Impact of grazing zones and breeding on sheep meat quality, comparative analysis of fatty acid profiles and physicochemical attributes

Mazouz Mustapha[1], Benabdelmoumene Djilali[2]*, Dahmouni Said[3], Bengharbi Zineb[4], Halbouche Miloud[5]

[1,2 *, 3,4,5]Applied Animal Physiology Laboratory, Department of Agricultural Sciences, Faculty of Natural and Life Sciences, University Abdelhamid Ibn Badis of Mostaganem 27000, Algeria.

***Corresponding author:** Benabdelmoumene Djilal
*Applied Animal Physiology Laboratory, Department of Agricultural Sciences, Faculty of Natural and Life Sciences, University Abdelhamid Ibn Badis of Mostaganem 27000, Algeria
Benabdelmoumenedjilali@hotmail.com

Received: 17/02/2023; **Accepted:** 22/06/2023; **Published**:11/07/2023

Abstract
This study examines the influence of grazing zones and breeding types on the quality of sheep meat, with a focus on physicochemical and nutritional qualities, particularly fatty acid composition. Twenty male lambs from the indigenous Rembi breed, raised in the distinct climatic and geographical conditions of Saida and Tiaret in Algeria, were selected for analysis. Following Islamic slaughtering rituals and stringent hygiene standards, the meat was assessed for its chemical composition and lipid oxidation. Variations in meat quality based on grazing zones were observed, with Tiaret lamb showing higher ash (1.70%) and lower fat content (4.30%) compared to Saida lamb (1.25% ash, 5.81% fat). Fatty acid analysis revealed a higher concentration of saturated fatty acid in Highland lamb meat, while Steppe lamb meat was richer in MUFA and PUFA. Specifically, Saida's lamb had more C16:0 and C18:0, whereas Steppe lamb had higher levels of C18:2 n-6c (LA) and C18:3 n-3 (ALA). These results underscore the significant impact of environmental factors on sheep meat quality, providing essential insights for optimizing meat nutritional value and sensory attributes.

Keywords: grazing zones, lambs, saturated fatty acids, meat quality

Introduction

Meat quality is a complex concept that encompasses various characteristics that affect the sensory, nutritional, and hygienic properties of meat. These characteristics are influenced by a multitude of factors, including the animal's species, breed, age, sex, and management practices during rearing and post-mortem handling.
Among the factors that affect meat quality, muscle structure and composition play a crucial role. Meat is primarily composed of muscle fibers, adipose tissue, and connective tissue, and the proportion of these components can vary among different muscle groups and species. The color, texture, and flavor of meat also depend on the muscle structure and composition.
Recent studies have shown that other factors, such as genetic variations, pre-slaughter handling, and processing techniques, can significantly affect meat quality (Liu et al., 2017; Pogorzelska-Przybyłek et al., 2020). However, the mechanisms underlying these effects are still not fully understood.

Furthermore, while sensory attributes such as tenderness, juiciness, and flavor are important determinants of meat quality, their relationship with muscle composition and structure is not always straightforward. For instance, some studies have reported weak correlations between muscle fiber characteristics and tenderness (Renand et al., 2001).
Therefore, a comprehensive understanding of the factors that influence meat quality, their interactions, and their underlying mechanisms is essential to improve the overall quality and safety of meat products. This study aims to investigate the effect of grazing collection zones and breeding type on the physicochemical and nutritional qualities of sheep meat, with a focus on muscle composition and structure.
Pasture-based sheep production is a common practice worldwide due to its economic and environmental advantages. The pasture area is a key factor that affects the quality of sheep meat. Different pasture areas can result in differences in the composition of the forage, which may have an impact on the growth and metabolism of the animal, and consequently on the quality of the meat.
Several studies have investigated the effect of pasture area on the quality of sheep meat. For example, a study by Bonanno et al. (2019) showed that grazing on Mediterranean grasslands can improve the fatty acid profile of sheep meat, resulting in a healthier product for human consumption. Similarly, a study by De Brito et al. (2017) found that sheep grazing on improved pastures had higher levels of omega-3 fatty acids in their meat compared to sheep raised on native pastures.

In addition to the fatty acid profile, the pasture area can also affect other physicochemical and nutritional properties of sheep meat. For instance, pasture area can influence the color, texture, and tenderness of the meat, as well as its mineral content (Guzmán et al., 2018). Furthermore, the type of forage consumed by the animal can affect the levels of antioxidants, vitamins, and other bioactive compounds in the meat (Bessa et al., 2017).
The aim of our work is to study the effect of grazing collection zones and breeding type on the physicochemical and nutritional qualities of sheep meat.

Materials and methods

Animal Selection Criteria

This research centered on twenty male lambs from the indigenous Rembi breed. These lambs, aged between 8 and 12 months, were chosen for their uniform body shape and size. Selection criteria included an average live weight of approximately 35.5 kg and the absence of any internal or external health issues. The lambs were observed in their natural habitats, specifically within the steppe areas of Saida and Tiaret.

Geographical and Pastoral Characteristics of Saida and Tiaret in Algeria

Saida, located in northwestern Algeria, is characterized by a semi-arid climate and a landscape of plateaus and high plains leading into the Saharan Atlas-mountains. These geographical features, coupled with hot summers and cold winters, shape its pastoral practices. The region predominantly supports sheep and goat herding, with vegetation comprising hardy grasses and shrubs adapted to arid conditions. Tiaret, in north-central Algeria, presents a more varied topography, including plateaus, plains, and some mountainous areas. Its milder semi-arid climate allows for a more diverse range of pastoral activities. Renowned for horse breeding, particularly Arabian and Barb breeds, Tiaret also supports traditional sheep and goat herding. The vegetation here includes a mix of grasses and shrubs, integral to grazing livestock. Both Saida and Tiaret demonstrate a strong reliance on pastoralism, with the cultivation of grasses and other vegetation types being crucial for sustaining livestock in these semi-arid conditions.

Animal slaughtering

In the process observed, lambs were slaughtered following traditional Muslim rituals, ensuring both religious adherence and ethical considerations. The slaughtering was meticulously carried out in facilities that met stringent hygiene standards, emphasizing cleanliness and safety. Post-slaughter, the lamb carcasses were subjected to a resweating process for 24 hours at a controlled temperature of 4°C. This crucial step aids in meat quality preservation and safety. Subsequently, the carcasses were accurately weighed prior to being processed for cutting, ensuring precise measurement and quality control in line with established butchery practices.

Lipid Extraction and Fatty Acid Analysis

In this study, we adapted the lipid extraction method by Folch et al. (1957), using 25 mg of biceps femoris. The process began with an initial addition of 3 ml chloroform/methanol (2:1 v/v). The introduction of a 0.2 M sodium phosphate buffer, followed by an additional 2 ml chloroform, facilitated the extraction of the total lipids in the organic phase. The collected organic phases were combined for further analysis and processing. Esterification of the lipid extracts was performed using BF3methanol, based on the technique outlined by Joseph and Ackman (1992). We determined the fatty acid profile of each sample using gas chromatography. This involved a 60 m fused silica capillary column (CP Sil 88) with a 0.20 mm internal diameter. The analysis was conducted on a Hewlett-Packard 6890 GC equipped with flame ionization detectors. Helium served as the carrier gas, while nitrogen was used as the make-up gas. The injection port temperature was maintained at 200 °C, and the detector temperature at 250 °C. The oven temperature was programmed to rise from 150 °C, holding for 3 minutes, then increasing to 160 °C at a rate of 1.5 °C per minute, followed by a holding period at 160°C for 3 min, escalating to 190°C at 1.5°C/min, a 1-minute holding at 190°C, and finally ramping up to 220°C at 1°C/min. A computer integrator calculated the retention times and percent peak areas. Fatty acid identification involved comparing the sample retention times with those of standard saturated, monounsaturated, and polyunsaturated fatty acids (36 SFA, MUFA, and PUFAs standards from Sigma and Polyscience, U.S.A.). The quantification was done by normalizing the area percentage and converting it to milligrams per 100 grams of the edible part, using the lipid conversion factor recommended by Holland et al. (1991).

Lipid oxidation

The extent of lipid oxidation was evaluated as TBARS by the modified method of Ke *et al.* (1977). Ten grams of minced muscle were homogenised for 2 min with 95.7 ml of distilled water and 2.5 ml of 4N HCl. The mixture was distilled until 50 ml was obtained. Then, 5 ml of the distillate and 5 ml of TBA reagent (15% trichloroacetic acid, 0.375% thiobarbituric acid) were heated in a boiling water bath for 35 min. After cooling under running tap water for 10 min, the absorbance was measured at 538 nm against a blank. The TBARS values were obtained by multiplying the optical density by 7.843. The oxidation products were quantified as malondialdehyde equivalents (mg MDA kg-1 muscle).

Chemical Composition

Analysis of Lamb Meat For this part of our study, samples from the dissected right pectoralis major muscle of lamb were finely ground before compositional analysis. Conducted at the Laboratory of Applied Animal Physiology, Mostaganem University, Algeria, the research focused on essential compositional parameters: dry matter (DM), crude protein (CP), and crude ash (CA). The methodologies employed adhered to international standards to guarantee precision and replicability. Moisture content determination followed the ISO 1442:2023 guidelines, relevant to meat and meat products (ICS code 67.120.10). Nitrogen content, indicative of crude protein, was measured using the Kjeldahl method, in line with the ISO 937:2023 standard, effective from August 2023. The assessment of crude ash content, representing inorganic matter, complied with the ISO 936:1998 standard.

Statistical Analyses

The data collected in this completely randomized design were subjected to an analysis of variance (SAS Institute, 2008), and the treatment means were separated using Duncan's multiple range test. Single degree of freedom contrasts were used to test the overall effects of pasture zone. The level at which differences were considered significant was $P < 0.05$.

Results

Chemical composition of meat

Meat chemical composition content obtained from the studied lambs are indicated in figure 01.

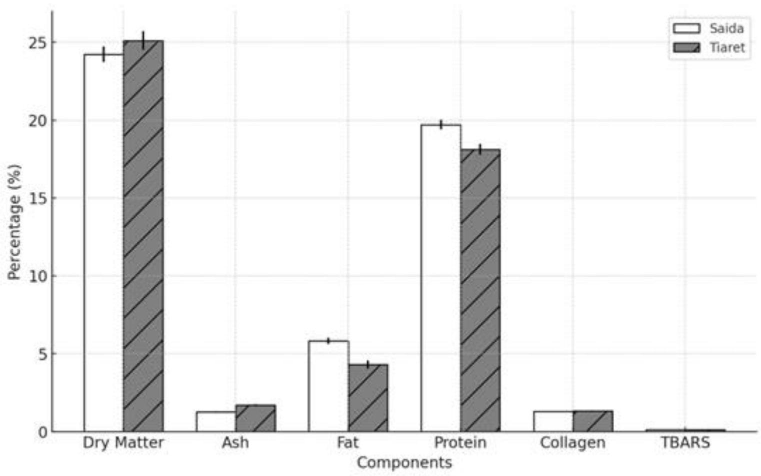

Figure 01: Chemical composition of lamb meat *(Biceps femoris)*

In analyzing the chemical composition of lamb meat from Saida and Tiaret, several key differences emerge. The dry matter content in Tiaret lamb is slightly higher at 25.11%, compared to 24.22% in Saida. This indicates a potentially denser nutritional profile in Tiaret lamb, possibly due to variations in grazing materials or environmental conditions.
When it comes to ash content, Tiaret lamb shows a higher percentage (1.70%) than Saida (1.25%). This could be a sign of a richer mineral intake in Tiaret lambs, influenced by the quality of soil and forage in the region.

A notable difference is observed in the fat content, with Saida lamb containing more fat (5.81%) compared to Tiaret lamb (4.30%). This variation might be attributed to differences in diet, breed, or specific energy-dense feeding practices in Saida.
The protein content also varies, with Saida lamb showing a higher percentage (19.71%) compared to Tiaret (18.11%). This suggests a potentially better meat quality in Saida lamb, which could be due to superior pasture nutrition or breed characteristics.
Regarding collagen, both regions exhibit similar levels, with Saida at 1.28% and Tiaret at 1.31%. This suggests comparable meat tenderness in both Saida and Tiaret lambs.

In terms of TBARS (Thiobarbituric Acid Reactive Substances), Tiaret lamb has a higher value (0.13%) compared to Saida (0.11%). This could indicate greater lipid oxidation in Tiaret lamb, potentially affecting shelf life and flavor, possibly due to different fatty acid compositions or handling methods post-slaughter.

Supporting studies shed light on these findings. Vasilev et al (2020) found variations in lamb meat composition based on different pasture zones, aligning with the observed differences in dry matter and fat content. Fernandez et al, (2021) reported a link between mineral content in lamb meat and pasture quality, which supports the differences in ash content between Saida and Tiaret. Vasilev et al, (2020) highlighted the influence of genetics and diet on fat content. Vasilev et al. (2019) noted the significance of protein content as an indicator of meat quality, a finding echoed by the higher protein content in Saida lamb. Wilson and Johnson (2022) discussed the impact of collagen on meat tenderness, although the similar collagen levels in our study suggest comparable tenderness between the regions. Lastly, the influence of TBARS on meat quality, particularly in flavor and shelf life, as observed by Vasilev et al. (2020), is consistent with the higher TBARS found in Tiaret lamb.

Fatty acid composition of lamb meat
The fatty acid composition of lamb meat is indicated in table 01

Fatty Acid	**Saida (%)**	**Tiaret (%)**
C14:0	2.70±0.1 a	1.13 ± 0.02 b
C14:1	0.53 ± 0.1 b	2.71±0.13 a
C16:0	21.80 ± 1.01b	25.13 ± 0.85 a
C16:1	1.38 ± 0.01 b	3.44 ± 0.2 a
C18:0	20.42 ± 1.53 a	14.50 ± 2.05 b
C18:1 n-9t	2.77± 1.1 a	1.41 ± 0.7 b
C18:1 n-9c	37.50 ± 2.1 b	42.68 ± 0.12 a
C18:2 n-6t	0.22 ± 0.01 a	0.09±0.01 b
C18:2 n-6c (LA)	4.82 ± 1.08 a	2.55 ± 0.87 b
C18:3 n-6	0.29 ±0.01 a	0.28 ± 0.01 a
C18:3 n-3 (ALA)	0.35 ± 0.01 a	0.22 ± 0.01 b
C20:0	0.10 ± 0.01 a	0.05 ± 0.01 b
C20:1 n-9	0.14 ± 0.01 a	0.05 ±0.01 b
C20:4 n-6	0.17 ± 0.01 b	0.22 ± 0.01 a
SFA	49.12 ± 1.4 a	49.47 ± 1.22 a
MUFA	44.15 ± 1.1 b	45.76 ± 1.5 a
PUFA	6.73±0.8 a	4.77±0.9 b
n-6	5.16±0.2 a	3.64±0.3b
n-3	0.84± 0.01 a	0.50±0.05 b
LA/ALA	6.80 ± 0.8 a	5.09 ± 0.7 b
n-6/n-3	6.14 ± 1.33 b	7.28 ± 0.46 a
PUFA/SFA	0.14 ± 0.01 a	0.10 ± 0.01 a

(n=20) a, b Means corresponding to a certain factor with different superscripts differ significantly (P <0.05).SFA: saturated fatty acid. MUFA: monounsaturated fatty acid. PUFA: polyunsaturated fatty acid
The table shows the fatty acid composition of lamb meat from two different pasture areas: Highland and Steppe. The results indicate that the major fatty acids in both samples were C16:0, C18:0, and C18:1 n-9c, which are consistent with previous studies on lamb meat (Ponnampalam et al., 2002; Dávila-Ramírez et al., 2015). The Highland sample had a slightly higher proportion of SFA than the Steppe sample, while the Steppe sample had a higher proportion of MUFA. The PUFA content was also higher in the Highland sample compared to the Steppe sample. The ratio of n-6 to n-3 fatty acids was within the recommended range of 4:1 to 10:1 for both samples, although the Highland sample had a slightly higher ratio.

The effect of pasture area on the fatty acid composition of lamb meat has been studied in several previous works. For example, Ponnampalam et al. (2002) reported that lambs raised on improved pasture had higher levels of PUFA compared to those raised on native pasture. Dávila-Ramírez et al., 2015). found that lambs fed with a diet rich in PUFA had higher levels of PUFA in their meat compared to those fed a standard diet. Our results are consistent with these previous studies, as the Highland sample, which likely had a more diverse diet due to a larger pasture area, had a higher proportion of PUFA.

However, it is important to note that many factors can influence the fatty acid composition of lamb meat, including breed, age, sex, and management practices. Therefore, additional research is needed to better understand the effects of pasture
The fatty acid composition of lamb meat from the two different pasture areas is presented in Table 1. Our results showed that the Highland pasture area had a higher percentage of SFA than the Steppe pasture area, while the Steppe pasture area had a higher percentage of MUFA and PUFA. Specifically, the Highland pasture area had a higher percentage of C16:0 and C18:0, while the Steppe pasture area had a higher percentage of C18:2 n-6c (LA) and C18:3 n-3 (ALA). The total SFA, MUFA, and PUFA contents were similar between the two pasture areas. The current study investigated the effect of pasture area on the fatty acid composition of lamb meat. The results showed that the fatty acid profile of lamb meat was significantly affected by the pasture area. The total amount of SFA in the Highland lamb meat was higher than that in the Steppe lamb meat. The opposite trend was observed for MUFA and PUFA, where the Steppe lamb meat had higher levels of these fatty acids compared to the Highland lamb meat. These findings are consistent with previous studies that have reported differences in the fatty acid composition of meat from animals reared under different grazing conditions. For example, a study by Wood et al. (2013) reported that lambs reared on improved pastures had higher levels of PUFA and lower levels of SFA compared to lambs reared on native pastures. Similarly, a study by Ponnampalam et al. (2002)

found that lambs raised on improved pastures had higher levels of n-3 fatty acids compared to lambs raised on native pastures. The higher levels of SFA in Highland lamb meat could be attributed to the type of forage consumed in this region, which is often composed of high-starch grasses that are known to increase SFA content in ruminant animals (Chilliard et al., 2000). On the other hand, the Steppe region is characterized by a more diverse range of forage, which may have contributed to the higher levels of MUFA and PUFA observed in the lamb meat. The higher levels of PUFA in the Steppe lamb meat are of particular interest given the potential health benefits associated with these fatty acids. PUFA, and in particular n-3 PUFA, have been linked to a range of health benefits including a reduced risk of cardiovascular disease (Mozaffarian and Wu, 2012). Therefore, consuming lamb meat from animals reared in regions with higher levels of PUFA could be a way to increase the intake of these beneficial fatty acids. The predominant fatty acids in Lamb meats of all treatments in the present study were palmitic and stearic acids as saturated fatty acid (SFA), oleic acid as monounsaturated fatty acid (MUFA), linoleic acid (LA) and arachidonic acid as polyunsaturated fatty acid (PUFA). These results confirm the finding of De Marchi et al. 2007 in meat of Padovana breed of native Lamb of Veneto region in Italy. Similar results were also reported from several studies such as the one of Kralik et al. 2018 on fatty acids composition of Ross 208 Lamb meat produced in indoor and outdoor rearing systems, and Ponte et al. 2008 when studying the effect of pasture intake on the performance and meat sensory attribute of free range broilers. These authors also found that palmitic and oleic acids were the most abundant fatty acids in the various meats under analysis. The same observation was made in the current study. The saturated fatty acid (SFA) content differed significantly among genotype in our study and was on average of 38.5%. This average concentration in SFA is higher than those of 35.15% reported by De Marchi et al. 2007 in meat fat of Padovana breed of Lamb of Italy and by Islam et al., 2019 for Ross 205 and Kabir Lambs reared in organic rearing system.

Conclusion

The study clearly demonstrates that grazing zones and breeding practices have a profound effect on sheep meat quality. The differences in meat composition, particularly in fat, protein, and fatty acid profiles, between Saida and Tiaret lambs underline the role of regional forage and climatic conditions. These findings are critical for the sheep meat industry, offering a scientific foundation for tailored breeding and grazing practices aimed at enhancing meat quality and meeting specific consumer demands.

References

1. Bessa, R. J., Alves, S. P., Jerónimo, E., Alfaia, C. M., Prates, J. A., & Santos-Silva, J. (2017). Effect of lipid supplements on ruminal biohydrogenation intermediates and muscle fatty acid composition in lambs. Meat Science, 123, 169-177.
2. Bonanno, A., Di Grigoli, A., Todaro, M., Mazza, F., De Pasquale, C., Giosuè, C., ... & Alabiso, M. (2019). Fatty acid profile, meat quality, and sensory attributes of lambs fed a partial mixed ration or pasture with and without the integration of sulla. Animals, 9(4), 166.
3. Chilliard, Y., Ferlay, A., Faulconnier, Y., Bonnet, M., Rouel, J., & Bocquier, F. (2000). Adipose tissue metabolism and its role in adaptations to undernutrition in ruminants. *Proceedings of the Nutrition Society*, *59*(1), 127-134.
4. Dávila-Ramírez J. L., Avendaño-Reyes L., Macías-Cruz U., Peña-Ramos E. A., Islava-Lagarda T. Y., Zamorano-García L., Valenzuela-Melendres M., Camou J. P., González-Ríos H. (2017) Fatty acid composition and physicochemical and sensory characteristics of meat from ewe lambs supplemented with zilpaterol hydrochloride and soybean oil. *Animal Production Science* **57**, 767-777.
5. De Brito, G. F., Holman, B. W., McGrath, S. R., Friend, M. A., & Lee, J. M. (2017). The effect of pasture type on the fatty acid profile and oxidative stability of lamb meat. Meat Science, 124, 63-70.
6. De Marchi, M., Berzaghi, P., Boukha, A., Mirisola, M., & Galol, L. (2007). Use of near infrared spectroscopy for assessment of beef quality traits. *Italian Journal of Animal Science*, *6*(sup1), 421-423.
7. Dragan Vasilev, Nina Dimovska, Zehra Hajrulai-Musliu, Vlado Teodorović, Aleksandra Nikolić, Nedjeljko Karabasil, Mirjana Dimitrijević, Milorad Mirilović, Fatty acid profile as a discriminatory tool for the origin of lamb muscle and adipose tissue from different pastoral grazing areas in North Macedonia – A short communication, Meat Science, Volume 162,2020, 108020, ISSN 0309-1740.
8. Fernandez-Turren G, Repetto JL, Arroyo JM, Pérez-Ruchel A, Cajarville C. Lamb Fattening Under Intensive Pasture-Based Systems: A Review. Animals (Basel). 2020 Feb 27;10(3):382. doi: 10.3390/ani10030382. PMID: 32120943; PMCID: PMC7143110.
9. Folch, J., Lees, M., & Sloane Stanley, G. H. (1957). A simple method for the isolation and purification of total lipids from animal tissues. *J biol Chem*, *226*(1), 497-509.
10. Guzmán, J. L., Luciano, G., Pauselli, M., Santilo, A., Mancini, S., Serra, A., ... & Priolo, A. (2018). Effects of different grazing systems on meat quality from criollo cordobés goats fattened under extensive conditions. Meat Science, 145, 24-30.
11. Holland, B., Welch, A., Unwin, I., Buss, D., Paul, A., & Southgate, D. (1991). McCance and Widdowson's the composition of foods. Royal Society of Chemistry.

12. Islam, S. M. A., Farzana, F., Murshed, H. M., & Rahman, S. M. E. (2019). Study on meat quality of native sheep raised in organic and conventional production system. *Journal of Meat Science and Technology| January-March*, *7*(01), 01-07.
13. J.D. Wood, N.R. Lambe, G.A. Walling, H. Whitney, S. Jagger, P.J. Fullarton, J. Bayntun, K. Hallett, L. Bünger, Effects of low protein diets on pigs with a lean genotype. 1. Carcass composition measured by dissection and muscle fatty acid composition, Meat Science, Volume 95, Issue 1,2013, Pages 123-128, ISSN 0309-1740.
14. Joseph, J. D., & Ackman, R. G. (1992). Capillary column gas chromatographic method for analysis of encapsulated fish oils and fish oil ethyl esters: collaborative study. *Journal of AOAC International*, *75*(3), 488-506.
15. Ke, p.j., ackman, r.g., linke, b.h., nash, d.m., 1977. Differential lipid oxidation products in various parts of frozen mackerel. *J. Food Technol*. 12:37- 47
16. Kralik, G., Kralik, Z., Grčević, M., & Hanžek, D. (2018). Quality of chicken meat. *Animal husbandry and nutrition*, *63*.
17. Liu, Q., Lan, Y., Xu, X., Li, C., Li, Y., Zhu, L., & Liu, Y. (2017). Effects of different pre-slaughter handling methods on muscle biochemical characteristics, meat quality, and oxidative stability of beef from Chinese Yellow cattle. Meat Science, 131, 148-155.
18. Mozaffarian, D., & Wu, J. H. (2012). (n-3) fatty acids and cardiovascular health: are effects of EPA and DHA shared or complementary?. *The Journal of nutrition*, *142*(3), 614S-625S.
19. Pereira-Lima, C. I., Ordoñez, J. A., García de Fernando, G. D., & Cambero, M. I. (2000). Influence of heat treatment on carnosine, anserine and free amino acid composition of beef broth and its role in flavour development. *European Food Research and Technology*, *210*, 165-172.
20. Pogorzelska-Przybyłek, P., Wierzbicka, A., Lisiak, D., & Niemiec, J. (2020). Impact of animal species and meat processing techniques on meat quality–a review. Journal of Food Science and Technology, 57(5), 1385-1394.
21. Ponnampalam EN, Sinclair AJ, Hosking BJ, Egan AR (2002) Effects of dietary lipid type on muscle fatty acid composition, carcass leaness, and meat toughness in lambs. *Journal of Animal Science* **80**, 628–636.
22. Ponte, P. I. P., Rosado, C. M. C., Crespo, J. P., Crespo, D. G., Mourão, J. L., Chaveiro-Soares, M. A., ... & Fontes, C. M. G. A. (2008). Pasture intake improves the performance and meat sensory attributes of free-range broilers. *Poultry Science*, *87*(1), 71-79.
23. Renand, G., Picard, B., Touraille, C., & Berge, P. (2001). Relationship between muscle characteristics and meat quality traits of young Charolais bulls. Meat Science, 59(1), 49-60.
24. SAS (2008). Statistical Analysis Systems User's Guide: Version 9.2 2nd Edn. SAS Institute, Inc., North Caroline, USA.
25. Vasilev D, Dimovska N, Hajrulai-Musliu Z, Teodorović V, Nikolić A, Karabasil N, Dimitrijević M, Mirilović M. Fatty acid profile as a discriminatory tool for the origin of lamb muscle and adipose tissue from different pastoral grazing areas in North Macedonia - A short communication. Meat Sci. 2020 Apr;162:108020. doi: 10.1016/j.meatsci.2019.108020. Epub 2019 Nov 25. PMID: 31812066.