Effect of geographic origin and grazing system on lambs' carcass traits and meat properties

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SUMMARY

Consumer preferences are shifting from meat quantity to its nutritional value and sensory qualities. Then, this study aimed to evaluate the effects of geographic origin and grazing system on carcass and meat quality specifically focusing on mountain "Djebel" lamb meat. For that, thirty-six lambs (6 months-old) were used: 12 from the mountainous "Djebel" areas in Northwest Tunisia, 12 from "East", and 12 from "Centre". The Djebel group grazed natural forests with woody species, while the other groups grazed herbaceous pasture and received concentrate (400g/head/day) and hay supplementation (500 g /head/day). The couple of coordinates (altitude in meter and distance from the sea in km) were 1000 with 37 for Djebel, 44 with 46 or East and 895 with 151 or the Centre. All lambs were slaughtered at 25.8, 26.8, and 22.6 kg for Djebel, East and Centre, respectively, to study the meat quality attributes.

The lambs' tissular composition was affected by lamb origin ($P< 0.05$) except to muscle proportion, which remained consistently around 60% across all groups. The meat pH was higher for lambs from Djebel and East than Centre group. The water cooking loss was significantly higher for East and Centre groups compared to that of Djebel one. The higher values of dry matter and crude protein were recorded in meat issued from Centre groups compared to Djebel and East groups. Meat redness (a*), chroma (C*) and Hue angle (H*) were not affected by the lamb's origin, however lightness (L*) and yellowness (b*) were highly affected. The storage time has significantly affected the meat colour parameters. Lipid oxidation was lower in the Djebel group; however, it increased progressively for all groups during 9 days of storage until reaching 0.359 mg MDA/ kg meat but without exceeding the meat rancidity threshold. Lamb origin did not affect meat tenderness and juiciness; however, flavor and overall impression were higher for lambs from Djebel and Centre areas. In conclusion, lambs grazing in the natural forests of the Djebel region produced meat with a higher ultimate pH and lower cooking loss, and their meat demonstrated an extended shelf life due to increased antioxidant capacity during storage, indicating superior nutritional quality.

KEY WORDS

Geographic origin; grazing system; lamb; meat quality; lipid oxidation.

INTRODUCTION

Meat production and livestock in general, offers economic and environmental benefits to several communities worldwide, since it provides livelihood and societal development for rural population, food for all people and environmental resilience by conserving and using marginal lands. In addition, it plays an important social role, since meat remains related to numerous traditions and strictly represents the main demanded product for various religious celebrations (1). Furthermore, meat is a crucial source of essential nutrients, offering high-quality proteins with essential amino acids, as well as energy, minerals, and vitamins. It also contributes to sensory enjoyment, cultural identity, and social status (2,3). However, consumer expectations are shifting beyond just the quantity of meat, with increasing emphasis on its nutritional value (healthier) and organoleptic qualities (4). An important issue to satisfy this consumer's preference is the meat geographical origin, which is considered as a significant credence attribute because consumers' ethnocentrism leads them to favor food from their own region (5). It has been reported that consumers value four key aspects of traditional food products: product familiarity, use of traditional recipes in processing, sensory properties, and the product's origin (6). In fact, they believe that lambs issued from specific regions or from mountain pastures offer higher meat quality compared to other types (4). They consider information about the origin of animals should be provided on meat' market (7). In mountainous areas, sheep and lambs graze on a diverse range of grasses, herbs, and foliage; they often traverse long distances, leading to potential differences in body structure compared to lambs raised in lowland paddocks (8). Several studies involving Italian, Norwegian, Spanish, French and British consumers revealed a preference for pasture-fed lamb. They perceive it as healthier, more natural, and tastier, while also acknowledging its positive impact on the environment and animal welfare (1). Additionally, it offers unique characteristics derived from specific plant and animal resources, distinguishing it from lowland counterparts (9). Notably, geo-

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graphic origin plays a pivotal role, with consumers favoring locally sourced or domestically produced meat (10). As the most traditional lamb production method in many countries, natural grazing is needing the lowest investment and provides the highest animal welfare and the best ecological benefits. The pasture grazing, as animal management system, has the potential to provide healthy meat with animal performance improving (4). Consumers generally believe that mutton produced under natural grazing conditions is "healthier, more nutritious, and more natural," which means that grazing is the most demanding way of producing lamb (11). Bernabéu and Tendero (12) revealed origin as the second most important attribute for consumers, next to type of lamb meat. Moreover, several studies have investigated and demonstrated the significance of «origin-locality» information on consumers' valuation and appreciation of traditional food products (5).

In this context, the current work aimed to study the effect of the geographic origin and the grazing system on carcass traits and meat quality of lambs issued from different areas. Accordingly, to characterize the lamb of mountainous areas of the Northwest of Tunisia named «Djebel» in comparison to lamb' meat issued from other feeding system origins.

MATERIAL AND METHODS

Experimental location, feeding and animals

The study was carried out in 2020 at three sites in Tunisia with different sheep production systems. The first region, in the North-West, is mountainous (Djebel) and lambs grazed natural forest' range with dominance of woody species. It is situated at 36° 58 31 North, 9° 04 51 East, and at 37 km from the sea (altitude 500-1000 m). In the second site, in Northeast (East), sheep grazed pasture based on herbaceous fallow pastures with supplementation of hay and concentrate. It is located at 36° 36 30 North, 10° 10 18 East (altitude 44 m), and it is 46 km from the sea. In the third region, located in the Centre-west (Centre), sheep were reared on overgrazed ranges (poor), but they received some supply of hay and concentrate. It is more far from the sea, 151 km, at 35° 50 North, 9° 35 East (altitude 895 m). From each region, 12 male lambs, 6 months-old and weighing averagely 25.8, 26.8, and 22.6 kg for Djebel, East and Centre, respectively were provided.

Slaughter, carcass cutting and sampling procedures

All lambs were transported to the abattoir of the National Institute of Agronomic Researches of Tunisia (INRAT) where they were slaughtered after a fasting of 12 h with only free access to fresh water. All the procedures employed in this study (transport and slaughtering) meet ethical guidelines and adhere to Tunisian legal requirements in accordance with Law no. 2005-95 (18 October 2005). Just before slaughtering, lambs were weighed. After slaughter, the hot carcasses were stored at 4°C for 24 h. After this, cold carcasses were split longitudinally into two halves. The shoulders of the left halves were removed and conserved to estimate the tissular carcass composition. They were dissected into adipose tissue, muscles and bones; each tissue was weighed individually. The tissular composition was calculated through the shoulder tissular composition given this piece is representative of the tissue composition of the entire carcass (13); the carcass composition data were reported as percentages. The *Longissimus thoracis and lumborum* muscle (LTL) was removed from the ribs and loin joints, got rid of adipose tissue and then used for meat quality analyses. It was divided into 5 samples for pH, water cooking loss, chemical composition, colour, TBARS and sensory attributes.

Meat physico-chemical properties

The initial and ultimate pH were measured using a penetrating electrode connected to a portable pH-meter (HI 99163; Hanna Instruments, Romania) after calibration with two buffers (7.01 and 4.01). To determine the water cooking loss (WCL), meat samples were weighed (initial weight, Wi) and held in plastic bags and then immersed in a water-bath (Memmert, Germany), at 75°C and heated for 30 min until the internal temperature reached 75°C, that was monitored with thermocou-

Table 1 - Lambs' tissular composition and meat physico-chemical properties.

	Djebel	East	Centre	SEM	p-value
Tissular composition					
% Muscle	61.5	59.8	59.6	0.81	0.36
% Fat	11.2^{b}	14.8^{a}	12.3^{b}	0.45	0.004
% Bone	23.1	23 .7	25.5	0.46	0.07
Meat physico-chemical properties					
Ultimate pH	6.01^{a}	5.95^{a}	5.55^{b}	0.04	0.001
Water Cooking Loss (%)	21.4^{b}	28.3^{a}	25^{ab}	0.98	0.02
Dry matter (%)	33.1^{b}	29.1^{c}	35.6^{a}	0.34	0.001
Crude protein (%)	16.3^{b}	16.5^{b}	18.3^{a}	0.31	0.04
Meat colour after blooming					
L*	40.8^{b}	44.5^{a}	46.9^{a}	0.55	0.001
a*	15.7	16.33	15.05	0.34	0.33
b*	2.43^{b}	3.29^{a}	1.95^{b}	0.17	0.01

Djebel: lambs issued from the djebel area; **East:** lambs issued from the east area; **Centre**: lambs issued from the centre area

Table 2 - Meat colour and lipid oxidation (TBARS) evolution.

	Origin (O)			Time (T)				Significance		
	Djebel	East	Centre	0	3	6	9	p-O	p-T	p-O*T
L*	47.16[a]	42.65[b]	47.31[a]	44.01	46.49	46.87	45.13	0.001	0.13	0.001
a*	13.74	14.24	13.07	15.71[a]	14.75[a]	12.39[b]	11.93[b]	0.16	0.001	0.001
b*	5.43[a]	3.10[b]	4.04[b]	2.57[c]	6.73[a]	4.55[b]	2.97[c]	0.001	0.001	0.03
C*	15.22	14.73	14.26	16.27[a]	16.42[a]	13.61[b]	12.71[b]	0.27	0.001	0.006
H*	25.64	26.73	27.79	12.02[c]	28.20[b]	30.35[b]	36.37[a]	0.30	0.001	0.14
TBARS (mg MDA/kg meat)	0.229[b]	0.375[a]	0.358[a]	0.186[b]	0.354[a]	0.359[a]	0.373[a]	0.04	0.001	0.001

Djebel: lambs issued from the djebel area; **East:** lambs issued from the east area; **Centre**: lambs issued from the centre area; **p-O:** P-value of the origin; **p-T:** P-value of the time; **p-O*T:** P-value of the interaction between origin and time

ple. Then, the bags were cooled under running tap water and blotted dry with paper towels. The cooked meat was weighed again (final weight, Wf). The WCL was calculated as: 100 × (Wi −Wf)/Wi. The samples of meat were analysed for dry matter (DM) and crude protein according to Association of Official Analytical Chemists (14). The meat DM was obtained after lyophilisation of samples which were then grounded (1 mm screen) and conserved for further chemical composition analyses. Meat Nitrogen (N) was determined by the Kjeldahl method and then the crude protein was calculated as N ×6.25.

Meat colour and Lipid oxidation measurements

Meat colour of LTL samples was measured using a Minolta CR-400 chromameter (Konica Minolta Holdings, Osaka, Japan). The LTL samples were wrapped with oxygen permeable PVC film, randomly assigned to 4 trays (0, 3, 6, and 9 days of storage), and kept in darkness at 4 °C. On each day of colour measurement, samples were measured twice and averaged. Colour coordinates (L*, a*, b*) were measured and C*, H* were calculated in the CIELAB space (15).

After colour measurement, the lipid oxidation (TBARS) assay was performed according to the method of Botsoglou et al. (16) where, 10 g of meat were homogenized with 20 ml of 10% trichloroacetic acid using an Ultra-Turrax (T25; IKA-Labortechnik, Staufen, Germany) for 15 seconds at 13,500 rpm. After homogenization, the mixture was centrifuged at 4000 rpm and 4°C for 30 min. The supernatant was decanted through a paper filter. Then, 2 ml of the filtrate was vortexed with 2 ml of thiobarbituric acid. The tubes were homogenized and incubated at 97°C in a water bath for 20 min to develop a pink absorbance. After cooling, the absorbance of sample was read against the appropriate blank at 532 nm by a spectrophotometer (Thermo Electron Corporation) and the TBARS values were expressed as milligrams of malondialdehyde (MDA) per kilogram of muscle.

Meat Sensory evaluation

After 3 days of storge, the meat samples, unsalted, were wrapped in aluminium foil and placed in a preheated oven at 180 °C for 30 min until the core temperature reached 71°C. Immediately after cooking, each sample was equally divided into 10 pieces, placed on white plastic trays, and individually marked with random digits for evaluation. The sensorial panel was made up of trained members and remained consistent throughout the sensory analysis of meat samples, as recommended by AMSA (17). There were 10 members and each one evaluated 36 samples issued from all lambs in 5 sessions. Panellists rated meat sample for different attributes on a nine-point hedonic scale corresponding to the intensity of their different feelings for each attribute. They were asked to note the tenderness (1 = extremely tough, 9 = extremely tender), juiciness (1 = extremely dry, 9 = extremely juicy), flavour (1 = very poor, 9 = very good), and the overall impression (1 = not acceptable, 9 = extremely acceptable).

Statistical analysis

A one-way analysis of variance for the lamb's geographic origin effects on carcass and non-carcass traits, tissular composition, physico-chemical properties and sensory attributes using GLM procedure in SAS was applied. Data concerning meat colour and lipid oxidation (TBARS) evolution during 9 days of storage were analysed using the MIXED procedure of repeated measures. The analyses were performed with origin (O) as between-subject fixed effect, storage time (T) as a within-subject effect and animal as random effect. The means were compared by the Duncan's multiple range test and the significance was set at 5% and trends were discussed for p-values < 0.05.

Table 3 - Lamb' meat sensory properties.

	Djebel	East	Centre	SEM	p- value
Tenderness	5.0	4.95	5.33	2.06	0.58
Juiciness	4.93	4.79	5.20	1.90	0.49
Flavor	5.16[a]	4.36[b]	5.77[a]	1.99	0.001
Overall impression	5.09[a]	4.22[b]	5.6[a]	1.95	0.001

Djebel: lambs issued from the djebel area; **East:** lambs issued from the east area; **Centre**: lambs issued from the centre area

RESULTS AND DISCUSSION

Carcass tissular composition

The carcass tissular composition was shown in Table 1. The tissues' proportions were affected by lamb's origin expect to muscle proportion which was similar for all lambs and averaged approximately 60% ($P>0.05$). The lack of diet effect on lean proportions was the consequence of the similarity in warm carcass weight (18). The similarity in the bone proportion can be explained by the fact that bone formation and development depend mostly on animal breed and age, not on its feeding condition (19). The East group presented a higher fat proportion, which may be attributed to differences in grazing systems. Fat deposition in lambs could be influenced by some factors such as nutritional intake and the efficiency of nutrient utilization (20).

Meat physico-chemical properties

The meat pH, water cooking loss, dry matter and protein values are summarized in Table 1. A significant difference between groups in the ultimate pH was observed ($P<0.05$). The pH was higher for Djebel and East than Centre group. This observed difference in meat pH may be attributed to differences in glycogen levels in muscles and pre-slaughter stress (21), since the pH is a vital index affecting the muscle glycolysis level (22). Additionally, Priolo et al. (23) linked higher ultimate pH levels to the physical activity of animals and extensive production systems. The high antioxidant capacity could generate a decrease in glycolytic potential through the improvement of cell membranes' stability, which led to differences in the pH (22). Despite these differences, the ultimate pH averaged 5.83 for all groups being in the recommended values to avoid meat quality deterioration (24). The water cooking loss was significantly higher for East and Centre groups compared to Djebel one. This difference could be generated by the difference in the ultimate pH. It was shown that a low ultimate pH leads to higher cooking loss in meat proteins, whereas a higher ultimate pH results in lower cooking loss (21). In fact, the meat issued from Djebel group with the highest pH, had the lowest water cooking loss. The higher values of dry matter and protein were recorded in meat issued from Centre groups compared to Djebel and East groups. The crude protein content for all groups was lower than that of lambs of the Spanish breeds that averaged 22% (25). For meat colour after blooming, the lamb's origin affected meat only L* and b*. The L*, which reflects the degree of lightness, was lower for Djebel than both other groups. It was shown that the lightness of meat was lower for grass-fed lambs than those fed concentrate (26). In fact, Djebel lambs were exclusively reared on grazing-past while Centre and East lambs received concentrate supply. The L* exceeded 40 for all groups, equal and superior values to 34 are acceptable by consumers for sheep meat (27). The redness was ranged between 15 and 16.3, being superior to 14.5 for all groups, assuring the acceptability of 95 % of consumers (28). Hence, the meat of these lambs should be well acceptable by consumers. The yellowness was the highest for the East group reared on platteland, however Dou et al. (22) recorded lower b* and higher a* for this kind of pasture compared to mountain-grazing.

Lipid oxidation (TBARS) and colour stability

The lipid oxidation (TBARS) or the content of MDA was significantly affected ($P<0.05$; Table 2) by lamb's origin, the time of display ($P = 0.0001$) and their interaction ($P= 0.001$) was also significant. The TBARS evolution among 9 days was reported in Fig. 1. The MDA is an index of lipid oxidation that affects consumer acceptance (22). The content of MDA in the LTL muscle of the Djebel group was decreased (0. 229 mg MDA/ kg of meat) indicating a lower degree of lipid oxidation than that of both other groups (0.375 and 358 mg MDA/ kg meat for East and Centre groups, respectively). This result could be originated by to differences in the composition of the forage

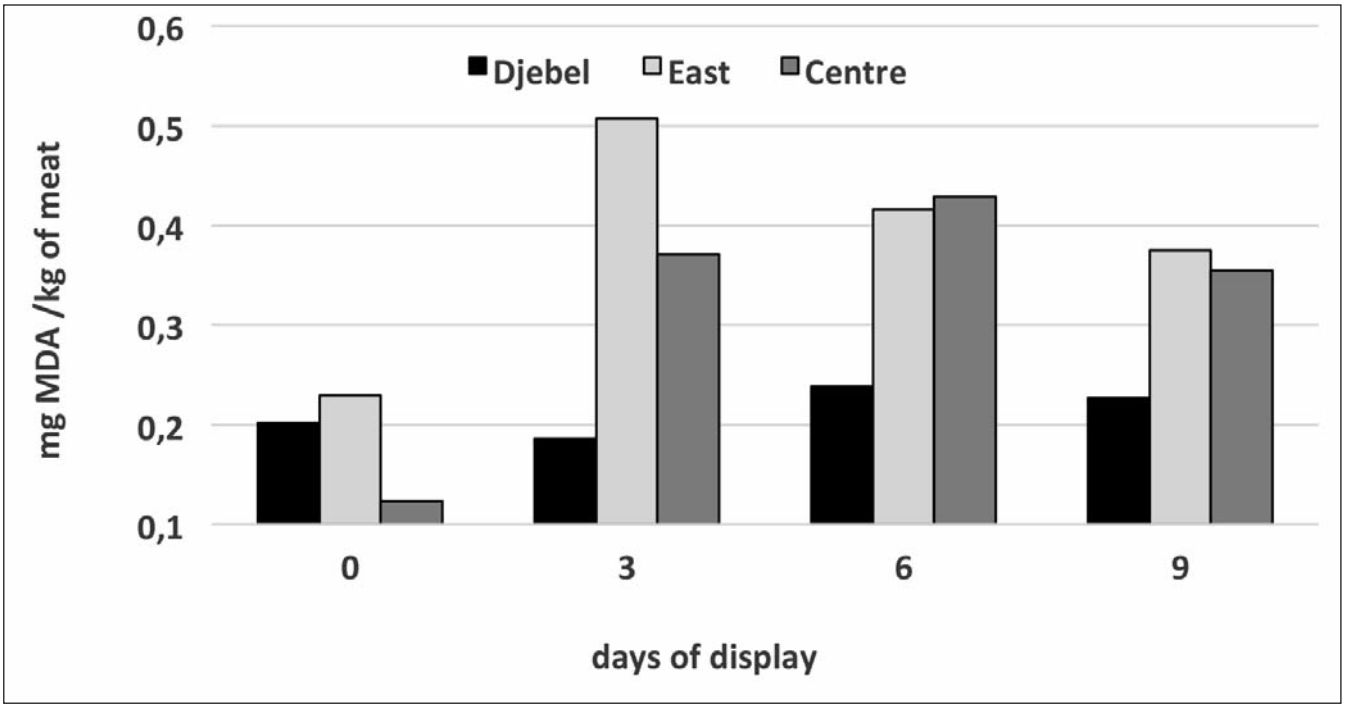

Figure 1 - Lipid oxidation evolution.
Djebel: lambs issued from the djebel area; **East:** lambs issued from the east area; **Centre:** lambs issued from the centre area.

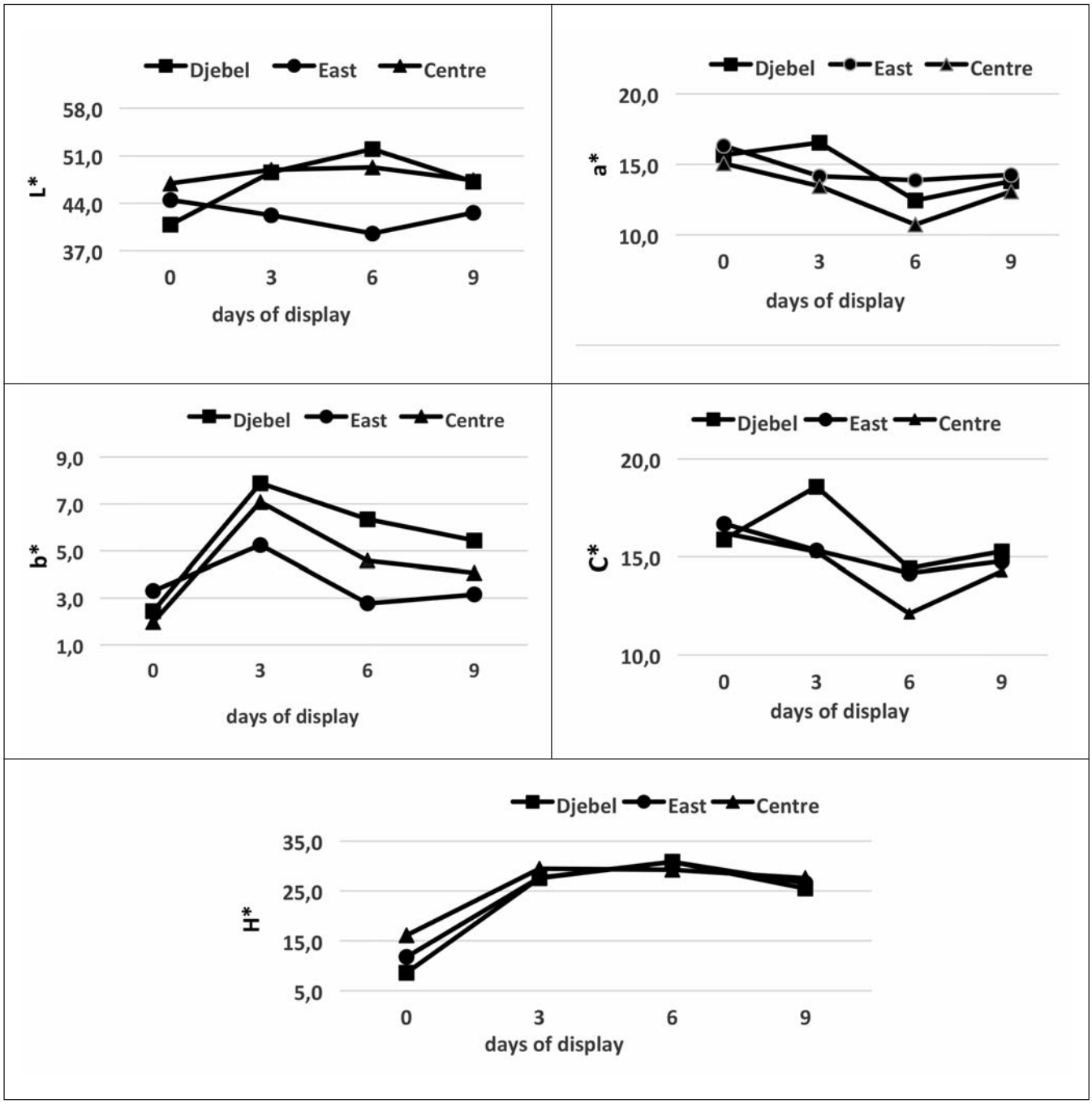

Figure 2 - Meat colour parameters evolution.
Djebel: lambs issued from the djebel area; **East:** lambs issued from the east area; **Centre:** lambs issued from the centre area.

and the feeding level and composition under the three feeding systems (22). The diet for the Djebel group was based on forest pasture rich in natural antioxidant, which resulted in a high antioxidant power of the meat as previously reported for goats (29). However, the lipid oxidation increased over the storage time, as expected, from 0.186 (d0) to 0.359 mg MDA/ kg of meat (d9). The TBARS values increased regardless the origin (Fig. 2) from day 3 especially for East and Centre groups however for D group the TBARS values seems constant during the first 3 days, however, for all groups, The TBARS values remained below the suggested threshold of acceptability of 1 mg MDA/Kg of meat (30). Compared to the meat of both groups grazing pasture based on herbaceous fallow with supplementation of hay and concentrate, the meat issued from lambs of Djebel group showed a higher resistance to oxidation up to 9 days of storage. The diet based on grazing of natural vegetation dominated by trees and shrubs rich in natural substances leads to a preservation of MDA formation, this phenomenon was observed for goats raised under forest conditions (22;29). The higher antioxidant capacity of lambs of the mountainous area could be the result of natural substances intake coupled with an appropriate amount of exercise, which promoted an increase in the antioxidant capacity of meat as recently suggested by Dou et al. (22).

The Table 2 summarized the lamb's colour parameters results. The lamb's origin affected meat lightness (L*) and yellowness (b*), but failed to affect redness (a*), chroma (C*) and hue angle (H*). All colour attributes were affected by storage time ex-

cept the lightness, which was unchanged during 9 days of display (Fig.2). For all days of storage, lightness (L*) values presented by all groups averaged 45 indicating a light-coloured meat, being in the range of average acceptability of meat but beyond 44 which is considered the value of acceptability by 95% of consumers (27). The recorded values of redness during storage were within these recommended values regardless the lamb's origin. The higher yellowness (b*) value was recorded for Djebel group than both other groups. This result could be attributed to the feeding system given; the meat colour tended to be more yellow in grass-based diets and this supremacy could be related to the richness of the diet in carotenes responsible of yellowness index (18). The chroma (C*) value was similar for all groups, however, the recorded values during storage decreased from 16.27 to 12.71 at day 9 which confirmed previous results showing that C* decreased as storage progressed resulting in pigment oxidation for lamb's meat (18).

Sensory evaluation

The lamb's origin had no effect on meat tenderness and juiciness (P>0.05; Table3) and meat of all groups was then, judged averagely tender (4.95-5.33) and juicy (4.79-5.20). Similar results were found for kids conducted under forest extensive system and forest-semi-intensive production system (29) but with higher attributed scores (6.4 and 7, respectively). However, Priolo et al. (23) found that meat of lambs raised on the pasture is less tender than those kept in the stall management system. For juiciness, Slimeni et al. (29) reported similar results among groups averaging 6 and thus meat was considered to be moderately juicy. The flavor and the general impression were significantly higher for Djebel and Centre groups compared to East (P<0.05). This difference could be originated by the difference in feeding systems among lambs. Besides, grazing natural pasture increased the meat flavor intensity and healthy fatty acid content of lamb meat (4). It was found that grazing regimen greatly affected the number of volatile flavor compounds, as evidenced by the enriched variety of volatile flavor compounds (22). Globally, the meat issued from Djebel and Centre groups were more accepted than that from East group given, the evaluation gave means greater than 5.0 compared to B group (4.22).

CONCLUSION

This study highlights the importance of meat origin given the increasingly demand of consumers for a high product quality and their need for identity. The results indicate that lambs grazing on mountain trees and shrubs exhibit higher quality attributes compared to those on lowland pastures. The forest-based feeding system enhances the meat's nutritional value due to its high content of antioxidants, which extend meat shelf life through preservation from lipid oxidation resulting in a meat without undesirable health effects.

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Author's contribution

YY: contributed in the laboratory analyses, analysed the data statistically and wrote the first draft manuscript; **IM:** conducted the experiment and contributed in the laboratory analyses**; ST:** contributed in the laboratory analyses; **SS:** conducted the experiment and contributed in the laboratory analyses**; NA**: conceived and designed the experiment, and revised the manuscript. All authors read and approved the manuscript.

Conflict of interest

The authors declare that they have no conflict of interest.

References

1. Font-i-Furnols, M., and Guerrero, L. 2022. Understanding the future meat consumers. *Meat. Sci.*, 193: 108941.
2. Godfray, H.C.J., Aveyard, P., Garnett, T., Hall, J.W., Key, T.J., Lorimer, J., Pierrehumbert R.T., Scarborough P., Springmann M., and Jebb, S. A. 2018. Meat consumption, health, and the environment. *Sci.*, 361 : 1-8.
3. Leroy, F., Smith, N.W., Adesogan, A.T., Beal T., Iannotti L., Moughan P.J., and Mann L. 2023. The role of meat in the human diet: evolutionary aspects and nutritional value. *Anim. Front.*, 13 : 11-18. https://doi.org/10.1093/af/vfac093
4. Ke, T., Zhao, M., Zhang, X., Cheng, Y., Sun, Y., Wang, P., Ren, C., Cheng, X., Zhang, Z., and Huang, Y. 2023. Review of Feeding Systems Affecting Production, Carcass Attributes, and Meat Quality of Ovine and Caprine Species. *Life.*, 13 : 1215.
5. Hersleth, M., Lengard, V., Verbeke, W., Guerrero, L., and Næs, T. 2011. Consumers' acceptance of innovations in dry cured ham: Impact of reduced salt content, prolonged aging time and new origin. *Food. Qual. Pref.*, 22 : 31-41.
6. Guerrero, L., Guardia, M. D., Xicola, J., Verbeke, W., Vanhonacker, F., Zakowska- Biemans, S., Sajdakowska, M., Sulmont-Rossé, C., Issanchou, S., Contel, M., Scalvedi, M.L., Granli, B.S., and Hersleth, M. 2009. Consumer-driven definition of traditional food products and innovation in traditional foods. A qualitative cross-cultural study. *Appetite.*, 52 (2): 345-354.
7. Henderikx, F. 2017. Labelling of food : a challenge for many. *Veterinarski Glasnik.*, 71(1):16-23.
8. Vasilev, D., Dimovska, N., and Hajrulai-Musliu, Z. 2020. 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.*, 162 : 108020. doi: 10.1016/j.meatsci.2019.108020
9. Hersleth, M., Næs, T., Rødbotten, M., Lind, V., and Monteleone, E. 2012. Lamb meat -Importance of origin and grazing system for Italian and Norwegian consumers. *Meat Sci.*, 90(4) : 899-907.
10. Prache, S., Schreurs, N., and Guillier, L. 2022. Factors affecting sheep carcass and meat quality attributes. *Animal.*, 16, 100330.
11. Liu, Y., Li, R., Ying, Y., Zhang, Y., Huang, Y., Wu, H., and Lin, K. 2022. Non-genetic factors affecting the meat quality and flavor of Inner Mongolian lambs : A review. *Front. Vet. Sci.*, 9 :1067880.
12. Bernabéu, R., and Tendero, A. 2005. Preference structure for lamb meat consumers. A Spanish case study. *Meat Sci.*, 71(3) : 464-470.
13. Yagoubi, Y., Smeti, S., Ben Saïd, S., Srihi, H., Mekki, I., Mahouachi, M., and Atti, N. 2021. Carcass traits and meat quality of fat-tailed lambs fed rosemary residues as a part of concentrate. *Animals.*, 11(3) : 655.
14. AOAC. 1990. Official Methods of Analysis of the Association of Official Analytical Chemists, Vol. II, 15th ed. Sec.985.29. The Association: Arlington, VA.
15. CIE, 1986. Colorimetry, 2nd ed. Vol. nº 15.2. Centre Inter-national de l'Eclairage, Vienna.
16. Botsoglou, N. A., Govaris, A., Giannenas, I., Botsoglou, E., and Papageorgiou, G. 2007. The incorporation of dehydrated rosemary leaves in the rations of turkeys and their impact on the oxidative stability of the produced raw and cooked meat. Int. J. Food. Sci.Nut., 58 : 312-320.
17. AMSA (2012). Meat Color Measurement Guidelines. Chicago, IL: American Meat Science Association.
18. Yagoubi, Y., Hajji, H., Smeti, S., Mahouachi, M., Kamoun, M., and Atti, N. 2018. Growth performance, carcass and non-carcass traits and meat quality of Barbarine lambs fed rosemary distillation residues. *Animal.*, 12 : 2407-2414.
19. Smeti, S, Atti, N, Mahouachi, M. 2014. Effects of finishing lambs in rich aromatic plant pasture or in feedlot on lamb growth and meat quality. *J. Appl. Anim. Res.*, 42 : 297-303.
20. Atti, N., Rouissi, H. and Mahouachi M. 2005. Effects of restricted feed-

ing and re-feeding of Barbarine lambs: Carcass composition and fatty acid composition. *Anim. Sci*., 81: 313-318.
21. Suliman, G.M, Al-Owaimer, A.N., El-Waziry, A.M., Hussein, E.O.S., Abuelfatah, K., and Swelum, A.A. 2021. A Comparative Study of Sheep Breeds: Fattening Performance, Carcass Characteristics, Meat Chemical Composition and Quality Attributes. *Front Vet Sci*., 19: 647192.
22. Dou, L., Jin, Y., Li, H., Liu, C., Yang, Z., Chen, X., Sun, L., Zhao, L., and Su, L. 2023. Effect of Feeding System on Muscle Fiber Composition, Antioxidant Capacity, and Nutritional and Organoleptic Traits of Goat Meat. *Animals*., 13 : 172.
23. Priolo, A., Micol, D., Agabriel, J., Prache, S., and Dransfield, E. 2002. Effect of grass or concentrate feeding systems on lamb carcass and meat quality. *Meat Sci*., 45 : 169- 181.
24. Majdoub-Mathlouthi, L., Saïd, B., Say, A., and Kraiem, K. 2013. Effect of concentrate level and slaughter body weight on growth performances, carcass traits and meat quality of Barbarine lambs fed oat hay-based diet. *Meat Sci*., 93: 557-563.
25. Panea, B., Ripoll, G., and Alcalde, M. J. 2023. Nutritional quality of meat from barren merino ewes in comparison to meat from traditional lambs. *Animals*., 13(17) : 2756.
26. Cañeque, V., Valesco, S., Diaz, M.T., De Huidobro, F.R., Perez, C., and Lauzurica S. 2003. Use of whole barley with a protein supplement to fatten lambs under different management systems and its effect on meat and carcass quality. *Anim. Sci*., 52: 271-285.
27. Khliji, S., Van de Ven, R., Lamb, T.A., Lanza, M., and Hopkins, D.L. 2010. Relationship between consumer ranking of lamb colour and objective measures of colour. *Meat Sci*., 85: 224-9.
28. Vahmani, P., Ponnampalam, E.N., Kraft, J., Mapiye, C., Bermingham, E.N., Watkins, P.J., Proctor, S.D., and Dugan, M.E.R. 2020. Bioactivity and Health Effects of Ruminant Meat Lipids. Invited Review. *Meat Sci*., 165 : 108114.
29. Slimeni, O., Hajji, H., Mekki, I., Smeti, S., Mahouachi, M., Saidani, F., and Atti, N. 2022. Is it possible to increase goat meat production under Mediterranean forest conditions using small amounts of concentrate without deterioration of its quality? *Anim. Sci. Pap. Rep*., 40 : 335-350
30. Ripoll, G., Joy, M., and Muñoz, F. 2011. Use of dietary vitamin E and selenium (Se) to increase the shelf life of modified atmosphere packaged light lamb meat. *Meat Sci.,* 87 : 88-93.

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