

WELFARE AND MEAT QUALITY OF LAMBS

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Abstract

Recently, in many parts of the world, greater importance has been given to lamb meat as well as to the intensive production of lamb and sheep, due to demand for this type of meat at affordable prices. In Serbia, similar to most European countries, the structure of total sheep meat production comprises about 70% lamb meat and 30% sheep meat. This study assessed resource-based measures on 11 dairy sheep farms and investigated, in a total of 30 lambs, the effects of sex, the presence of bruises and pneumonia in carcasses, and carcass and meat quality. Carcass (carcass length, thigh length, croup width, subcutaneous fat thickness, presence of bruises) and meat quality (pH, temperature, drip, thawing and cooking losses, color, and meat quality classes)

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traits were measured *post mortem*. The most common deficiencies on farms were high stocking density, poor hygienic conditions, dirty drinkers, and lack of outdoor access. Regarding sex differences, higher prevalences of carcass bruises and severe pneumonia were recorded in male lambs. Meat pH ($\text{pH}_{45\text{min}}$), sensory color score, and prevalence of dark, firm and dry (DFD) meat were higher in lambs with carcass bruises. The occurrence of quality defects (DFD meat) was higher in lambs with severe pneumonia. It can be concluded that it is necessary to improve the welfare conditions on the lamb farms and pre-slaughter conditions in order to achieve better lamb meat quality.

Key Words: carcass, lamb, meat quality, welfare

INTRODUCTION

Serbia has a population of 1 711 677 sheep (FAOSTAT, 2018), and like in most European countries, the structure of total sheep meat production comprises about 70% lamb meat and the rest, sheep meat (Petrović et al., 2010). Consumers are becoming increasingly demanding with regard to food, not only in terms of taste, aroma, the environment, and sustainability, but also that the food comes from animals with adequate welfare conditions in the meat production chain from farm to slaughterhouse (Phillips et al., 2009). This means the welfare of farm animals is a growing public concern.

Intensive sheep production systems with poor housing hygiene, unacceptably high stocking density, inappropriate ventilation rates, and without outdoor access cause stress to the animals, the appearance of aggressive behavior, and reduce daily weight gain and growth rate of animals (Caroprese, 2008; Dwyer, 2008). It is expected that meat animals experience some level of stress prior to slaughter, and this, in turn, could have detrimental effects on meat quality (Miranda-de la Lama et al., 2010; Gallo et al., 2018).

What is also known is that improper handling at the slaughterhouse (use of electric prods, slipping in the stunning box, missed stuns, sharp edges on equipment), novel/unfamiliar environments, food and water deprivation, changes in social structure, and changes in climatic conditions lead to a number of negative consequences in the form of death, poor meat yield, spotting in the meat, bruises and skin damages, broken bones, carcass contamination, and development of the meat quality defect, dark, firm, and dry (DFD) meat (Vergara et al., 2005; Grandin 2007; Mikuš et al., 2016; Gallo et al., 2018).

In Serbia, no systematic survey of sheep farm conditions from the animal welfare point of view has been assessed. Therefore, the aim of this study was to examine the welfare conditions of lambs on the farm and at slaughterhouse, as well as to connect these preconditions with the carcass and meat quality examined parameters.

MATERIALS AND METHODS

Resource-based measures

The study was carried out in the period of June-July 2020. The data were obtained from 11 farms (104 ± 23 average number of animals), the primary purpose of which was to rear dairy sheep, while part of the lambs are sold for slaughter. The welfare assessment was conducted between 09:00 h and 16:00 h by two assessors, using the AWIN welfare assessment protocol for sheep (AWIN, 2015), which is grouped into 12 welfare criteria based on principles of good feeding, good housing, good health, and appropriate behavior. In this study, only the following resource-based measures were used: water availability, stocking density, and access to external areas.

Animals, transport, and lairage

The study was carried out on 30 lambs (16 males, 14 females), Romanov breed, about 5 months old, with the average live weight of 31 kg. All lambs originated from two different farms. We chose lambs only from two the most representative farms. The transport of animals from the farm to the slaughterhouse took less than 60 min. After arrival at the slaughterhouse, the lambs were transferred to the lairage, where they remained for less than 3 h at the stocking density of 0.4 m²/lamb. During lairaging, lambs were deprived of food and water. Slaughter of the lambs and carcass processing were conducted following the standard industry-accepted practices by the same personnel.

Carcass quality

External carcass length (from the midpoint of the front face of the atlas to the articulation of the last sacral vertebra with the first caudal vertebra), thigh length (from the cranial margin of the pubic symphysis to the medial malleolus), and croup width (maximum width at the level of trochanters) were determined 24 h after slaughter as recommended by Sabbioni et al. (2016). The presence of bruises on lamb carcasses was assessed in a cold chamber 45 min after slaughter, based on the method described by Tarumán et al. (2018). For the qualitative evaluation of carcass quality, subcutaneous fat thickness and conformation were evaluated 45 min after slaughter (Council Regulation (EEC) No 2137/92, 1992). Subcutaneous fat thickness was evaluated subjectively by the quantity and distribution on the outside of the carcass varying from 1 (very thin) to 5 (very fat).

Meat quality

Both pH ($\text{pH}_{45\text{min}}$ and $\text{pH}_{24\text{h}}$) and temperature ($T_{45\text{min}}$ and $T_{24\text{h}}$) of the *Musculus longissimus dorsi* were measured (in triplicate) 45 min and 24 h postmortem on the left half of the carcass using a pH meter (Testo 205, Testo AG, Lenzkirch, Germany).

For determination of water holding capacity, two boneless loin samples (*Musculus longissimus dorsi*) were cut 24 h postmortem by trained slaughterhouse personnel from each selected carcass. To evaluate water holding capacity, drip loss, thawing loss, and cooking loss were determined according to Honikel (1998), as described in Čobanović et al. (2020). Subjective meat color was evaluated 45 minutes postmortem on the *Musculus rectus abdominis* according to the European Union color standard (1994). Meat quality classes were determined using pH values measured 24 h after slaughter according to Gallo et al. (2018). The carcasses showing pH_{24h} values higher than 6.2 were classified as DFD lamb meat, while the carcasses showing pH_{24h} values lower than 6.2 were classified as normal lamb meat.

Health indicators

The plucks of slaughtered lambs, consisting of the heart, lungs, and liver, were removed from the carcasses by slaughterhouse personnel. Afterwards, eviscerated lungs were examined visually, by a trained investigator using the palpation technique, for gross lesions of pneumonia. Pneumonic lesions were defined as compacted, dark purple-red areas of the lung that were firm to touch. Pneumonic lesions were scored at the individual level using a 5-point scale based on the method described earlier (McRae et al., 2016). Each of the five lobes was scored from 0 to 5 depending on the percentage of the lobe affected: 0 = no lesions present; 1 = small lesions; 2 = approximately 25% of the lobe affected; 3 = approximately 50% of the lobe affected; 4 = approximately 75% of the lobe affected, and; 5 = 100% of the lobe affected. The sum of the individual lobe scores was calculated and recorded as a total lesion score. Total lesion scores of 1 to 9 indicated mild pneumonia, while a score ≥ 10 to 25 was regarded as severe pneumonia.

Statistical analysis

Data were analyzed using Graph Pad Prism 7.0 software. Based on sex, lambs were divided into the following two groups: males (n=16) and females (n=14). Bearing in mind that the degree of injuries on carcasses was the same in all lambs with bruises (length from 6 to 10 cm, located in the middle of the carcass), the individuals were divided into two categories: without bruises (n=10) and with bruises (n=20). Based on the presence and the degree of pneumonic lesions, lambs were classified into two groups: mild changes - individuals with a cumulative score for pneumonic lesions between 0 and 10 (n=6); severe changes - individuals with a cumulative score for pneumonic lesions ≥ 10 and (n=24). All results were described by descriptive statistic parameters - mean value and standard deviation. The t-test was used to examine the differences between the mean values of the two examined groups. Fisher's exact test was used to determine the differences between the prevalence of two different treatments such as the effect of sex on meat and carcass quality between males and females, effects of carcass bruises on meat quality between the lambs with presence and

absence of bruises and effects of pneumonia severity on the meat and carcass quality between lambs with mild and severe pneumonia. In all statistical tests, significance of differences was determined at the significance levels of $p \leq 0.05$, $p < 0.001$, while p -values between >0.05 and <0.10 were considered a tendency.

RESULTS

Resource-based measures

Survey results of resource-based measures of the farms are depicted in Table 1. The average number of animals per farm was 105 ± 77 . The most common breed was Ile de France (54.54%, 6/11), followed by Romanov (18.18%, 2/11), Suffolk (18.18%, 2/11), and Bergamo (9.10%, 1/11). The number of lambs per pen ranged from 3 to 70 (32 ± 21). Regarding stocking density, four farms had less than $1.5 \text{ m}^2/\text{animal}$, five farms had 1.5 to $2 \text{ m}^2/\text{animal}$, and two farms had more than $2 \text{ m}^2/\text{animal}$. Dirty litter and drinkers were observed on five and six farms, respectively. Outdoor access was recorded on six farms (6/11, 54.54%).

Table 1. Resource-based measures of the examined farms ($n = 11$)

Farm number	Breed	Total number	Lambs	Pen dimensions (m ²)	Stocking density (m ² /animal)	Litter cleanliness	Type of water points	Drinker cleanliness	Outdoor access
I	Romanov	130	50	72(n=2)	1.1	NO	trough	YES	NO
II	Bergamo	130	30	105 (n=2)	2.65	YES	trough	NO	NO
III	Ile de France	102	20	20	1.8	NO	trough	YES	YES
				187.5	2.67	NO	trough	YES	YES
IV	Suffolk	33	9	40	1.66	YES	trough	NO	YES
V	Ile de France	120	30	160	1.77	YES	trough	NO	NO
VI	Romanov	13	3	11.28	1.17	YES	bucket	NO	YES
				15.83	0.83	NO	trough	YES	NO
				20.79	1.3	NO	trough	YES	NO
				17.72	1.8	NO	trough	YES	NO
VII	Ile de France	90	30	17.72	1.40	NO	trough	YES	NO
VIII	Ile de France	23	4	19.14	1.0	NO	bucket	YES	NO
IX	Suffolk	120	70	80	1.6	YES	trough	NO	YES
X	Ile de France	92	52	70	1.75	YES	bucket	YES	NO
XI	Ile de France	300	50	336	1.4	NO	trough	YES	YES

Effects of sex, presence of carcass bruises, and pneumonia severity on carcass and meat quality of fattening lambs

Effects of sex on the carcass and meat quality of fattening lambs are shown in Table 2. Meat variables did not differ between sexes. Higher presence of carcass bruises ($p < 0.05$) and severe pneumonia ($p < 0.001$) were found in male lambs, while higher subcutaneous fat thickness ($p < 0.05$) was found in female lambs. The tendency of a higher carcass length and greater thawing loss was found in males compared to females.

Table 2. Effects of sex on meat and carcass quality of lambs (n=30)

Parameters	Sex		p-value
	Males (n=16)	Females (n=14)	
	Mean± SD	Mean± SD	
Carcass quality			
Carcass length (cm)	63.00±3.22	60.50±3.16	0.09 ^t
Thigh length (cm)	15.71±1.74	15.19±1.13	0.46
Croup width (cm)	11.63±0.77	12.25±1.28	0.18
Bruises (%)	75.00	57.14	0.02 [*]
Subcutaneous fat thickness	1.94±0.68	2±0.55	0.78
Severe pneumonia (%)	93.75	64.28	0.00 ^{***}
Meat quality			
pH _{45min}	6.72±0.41	6.90±0.33	0.21
T _{45min} (°C)	32.50±3.70	32.24±3.45	0.84
pH _{24h}	6.15±0.16	6.14±0.16	0.81
T _{24h} (°C)	3.80±0.33	3.56±0.37	0.07
Drip loss (%)	4.88±2.98	3.25±0.92	0.23
Thawing loss (%)	4.69±1.16	3.05±1.27	0.07 ^t
Cooking loss (%)	24.53±9.99	24.75±4.50	0.96
Sensory color score	1.06±0.77	1.21±0.70	0.57
Normal meat (%)	50.00	50.00	1.00
DFD meat (%)	50.00	50.00	1.00

* $p < 0.05$; *** $p < 0.001$; t - tendency (p-values between > 0.05 and < 0.10); DFD - dark, firm and dry lamb meat

The effects of carcass bruises on meat quality of fattening lambs are shown in Table 3. Higher meat pH_{45min} and sensory color score ($p < 0.05$) were measured in the lambs with carcass bruises. Bruised carcasses produced a greater prevalence of DFD meat ($p < 0.001$). A tendency for a higher T_{45min} was found in lambs without bruises.

Table 3. Effects of carcass bruises on meat quality of lambs (n=30)

Parameters	Carcass bruises		p-value
	Presence (n=20)	Absence (n=10)	
	Mean± SD	Mean± SD	
pH _{45min}	6.90±0.29	6.60±0.45	0.03*
T _{45min} (°C)	31.56±3.22	34.01±3.71	0.07t
pH _{24h}	6.17±0.15	6.09±0.16	0.22
T _{24h} (°C)	3.67±0.39	3.73±0.33	0.68
Drip loss (%)	4.01±0.95	3.87±2.81	0.53
Thawing loss (%)	4.19±1.17	3.59±1.54	0.71
Cooking loss (%)	23.64±7.17	28.74±0.16	0.36
Sensory color score	0.95±0.69	1.50±0.71	0.04*
Normal meat (%)	40.00	70.00	0.00***
DFD meat (%)	60.00	30.00	0.00***

* p<0.05; *** p<0.001; t – tendency (p-values between >0.05 and <0.10); DFD - dark, firm and dry lamb meat

Table 4. Effects of pneumonia severity on the meat and carcass quality of fattening lambs (n=30)

Parameters	Pneumonia severity		p-value
	Mild (n=6)	Severe (n=24)	
	Mean± SD	Mean± SD	
Carcass quality			
Carcass length (cm)	59.00±7.07	62.33±2.91	0.18
Thigh length (cm)	15.00±1.4	15.56±1.55	0.63
Croup width (cm)	11.50±2.12	11.92±0.94	0.59
Subcutaneous fat thickness	2±0.66	1.83±0.41	0.56
Meat quality			
pH _{45min}	6.96±0.21	6.77±0.40	0.28
T _{45min} (°C)	31.00±3.17	32.72±3.60	0.29
pH _{24h}	6.21±0.15	6.13±0.16	0.27
T _{24h} (°C)	3.52±0.43	3.73±0.34	0.20
Drip loss (%)	3.66±0.78	4.07±2.65	0.91
Thawing loss (%)	3.60±1.18	3.79±1.68	0.91
Cooking loss (%)	25.54±5.45	24.08±7.84	1.00
Sensory color score	1.17±0.75	1.13±0.74	0.90
Normal meat (%)	58.33	16.66	0.000***
DFD meat (%)	41.66	83.33	0.000***

*** p<0.001; DFD - dark, firm and dry lamb meat

The effects of pneumonia severity on the carcass and meat quality of fattening lambs are shown in Table 4. The prevalence of DFD meat was higher ($p < 0.001$) in the lambs with severe pneumonia, while the prevalence of normal meat was higher ($p < 0.001$) in lambs with mild pneumonia.

DISCUSSION

Sheep and lambs are gregarious and non-aggressive animals characterized by a state of fear, anxiety, and frustration that can be caused by even simple husbandry operations and by their limited adaptability to indoor confinement (Fitzpatrick et al., 2006). Many factors can affect and improve the health and welfare of housed sheep, like providing free access to outdoor areas, protection from thermal extremes, sufficient space allocation, and appropriate control of indoor climate, hygiene, ventilation, and light regimes (Sevi et al., 1999; Casamassima et al., 2001; Dwyer, 2008). In the present study, it was observed that the most common deficiencies on farms were high stocking density, poor hygienic conditions, dirty drinkers, and lack of outdoor access. The increase in stocking density influences profoundly the quality of air, in terms of airborne microorganisms, gases, and dust, thus negatively affecting the health and welfare of farmed animals (Caroprese, 2008, Čobanović et al., 2019). According to Casamassima et al. (2001), providing free access to outdoor areas had beneficial effects on immune reactivity, behavioral activities, and production performance of sheep.

No significant differences were found between the sexes in our lambs in the subcutaneous fat thickness, although females had a slightly higher values than males. Other authors found that the female carcasses were significantly more covered with adipose tissue than were male carcasses (Lind et al., 2010; Sabbioni et al., 2016). Slightly higher subcutaneous fat thickness in females can be explained by the fact that female lambs have a slower growth rate than male lambs and display a greater tendency to accumulate fat from an early age (Sañudo et al., 1998). According to de Lima et al. (2016), female carcasses are often richer in lipids compared to carcasses from male individuals. We also found that sex affected the presence of bruises, whereby a higher percentage of carcass bruise lesions was recorded in male lambs. This might be the result of social mixing of unfamiliar lambs and increasing agonistic interactions, as males initiated significantly more aggressive interactions than females (including head-to-head clashes, head-to-body buttings, and mountings) (Sevi et al., 2001). Sex did not significantly affect meat pH nor its rate of decrease, which agrees with the findings of Vergara (1999), who also failed to find an effect of sex on meat pH, suggesting that both sexes respond equally to stress at slaughter at these early ages.

The presence or absence of carcass bruises is one of the main welfare indicators regarding the management of fattening lambs during the pre-slaughter period (Grandin, 2007). In agreement with Taruman et al. (2018), the predominant anatomical location of carcass bruises in the present study was loin, presumably due to handlers pulling the lambs by grabbing the wool on their back. This supports findings of Jarvis

and Cockram (1994), who found a relationship between the occurrence of wool pulls by handlers and bruising on the lamb carcasses. Meat quality analysis revealed that the presence of carcass bruises was associated with a higher meat pH_{45min} and the occurrence of DFD meat. This shows that stressors like harsh handling and exposure to aggressive handler behavior, undergone previous to slaughter when bruises occurred the most, is one of the main factors that affected meat pH.

Our study also showed a high percentage of pneumonic lesions in fattening lambs (80.00%). The observed prevalence of pneumonia is in general agreement with those recorded by Lindström et al. (2018) (71.00-83.00%), while a much lower prevalence was found by Azizi et al. (2013) (4.20%). In addition, rearing systems, stress factors, climatic changes, unhygienic conditions, sudden changes in feed, and a low level of herd health status are stated as predisposing factors to bacteria and viruses (Caroprese M., 2008). In sheep, respiratory disease is etiologically complex, resulting from an interaction of the infectious agents (bacterial, mycobacterial, and viral) with the host's defense mechanisms, which are often compromised by environmental factors (Alley, 2002).

Furthermore, the presence of severe pneumonia in fattening lambs was associated with low subcutaneous fat thickness. This can be ascribed to the fact that pneumonia can reduce weight gain in lambs by placing extra metabolic demands on the animals for repairing damaged lung tissue (Dijkhuizen and Morris, 1997). Prolonged stimulation of the immune system causes a stress-like response and ultimately inhibits growth in sheep, consequently decreasing subcutaneous fat thickness (Kolb et al 2000). The immune system requires considerable nutritional support, especially during challenge by a pathogen, resulting in a less efficient conversion of available feed to body mass. In addition, the presence of severe pneumonia in fattening lambs was associated with the increased occurrence of DFD meat in the current study. According to Gardner et al. (2014), sick animals need a higher amount of energy, which leads to a decrease in glycogen reservoirs with the consequent decrease in lactic acid in the muscles and a higher meat pH which leads to the occurrence of DFD lamb meat.

CONCLUSION

A higher prevalence of severe pneumonia in males indicates that they have a higher predisposition for the occurrence of chronic respiratory infections compared to females. A high prevalence of lambs with subclinical pneumonia is a reflection of adverse environmental conditions and indicates the presence of significant health problems and impaired welfare on the farm of origin. The occurrence of carcass bruises and their negative effect of meat quality could be decreased by reducing the stressors during the day of slaughter. The results showed that it is necessary to change and improve the environmental conditions and management of dairy sheep farms in order to ensure better animal health and welfare, as well as better quality lamb meat.

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Authors' contributions

KN wrote the manuscript with input from all authors. NK study conception and design. NČ, KN acquisition of data, analysis and interpretation of data. DB, TM, EV, MZŠ, MK, NK, NČ critical revision.

Competing interests

The authors declare that they have no competing interests.

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DOBROBIT I KVALITET MESA JAGNJADI

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Kratak sadržaj

U mnogim delovima sveta, sve više se daje na značaju jagnjećem mesu kao i intenzivnom načinu gajenja jagnjadi i ovaca, usled velike potražnje za jagnjadima po povoljnim cenama. U Srbiji, kao i u najvećem broju zemalja Evrope, akcenat je stavljan na jagnjeće meso, pri čemu u strukturi ukupne proizvodnje ovčijeg mesa oko 70% čini zaklana jagnjad, a ostatak ovce i ovnovi. U ovom istraživanju, ispitani su uslovi dobrobiti na 11 farmi ovaca na osnovu indirektnih pokazatelja, kao i uticaj pola, prisustva modrica i pneumonije na kvalitet trupa i mesa 30 jagnjadi. Postmortem su određivani pokazatelji kvaliteta trupa (dužina trupa, dužina buta, širina sapi, prekrivenost trupa masnim tkivom, prisustvo pneumonija, konformacija i prisustvo modrica) i mesa tovnih jagnjadi (pH, temperatura, sposobnost vezivanja vode mesa, boja mesa, klase kvaliteta mesa). Najčešći nedostaci na ispitivanim farmama su velika gustina naseljenosti, loši higijenski uslovi, prljave pojilice, kao i nedostatak ispusta. Kod muške jagnjadi utvrđen je veći procenat modrica na trupu i patoloških promena na plućima, u odnosu na žensku

jagnjad. Kod jagnjadi sa modricama na trupu utvrđena je viša pH ($\text{pH}_{45\text{min}}$) vrednost meša i senzorna ocena za boju mesa, kao i veća učestalost tamnog, suvog i čvrstog (TČS) mesa. Učestalost TČS mesa bila je veća kod jagnjadi sa teškom pneumonijom. Na osnovu rezultata može se zaključiti da je neophodno poboljšati uslove dobrobiti jagnjadi na farmi i tokom postupanja sa jagnjadima pre klanja, kako bi se dobilo meso boljeg kvaliteta.

Ključne reči: dobrobit, jagnjad, kvalitet mesa, kvalitet trupa