant

the average values were 5.42 and 5.33, respectively. The between-group differences were not significant.

The WHC of SM in animals from the three groups varied within a narrow range with slight differences. The average WHC value was 26.70% in controls, in crosses with IF – 30.86% and in crosses with MC – 30.00%. Differences related to WAC in distilled water were insignificant – 4.60%, 5.09% and 3.70% for groups I, II and III, respectively. A similar tendency was found out for WAC in saline. The SM meat tenderness in BDSP × IF an BDSP × MC crosses (396.20°P and 397.00°P) exceeded insignificantly the average SM tenderness in control lambs – 390.40°P. Cooking loss percentages varied within a close range without statistically significant differences among the groups – 37.15%, 38.80% and 37.00% for groups I, II and III, respectively. Data from Table 3 demonstrated that the differences in average values in the three groups were only slight, indicating a normal and simultaneous course of meat ageing.

Figure 1 presents the results from pH measurements of SM after 24-hour and 7-day refrigerated storage. In slaughter carcasses of control lambs, the value of pH_{24} was 5.14 after 24-hour storage and 5.27 after 7-day storage at 0–4°C. A similar tendency towards increase in meat pH during cold storage was observed in the other two groups as well. In crosses with IF, average SM pH_{24} was 5.25 after 24 hours which increased to 5.42 by the 7th day. In the meat with crosses with MC, pH_{24} was 5.25 and after 7 days of refrigerated storage – 5.33. The difference in % between the two storage durations in group I, II and III was by 2.46%, 3.14% and 1.50%, respectively. The increase in pH with storage duration is due to the release of primary degradation products from meat myofibrillar proteins during its ageing. The differences were statistically significant ($P \leq 0.05$) and in line with already reported results. Callejas-Cárdenas et al. (2014) found out that pH of m. *Biceps femoris* and m. *Quadriceps femoris* in lambs increased from the 7th until the 14th day of storage compared to initial values. Ercolini et al. (2006) also affirmed that pH of beef m. *Longissimus dorsi* increased from slaughter to the 7th day of storage. Similarly, Pezeshki et al. (2016) reported that pH of lamb thigh were also lower in the beginning of storage, and showed a continuous increase up to the 14th storage day.

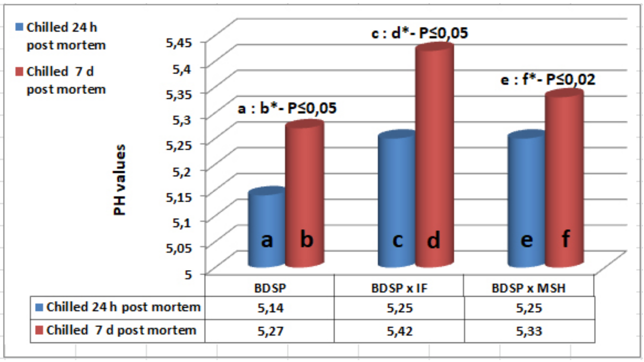

Fig 1. pH of SM meat stored for 24 h and 7 days at 0-4°C in lambs from the three groups
$* – P \leq 0.05$

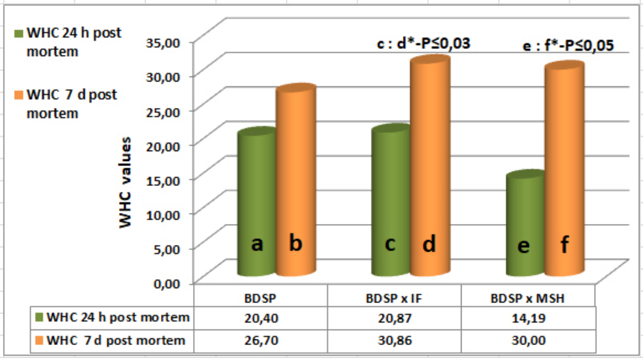

Fig 2. WHC of SM meat stored for 24 h and 7 days at 0–4°C in lambs from the three groups
$* – P \leq 0.05$

Figure 2 depicts data about WHC of SM meat in the three groups of lambs on the 24th h and 7th day of refrigerated storage. For control lambs, the average WHC of SM was 20.40% by the 24th hour and increased to 26.70 on the 7th day of storage. The results obtained in the other two groups were comparable to those of controls. In BDSP x IF crosses, WHC was 20.87% 24 h after slaughter and 30.86% after 7 days of cold storage. In BDSP × MC crosses, respective average values were 14.19% and 30.00% after 24-hour and 7-day storage. It was demonstrated that after refrigerated storage for 7 days, WHC increased in all three groups. As WHC percentage indicates the amount of water released by meat, by the 24th post-slaughter hour meat holding capacity was stronger, hence water losses – lower. After 7 days of storage, this capacity decreases considerably which results in higher water losses. The differences were statistically significant ($P \leq 0.05$). It was reported that WHC of pork and beef became worse parallelly to storage duration time (Kristensen & Purslow, 2001; Farouk et al., 2012).

Water absorption capacity of lamb SM meat (WAC) in distilled water are shown on Figure 3. Data showed that after 24-hour cold storage, WAC in BDSP lambs was higher than that after 7-day cold storage (12.23% and 4.60%, respectively). For BDSP × IF crosses, WAC values were 12.41% (by the 24th hour) and 5.09% (by the 7th day). The WAC in distilled water of SM meat in BDSP x MC crosses decreased from 12.34% by the 24th post-slaughter hour to 3.70% by the 7th day of cold storage. Here again, WAC in distilled water demonstrated higher percentages by the 24th hour compared to the 7th day of storage. The results suggested that 24 h after slaughter, the capacity of meat to absorb additionally added water was stronger, whereas this capacity significantly decreased by the 7th day of storage at 0–4°C ($P \leq 0.05$).

The WAC of lamb SM in saline in the three groups are presented on Figure 4. The results were comparable to those

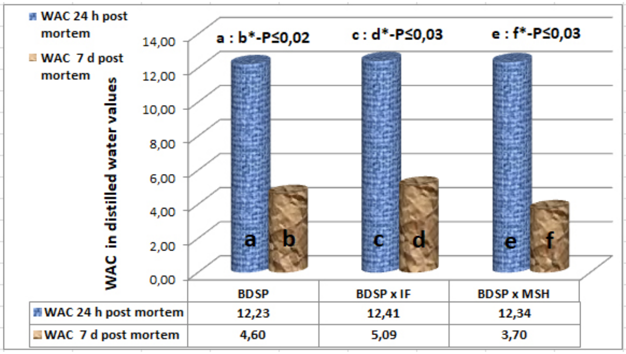

Fig. 3. WAC (distilled water) of SM meat stored for 24 h and 7 days at 0–4°C in lambs from the three groups
$* – P \leq 0.05$

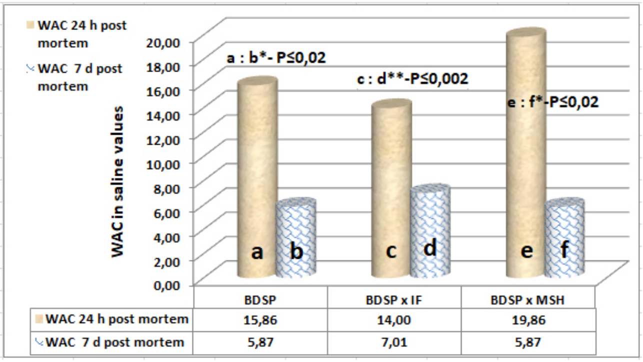

Fig. 4. WAC (saline) of SM meat stored for 24 h and 7 days at 0–4°C in lambs from the three groups
$* – P \leq 0.05$, $** – P \leq 0.01$

obtained in distilled water – a stronger capacity to absorb the added saline solution during the first 24 h of storage compared to that after a more prolonged storage. The differences, again, were statistically significant ($P \leq 0.05$).

The average cooking loss percentages (Figure 5) of SM samples stored for 24 hours in refrigerated conditions were 31.46%, 36.23% and 32.05% for groups I, II and III, respectively. After 7-day storage, the average values were higher in the three groups (37.15%, 38.80% and 37.00%). The differences in cooking loss percentages between the 24th hour and the 7th day were significant in control lambs ($P \leq 0.01$) and BDSP x MC crosses ($P \leq 0.05$).

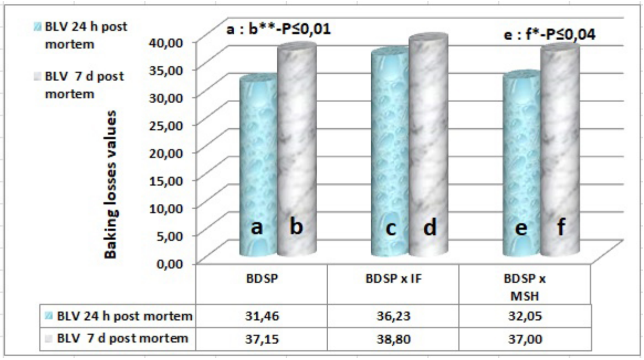

Fig. 5. Baking loss value of SM meat stored for 24 h and 7 days at 0–4°C in lambs from the three groups
$* – P \leq 0.05$, $** – P \leq 0.01$

As storage duration increased, these increased losses could be attributed to reduced WHC of meat on one hand, and on the other, to muscle proteins denaturation during the thermal meat processing beginning at 40–45°C (Tornberg, 2005). At this temperature, both myofibrillar and sarcoplas-

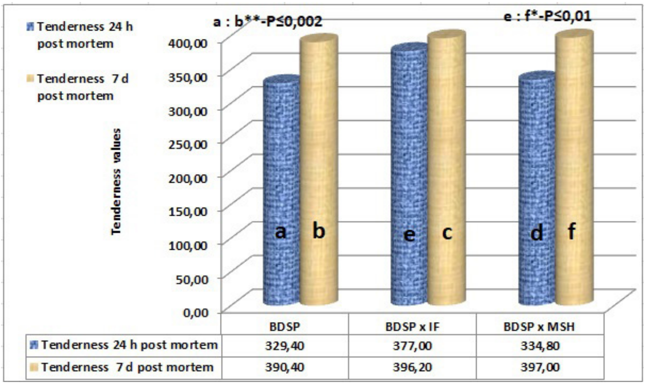

Fig. 6. Tenderness of SM meat stored for 24 h and 7 days at 0-4 °C in lambs from the three groups;
* – P≤0.05, ** – P≤0.01

mic proteins coagulate, leading to shrinkage of myofilaments and released of the inherent water.

Meat tenderness by the 24th post-slaughter hour was on the average 329.40°P, 377.00°P and 334.80°P in groups I, II and III (Figure 6), and values increased after 7 days of cold storage to 390.40°P, 396.20°P and 397.00°P. The differences were statistically significant in BDSP lambs ($P \leq 0.01$) and BDSP x MC crosses ($P \leq 0.05$). The results suggested that as the storage duration of SM meat increases, its tenderness increased too (the meat became softer and more tender). After prolonger storage, this process was due to tissue degradation of complex compounds (carbohydrates, lipids and proteins) during autolysis (Dave & Ghaly, 2011). The established changes in meat tenderness are confirmed by previous reports; according to Silva et al. (1999), beef stored for days had lower shear force values associated with tenderness in comparison to values from initial days.

Conclusions

The results from the experiments showed that the average fat content of SM from BDSP × Mouton Charollais crosses was statistically significantly lower by 12.39% than that of control lambs. The tenderness of SM from BDSP crosses with Ile-de-France was statistically significantly higher compared to that of control group ($P \leq 0.01$) by the 24th post slaughter hour.

There were no statistically significant between-group differences in technological properties of SM meat after 7 days of cold storage. There were only substantial differences between the two terms of storage (24th hour and 7th day) with no crossbreeding effect. The pH_{24} values of SM were lower compared to those after 7 days of cold storage in the three groups of animals ($P \leq 0.05$). The WHC of SM meat by the 24th post-slaughter hour was markedly better than that on the 7th day of cold storage in the three groups, but differences were relevant only in crosses with Ile-de-France and Mouton Charollais rams ($P \leq 0.05$). The cooking loss percentages on the 24th hour post-slaughter in the three groups of lambs were higher compared to values obtained 7 days after refrigerated storage. The differences were significant in BDSP lambs ($P \leq 0.01$) and in BDSP x MC crosses ($P \leq 0.05$). It was also found out that after 7-day storage, the SM tenderness was improved compared to that on the 24th hour; yet the differences were significant only in control lambs ($P \leq 0.01$) and BDSP crosses with Mouton Charollais ($P \leq 0.05$).

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