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CHANGES IN MEAT QUALITY OF *MUSCULUS LONGISSIMUS THORACIS ET LUMBORUM* AFTER 1 AND 4 MONTHS OF FROZEN STORAGE AT -18 °C, OBTAINED FROM LAMBS

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Abstract: The present study aimed to evaluate the effect of freezing and frozen storage duration (1 and 4 months) on the chemical composition and technological properties of lamb meat. Meat samples from Musculus Longissimus thoracis et lumborum were collected from Bulgarian Dairy Synthetic Population and their crosses with Ile-de-France and Mouton Charollais breed, with a slaughtering weight of 22-23 kg._Samples were frozen in a freezer at –18 °C. Frozen meat samples were thawed in a refrigerator at 4 °C 1 month and 4 months after freezing and analysed for determination of chemical composition and technological properties. It was established that lamb meat from the control group kept frozen for 1 month had statistically significantly higher water content compared to crosses of Bulgarian Dairy Synthetic Population with the Ile-de-France breed. Furthermore, dairy lambs were outlined with substantially higher meat fat content compared to crosses of Bulgarian Dairy Synthetic Population with the with Mouton Charollais. The chemical analysis of meat kept frozen for 4 months demonstrated significantly lower water content and higher dry matter and protein content in Ile-de-France crosses with Bulgarian Dairy Synthetic Population than in the control group. The meat protein percentage was higher while fat content – was lower in crossed Bulgarian Dairy Synthetic Population with Mouton Charollais compared to respective values in controls. Meat pH values of Mouton Charollais crosses differed significantly between the 1st and 4th month of frozen storage ($P \leq 0.01$). It was found out that the tenderness of meat frozen for 1 and 4 months was statistically significantly elevated in crosses of Bulgarian Dairy Synthetic Population with Ile-de-France and Mouton Charollais breeds compared to meat from control lambs.

Key words: sheep farming, meat quality, freezing

Introduction

It is common knowledge that meat provides essential nutrients e.g. protein, lipids, vitamins and minerals (*Akhtar et al., 2013; Akram et al., 2019; Devi et al., 2019*). According to these authors, the demands of today's busy and stressful life drive some consumers to buy meat for future consumption and store it frozen.
The primary cause for meat spoilage are microorganisms that replicate onto its surface and cause spoilage.To prevent this, conditions should be created so that microorganisms are either destroyed or could not replicate (*Kim et al., 2015; Ishevskiy and Davydov, 2017*). A technique for the creation of such conditions is freezing of products (*Lisitsyn et al., 2019*). Meat freezing is a practice for increasing its shelf-life (*Kiani and Sun, 2011; Akhtar et al., 2013; Akram et al., 2019; Tan et al., 2021*).

Literature data demonstrates that freezing of meat from various animals at different temperatures and for different periods causes both deterioration of some along with improvement of other technological and chemical properties of meat are available. It is generally agreed that meat tenderness was enhanced following freezing and thawing, in other words, the meat becomes more tender (*Shanks et al., 2002; Akhtar et al., 2013; Lagerstedt et al., 2008*). It is considered that the mechanism involved in meat tenderness increase is a combination of muscle fibres' degradation, meat aging and loss of structural integrity consequently to ice crystals formation (*Vieira et al., 2009*).

According to some researchers, the water content of cooled and frozen meat is different (*Khadeeja and Husseiny, 2017*). Others affirm that meat pH values do not change during freezing and thawing (*Akhtar et al., 2013; Daszkiewicz et al., 2017*). The cooking loss percentage of four bovine muscles increases both after meat freezing and with frozen storage period prolongation (*Cho et al., 2017*).

The present study aimed to evaluate the effect of freezing and frozen storage duration (1 and 4 months) on the chemical composition and technological properties of lamb meat.

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: 18 F_1 crosses of Bulgarian Dairy Synthetic Population (BDSP) ewes and rams from meat breeds Mouton Charollais (MC) and Ile-de-France (IF), as well as 9 BDSP lambs. The animals were distributed into 3 groups – 9 BDSP lambs (first group, control), 9 F_1 BDSP×IF crosses (second group, experimental) and 9 F_1 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 *Musculus Longissimus thoracis et lumborum* were collected for analysis of technological properties and chemical meat composition at the level of 11^{th}-12^{th} thoracic vertebrae. Meat samples were frozen in a freezer at –18 °C for 1 and 4 months.

Frozen meat samples were thawed in a refrigerator at 4 °C on post freezing months 1 and 4 and analysed for determination of chemical composition and technological properties. Meat pH was measured on Testo 205 pH meter. The water holding capacity of meat (WHC) was evaluated by the classical pressing method of *Grau and Hamm (1953)*, described by *Zahariev and Pinkas (1979)* with modifications of *Petrov (1982).* The water absorption capacity of meat (WAC) was determined by the method proposed by *Kyosev and 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 degrees - °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.* To this end, a Kjeldahl automatic distiller UDK 149 VELP Scientifica, Italy was used. 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

Table 1 presents the results from the chemical analysis of lamb *Musculus Longissimus thoracis et lumborum* samples, stored frozen at –18 °C for 1 and 4 months. Meat water content after 1-month frozen storage varied from 75.03% to 76.08%. The meat of BDSP lambs was outlined with the highest water content – 76.08%. The differences between groups 1 and 2 were statistically significant

(P≤0.05). *Ablikim et al. (2016)* reported a water percentage of 76.16% in *Musculus longissimus dorsi* meat of Bashbay and Xinjiang Merino, 7-9 months of age, kept frozen for 1 month. This value is comparable to ours. The highest dry matter content of meat frozen for 1 month was obtained for IF crosses – 24.97%, while the lambs from the control group had the lowest meat dry matter percentage – 23.92%. The table showed that meat dry matter of group 2 exceeded substantially that of controls (P≤0.05). As for meat fat content after 1 month of frozen storage (Table 1), BDSP×MC crosses exhibited the lowest value – 2.63%, while the control group with the highest meat fat content - 3.32%. There was a statistically significant difference with respect to this trait between dairy lambs and BDSP×MC crosses (P≤0.05). The meat of group 3 had by 20.78% less fat compared to the control group. No significant differences between the groups in meat protein and mineral contents were observed.

Table 1. Chemical composition of lamb *Musculus Longissimus thoracis et lumborum*, stored at –18 °C for 1 and 4 months

Traits	Groups of animals						
	Group 1 BDSP (a)		Group 2 BDSP x IF (b)		Group 3 BDSP x MC (c)		Significance
Frozen storage at –18 °C for 1 month	n	$\bar{x}$±SD	n	$\bar{x}$±SD	n	$\bar{x}$±SD	
Water, %	6	76.08±0.60	6	75.03±0.21	6	75.96±0.25	a:b*
Dry matter, %	6	23.92±0.42	6	24.97±0.25	6	24.04±0.26	a:b*
Protein, %	6	19.50±0.70	6	20.77±0.26	6	20.21±0.12	NS
Fat, %	6	3.32±0.25	6	3.02±0.12	6	2.63±0.07	a:c*
Minerals, %	6	1.10±0.11	6	1.18±0.07	6	1.20±0.04	NS
Frozen storage at –18 °C for 4 months	n	$\bar{x}$±SD	n	$\bar{x}$±SD	n	$\bar{x}$±SD	Significance
Water, %	6	75.92±0.22	6	75.06±0.12	6	75.84±0.10	a:b*
Dry matter, %	6	24.08±0.12	6	24.94±0.10	6	24.16±0.22	a:b***
Protein, %	6	19.75±0.10	6	20.84±0.22	6	20.47±0.12	a:b*; a:c*
Fat, %	6	3.18±0.10	6	2.89±0.10	6	2.51±0.10	a:c*
Minerals, %	6	1.15±0.10	6	1.21±0.10	6	1.18±0.10	NS
Within-group statistical significance between months 1 and 4	1st month	4th month	1st month	4th month	1st month		4th month
Groups of lambs	Group 1 BDSP		Group 2 BDSP x IF		Group 3 BDSP x MC		
Water, %	NS		NS		NS		NS
Dry matter, %	NS		NS		NS		NS
Protein, %	NS		NS		NS		NS
Fat, %	NS		NS		NS		**
Minerals, %	NS		NS		NS		NS

BDSP - Bulgarian Dairy Synthetic Population, IF - Ile de France, MC - Mouton Charollais, * - P≤0.05, ** - P≤0.01, *** - P≤0.001, NS - not significant

According to Table 1, meat samples frozen for 4 months showed the highest water content in the control group - 75.92%. Dry matter of *Musculus Longissimus thoracis et lumborum* after 4 months of frozen storage was the highest in IF crosses – 24.94%, followed by MC crosses with 24.16% and finally, controls (24.08%). There were very significant differences between meat dry matter of lambs from control group and BDSP×IF crosses (P≤0.001) – in the latter, it was by 3.57% higher. The BDSP×IF crosses had also the highest meat protein percentage - 20.84%, followed by BDSP×MC crosses and BDSP lambs -20.47% and 19.75%, respectively. The meat of crosses with MC and IF had statistically significantly higher protein content compared to controls (P≤0.05). Protein content of frozen lamb similar to ours – 18.60% was reported by other authors (*Khadeeja and Husseiny, 2017*). As fat content was concerned, the highest values were found out in BDSP lambs – 3.18%. This trait differed considerably between controls and BDSP×MC crosses: the latter had by 21.07% less fat.

The chemical composition of meat after 1 and 4 months of frozen storage did not show any statistically significant within-group differences in groups 1 and 2. On the contrary, BDSP×MC crosses showed substantially difference meat fat content between the two periods (P≤0.01).

Table 2 presents the chemical composition of cooled meat from the same crosses from a previous study of ours (*Ivanov, 2019*). Data demonstrate that meat water content of the three groups varied with a tendency for reduction from cold storage to 1-month and 4-month frozen storage. Water percentage in cooled meat in control lambs according to *Ivanov (2019)* was 76.69%, after 1 month frozen storage it was 76.08% and after 4 months: 75.92%. Cooled BDSP×IF meat had a water content of 75.37% (*Ivanov, 2019),* whereas the values after 1 and 4 months of frozen storage were 75.03% and 75.06% respectively. For BDSP×MC crosses, cooled meat contained 76.59% water (*Ivanov, 2019*), and frozen meat: 75.96% after 1 month and 75.84% after 4 months. Our results were in line with those of *Khadeeja and Husseiny (2017)* who reported higher water content in cooled meat compared to frozen meat.

On the contrary, meat dry matter content of lamb meat tended to increase in association with cold to 1-month or 4-month frozen storage. Data of *Ivanov (2019)* demonstrated that cooled meat of BDSP lambs had a dry matter content of 23.31%, which increased to 23.92% after 1 month in the freezer and to 24.08% after 4 months of frozen storage. The same tendency was observed for dry matter content of BDSP crosses with either Ile-de-France or Mouton Charollais. The reduced water content in frozen vs fresh meat is associated with water extraction during freezing and release of more liquid during meat thawing. Dry matter increase is explained with reduction of water during the freezing process. Meat is composed of water and dry matter. The increase in water leads to decrease in dry matter and vice versa, as both are negatively correlated. Meat dry matter is represented by protein, fat and minerals. Thus, increased dry matter corresponds to increased proportions of protein, fat and minerals, as shown in Tables 1 and 2.

Table 2. Chemical composition of *Musculus Longissimus thoracis et lumborum* from light carcasses at post mortem hour 24 (*Ivanov, 2019*)

Traits	Groups of animals						
	Group 1 BDSP (a)		Group 2 BDSP x IF (b)		Group 3 BDSP x MC (c)		Significance
	n	$\bar{x}\pm S\bar{x}$	n	$\bar{x}\pm S\bar{x}$	n	$\bar{x}\pm S\bar{x}$	
Water, %	3	76.69±0.70	3	75.37±0.20	3	76.59±2.19	NS
Dry matter, %	3	23.31±0.70	3	24.63±0.20	3	23.41±2.19	NS
Protein, %	3	2.70±1.29	3	3.08±1.49	3	2.53±1.20	NS
Fat, %	3	19.37±0.55	3	20.48±1.39	3	19.69±2.37	NS
Minerals, %	3	1.23±0.15	3	1.07±0.07	3	1.19±0.34	NS
Fat, % DM,	3	11.53±5.20	3	12.48±6.00	3	10.80±5.10	NS
Protein, % DM	3	83.18±4.43	3	83.17±5.96	3	84.10±5.76	NS

DM - dry matter, NS - Not Significant, n - number of samples, BDSP - Bulgarian Dairy Synthetic Population, IF - Ile de France, MC - Mouton Charollais

Table 3 presents the results about the technological properties of lamb meat, kept frozen for 1 and 4 months. It demonstrated that meat pH after 1 month of frozen storage varied within a narrow range for the three groups. The lowest meat pH was found out in BDSP – 5.30, and the highest values were found in BDSP×Mouton Charollais crosses - 5.41. The differences between controls and Mouton Charollais crosses were statistically significant (P≤0.05). Meat pH of 7-9-month-old Bashbay's and Xinjiang Merino's *Musculus longissimus dorsi* after 1-month frozen storage was reported to be 5.83 *(Ablikim et al., 2016)* which is slightly higher than our values. As WHC results were concerned, values were comparable and insignificant. The same was true for WHC in distilled water which were 3.76%, 3.00% and 3.47% in group 1, 2 and 3 respectively. Inconsistent differences were found out for WHC in saline. The lowest values were found out in BDSP×Mouton Charollais crosses – 11.43%, while the highest meat WHC was exhibited by lambs from control group - 16.54%. The tenderness of meat stored at –18 °C for 1 month, the highest values corresponding to the most tender meat were those of BDSP×Mouton Charollais crosses – 313.28 °P, and the lowest meat tenderness (e.g. the toughest or hardest meat) was that of BDSP lambs - 236.11°P. This parameter differed statistically significantly between controls and crosses with Ile-de-France (P≤0.05) as well as between controls and crosses with Mouton Charollais (P≤0.001). The most significant meat cooking losses occurred in lambs from the control group – 39.07%, and the lowest – in crosses with Ile-de-France – 35.36%. Average cooking loss in the meat of BDSP×Mouton Charollais lambs was 37.96%. *Ablikim et al. (2016)* reported cooking loss percentage of 34.95% in the meat from two Chinese sheep breeds, stored frozen for one month at –18 °C.

Others *(Choi et al., 2018)* gave proofs for cooking losses of 41.59% in lamb meat kept frozen at – 18 °C for one month.

Table 3. Technological properties of lamb *Musculus Longissimus thoracis et lumborum*, stored at – 18 °C for 1 and 4 months

Traits	Groups of animals						Significance
	Group 1 BDSP (a)		Group 2 BDSP x IF (b)		Group 3 BDSP x MC (c)		
Frozen storage at –18 °C for 1 month	n	$\bar{x}$±SD	n	$\bar{x}$±SD	n	$\bar{x}$±SD	
pH	9	5.30±0.05	9	5.35±0.14	9	5.41±0.09	a:c *
WHC, %	9	29.24±4.71	9	27.95±2.76	9	29.42±3.39	NS
WHC – distilled water	9	3.76±2.33	9	3.00±2.16	9	3.47±2.66	NS
WHC – saline	9	16.54±5.88	9	12.99±3.09	9	11.43±3.17	NS
Tenderness,°P	18	236.11±51.68	18	280.56±49.12	18	313.28±28.21	a:b*; a:c***
Cooking losses, %	9	39.07±5.23	9	35.36±3.98	9	37.96±4.64	NS
Frozen storage at –18 °C for 4 months	n	$\bar{x}$±SD	n	$\bar{x}$±SD	n	$\bar{x}$±SD	Significance
pH	9	5.40±0.11	9	5.40±0.09	9	5.27±0.08	a:c***
WHC, %	9	26.19±3.39	9	26.08±1.56	9	29.62±1.83	NS
WHC – distilled water	9	7.65±4.53	9	3.67±2.97	9	7.04±4.53	NS
WHC – saline	9	17.87±4.72	9	11.87±5.89	9	18.84±5.03	NS
Tenderness,°P	18	233.83±39.39	18	292.28±35.83	18	316.39±28.69	a:b***; a:c***
Cooking losses, %	9	37.59±1.65	9	34.14±3.28	9	36.44±4.51	a:b*
Within-group statistical significance between months 1 and 4	1st month	4th month	1st month	4th month	1st month		4th month
Groups of animals	Group 1 BDSP x BDSP		Group 2 BDSP x IF		Group 3 BDSP x MC		
pH	*		NS		**		
WHC, %	NS		NS		NS		
WHC – distilled water	*		NS		NS		
WHC – saline	NS		NS		*		
Tenderness,°P	NS		NS		NS		
Cooking losses, %	NS		NS		*		

BDSP - Bulgarian Dairy Synthetic Population; IF - Ile de France; MC - Mutton Charollais;
n - number of samples, °P - Penetrant degrees, * - P ≤ 0.05, ** - P ≤ 0.01, *** - P ≤ 0.001, NS - not significant

The lowest pH of meat stored for 4 months (Table 3) was observed in BDSP×Mouton Charollais crosses – 5.27, whereas pH values of lambs from the other two groups were equal (5.40). The differences between control meat pH and that of BDSP×Mouton Charollais crosses were significant (P≤0.001).

WHC values showed the same tendency for samples frozen for 1 month. Again, the lowest WHC of meat was found out in Ile-de-France crosses – 26.08%, the highest values - 29.62% were those of BDSP×Mouton Charollais crosses.

There were no significant differences with respect to WHC is water and WHC in saline among the three groups. Similarly, meat tenderness after 1 months of frozen storage, showed the highest values in BDSP×Mouton Charollais crosses, followed by lambs from group 2 and BDSP lambs - 316.39 °P, 292.28 °P and 233.83 °P, respectively.

Similarly to the first analysis of cooking losses (meat frozen for 1 month), the same tendency was outlined. The lowest cooking losses in the meat kept frozen for 4 months was found out in BDSP×Ile-de-France crosses, followed by BDSP×Mouton Charollais crosses and control lambs – 34.14%, 36.44% and 37.59 respectively.

Technological properties of meat frozen for 1 and 4 months demonstrated statistically significant differences with respect to meat pH ($P \leq 0.05$) and WHC in saline ($P \leq 0.05$). In group 2, there were no relevant within-group differences. In group 3 (BDSP×Mouton Charollais crosses), substantial differences were observed for meat pH ($P \leq 0.01$), WHC in saline ($P \leq 0.05$) and cooking losses ($P \leq 0.05$).

Table 4 presents the results for technological properties of cooled lamb Musculus Longissimus Lumborum from another study of ours *(Ivanov et al., 2017).* The comparison of data from Tables 3 and 4 indicated that meat pH in BDSP lambs did not change considerably after freezing for 1 and 4 months compared to cooled samples. The cooled meat pH was 5.40, after 1-month frozen storage: 5.30, and after 4-month frozen storage: 5.40. No statistically significant differences were found between meat pH of crosses with Ile-de-France after either cold storage or frozen storage for 1 and 4 months: 5.37, 5.35 and 5.40. Higher differences were observed in meat pH of BDSP×Mouton Charollais lambs: pH 5.38 in cooled meat, 5.41 in meat frozen for 1 month and 5.27 for meat frozen for 4 months.

Data from Table 3 and 4 regarding WHC showed increased percentages from cooled to frozen meat in the three groups of lambs. The reported value in BDSP lambs for cooled meat was 19.19% (*Ivanov et al., 2017*). Meat WHC of the same group after 1-month frozen storage was 29.24%, and after 4-month frozen storage: 26.19%. In the first groups of lambs, WHC was deteriorated after freezing for one month by 52.37%, and after freezing for 4 months: by 36.48%. A similar trend was outlined for BDSP×Ile-de-France crosses – worse WHC by 17.78% after one month and by 9.90% after 4 months. In BDSP×Mouton Charollais crosses, the water holding ability of meat became worse after 1 month of frozen storage – by 26.00%, whereas after the 4th month: by 26.85%. This worsening of meat WHC was due to tissue damage caused by the formation and movement of ice crystals and its reduced ability to hold water *(Choi et al., 2018).*

Table 4. Technological properties of lamb *Musculus Longissimus Lumborum* after 24 hours of cold storage at 0-4 °C (*Ivanov et al., 2017*)

Characteristics	Group						Significance
	Group 1 BDSP (a)		Group 2 BDSP x IF (b)		Group 3 BDSP x MC (c)		
	n		n		n		
pH values on the 24th hour post mortem	9	5.40±0.07	9	5.37±0.09	9	5.38±0.12	a:b**
WHC, %	9	19.19±3.59	9	23.73±1.07	9	23.35±3.60	a:c*
WAC/distilled water, %	9	7.91±3.69	9	7.60±3.54	9	7.17±6.73	a:c*
WAC/saline solution, %	9	14.33±6.43	9	15.77±2.57	9	13.46±3.65	NS
Meat tenderness values, °P	15	236.47±61.69	15	330.80±52.69	15	240.00±70.57	a:b***
Cooking losses, %	9	41.75±2.92	9	43.96±2.32	9	45.02±2.27	a:c***

BDSP - Bulgarian Dairy Synthetic Population; IF - Ile de France; MC - Mutton Charollais;
N - number of samples; °P - Penetrant degrees; * - P ≤ 0.05, ** - P ≤ 0.01, *** - P ≤ 0.001, NS - not significant

As meat tenderness was concerned, BDSP lambs showed no consistent differences between cooled *(Ivanov et al., 2017)* samples and those kept frozen for 1 and 4 months – 236.47 °P, 236.11 °P and 233.83 °P respectively. The meat tenderness in IF crosses varied between cooled samples - 330.80 °P, those stored frozen for a month - 280.56 °P and 4 months - 292.28 °P. Tenderness values decreased by 15.19% and by 11.64% in meat frozen for 1 month and 4 months respectively compared to cooled meat in the same group. Tenderness of meat in BDSP×Mouton Charollais crosses was also variable. The tenderness of cooled meat was 240.00 °P, that kept frozen for 1 month – 313.28 °P, and after 4 months of frozen storage – 316.39 °P, It was noted that the meat of MC crosses that have been frozen for 1 month was more tender by 30.53% than cooled meat whereas the meat frozen for 4 months: by 31.83%. Data from other researchers evidence that the tenderness of lamb meat increased after freezing, e.g. shear force values were higher for cooled meat compared to frozen/thawed meat (*Wiklund et al., 2009; Qi et al., 2012*). The trend is the same for frozen and then thawed horse meat samples (*Seong et al., 2017*) and veal meat from *Longissimus dorsi* (*Shanks et al., 2002*) – the shear strength of the chilled sample is higher than that of the thawed sample.

Cooking losses decreased from cooled to frozen meat (for 1 and 4 months) in all three groups of lambs. Cooking loss percentages of BDSP meat were 41.75% (cooled meat), 39.07% (1-month frozen storage) and 37.59% (4-month frozen storage). In the dairy lamb group, cooking losses of cooled meat were by 6.42% and 9.96% higher than those of meat frozen for 1 and 4 months respectively. For the BDSP×Ile-de-France crosses, cooking losses were 43.96% for cooled meat, 35.36% for meat kept frozen for a month and 34.14% for meat strode frozen for 4 months. Cooled meat of BDSP×Mouton Charollais crosses demonstrated by 19.07% higher cooking loss than meat stored frozen for 1 month and by 21.86% compared to meat frozen for 4 months. Cooking loss values for these crosses was 45.02% (cooled meat), 37.96% and 36.44% (meat stored frozen for 1 and 4 months respectively). Thus, compared to frozen meat stored for 1 and 4 months, respective cooking loss percentages of cooled meat were by 15.68% and 19.06% higher.

Conclusion

The results from the present study allowed concluding:

The meat samples from control lambs had statistically significantly higher water content than the meat of Ile-de-France crosses after 1 month of frozen storage.

The meat of lambs from the Bulgarian Dairy Synthetic Population, kept frozen for 1 month, demonstrated statistically significantly higher fat content compared to BDSP×Mouton Charollais crosses.

In the meat stored frozen for 4 months, water content was substantially reduced along with significantly higher dry matter and protein percentages in BDSP×Ile-de-France cross compared to lambs from the control group. Furthermore, protein content in the meat of BDSP×Mouton Charollais crosses was significantly higher, yet fat content: was significantly lower compared to those in dairy lambs.

Meat water content showed as insignificant decrease from cold to frozen storage. Meat water is encountered in three forms – bound, free and immobilized. Free and immobilized water is important during meat storage. Free water is easily removed from the meat and lost, being held by weak forces. Entrapped water is extracted by drying or pressing and is easily transformed into ice during freezing. The decrease in water content in meat from cold to frozen storage is due namely to its extraction during freezing and release after thawing. On the other hand, the insignificant increase in dry matter is due to the negative water-dry matter relationship, so as water decreases, dry matter (protein, fat and minerals) in meat becomes greater.

Meat tenderness after 1 and 4 months of frozen storage was statistically significantly higher in crosses with Ile-de-France and Mouton Charollais breeds compared to that of meat of control lambs.

Cooking losses of meat stored frozen for 4 months were statistically significantly lower in BDSP×Mouton Charollais crosses compared to those in controls.

Promene u kvalitetu *Musculus Longissimus thoracis et lumborum* jagnjadi nakon jednog i četiri meseca skladištenja na -18 °C

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Rezime

Cilj ovog istraživanja je bio da se proceni uticaj trajanja zamrzavanja i zamrznutog skladištenja (1 i 4 meseca) na hemijski sastav i tehnološka svojstva jagnjećeg mesa. Uzorci mesa *Musculus Longissimus thoracis et lumborum* prikupljeni su od grla bugarske sintetičke mlečne populacije i njihovih meleza sa rasama il de frans i šarole, klanične težine 22-23 kg. Uzorci su zamrznuti u zamrzivaču na -18°C. Uzorci smrznutog mesa su odmrznuti u frižideru na 4°C jedan, odnosno četiri meseca nakon zamrzavanja i podvrgnuti analizi u cilju određivanja hemijskog sastava i tehnoloških svojstava. Utvrđeno je da je jagnjeće meso iz kontrolne grupe koje je držano zamrznuto jedan mesec imalo statistički značajno veći sadržaj vode u poređenju sa melezima bugarske mlečne sintetičke populacije sa rasom il de frans. Štaviše, jagnjad mlečne populacije je označena sa znatno većim sadržajem masti u mesu u poređenju sa melezima bugarske sintetičke mlečne populacije sa šaroleom. Hemijska analiza mesa koje je držano zamrznuto 4 meseca pokazala je značajno manji sadržaj vode i veći sadržaj suve materije i proteina kod meleza rase il de frans sa populacijom bugarskih mlečnih grla nego u kontrolnoj grupi. Procenat proteina u mesu je bio veći, dok je sadržaj masti – bio niži kod meleza bugarske sintetičke mlečne populacije sa rasom šarole u poređenju sa odgovarajućim vrednostima u kontrolama. Vrednosti pH mesa meleza sa šaroleom značajno su se razlikovale između 1 i 4 meseca zamrznutog skladištenja ($P \leq 0{,}01$). Utvrđeno je da je mekoća mesa zamrznutog 1 i 4 meseca statistički značajno povećana kod meleza bugarske mlečne sintetičke populacije sa rasama il de frans i šarole u poređenju sa mesom kontrolne jagnjadi.

Ključne reči: ovčarstvo, kvalitet mesa, zamrzavanje

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