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NIKOLAY TODOROV IVANOV

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Sheep welfare during transport and slaughter in Bulgaria – Impact of welfare on slaughter carcass and meat quality: a review

Nikolay Todorov IVANOV*
Department of Sheep Breeding and Husbandry, Agricultural Institute, Stara Zagora, Bulgaria

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Abstract: The present work aimed to review the state of sheep welfare in Bulgaria during transportation and slaughter and to evaluate its relationship with slaughter carcass and meat quality. Over the last few years, animal welfare has become increasingly important. Normative documents related to welfare during rearing, transport, and slaughter of animals have been developed and promulgated. A major percentage of these animals are reared for meat production, but attempts to minimize stress and pain during transport and slaughter should be made. Stress reduction and pain control improve animal welfare and also impact carcass and meat quality. This overview demonstrates that improper preslaughter handling deteriorates meat quality and increases stress levels in animals. Consumers are increasingly concerned about meat quality and are even ready to pay more to purchase products of higher quality. One of the main ways for improvement of meat quality is to comply with animal welfare standards. This review focuses on some EU countries such as Bulgaria, taking interest in proper preslaughter handling of sheep due to its beneficial effects on meat and carcass qualities. In addition, this review highlights the factors to consider in sheep handling and their effect on meat and carcass quality.

Key words: Animal welfare, animal handling, carcass and meat quality, transportation

1. Introduction

The issues of animal welfare and humane attitudes to animals have gained increasing popularity in recent years, both in European countries in general and in Bulgaria.

Animal welfare is a concern for the animals' suffering and satisfaction [1]. Stress is a physiological response of animals to threats or harmful situations. An example of stress is the uncontrollable shaking of some animals exposed to loud sounds and situations in a slaughterhouse. The most practical definition of good welfare states that the animal is healthy and has all it wants [2]. The emphasis placed on animal health underlines the importance of factors related to health (food, water, and lack of injuries), although the issue of what an animal wants means that good welfare goes beyond physical health [3].

It becomes clear that the above-mentioned animal welfare definitions differ, although key words in them all are "physical and mental state", "needs", "animal suffering", and "health". In this regard, it is said that animal welfare is difficult to be determined [4], because it is multidimensional. It includes health, comfort, behavior expression, etc. Therefore, its evaluation requires multicriteria analysis [5].

In relation to animal welfare, the so-called "five freedoms concept" has gained popularity [1]. According to this concept, animals are entitled to:

- Freedom from hunger and thirst - the animals should have permanent access to fresh water and feed to maintain their health.
- Freedom from a discomfort - the animal should be provided with an appropriate environment including shelter and a lairage area.
- Freedom from pain, injury, or disease - animals should receive disease prevention and rapid and appropriate treatment.
- Freedom to express normal behavior - animals should be provided with sufficient space, proper facilities, and interaction with individuals from their species/ breeds.
- Freedom from fear and distress - when handling animals, it should be done in a way to avoid stress and suffering.

The compromised welfare of animals during their handling for slaughter is related to 5 main factors [6]:

1. The equipment of the vehicles and the means of transport;

* Correspondence: n_t_ivanov@abv.bg

2. Poor and inadequate training of the staff involved in loading/unloading of the animals;

3. The extreme physical load of the animals during their transportation;

4. Inappropriate devices and equipment of premises for preslaughter handling and for stunning;

5. Poor general condition of the animals arriving at the slaughterhouse.

During the last few years, a number of normative documents have been developed, including laws and regulations governing the welfare of animals during husbandry, transport, and slaughter. The most important legal acts regulating the welfare of animals in Bulgaria are:

1.1 Animal Protection Act, effective from 31.01.2008 (Prom. State Gazette Issue 13 of 8 February 2008) [7];

1.2 Ordinance No. 22 of 14 December 2005 to minimize animal suffering during slaughter or killing (Prom. State Gazette No. 42 of 25 May 2006) [8];

1.3 Ordinance No 16 of 3 February 2006 on the Protection and Welfare of Farm Animals during Production and Improvement. (Prom. State Gazette Issue 18 of 28 February 2006) [9];

1.4 Ordinance No. 26 of 28 February 2006 on Conditions for the Protection and Welfare of Animals During Transport (Publ. State Gazette No. 23 of 17 May 2006) [10];

1.5 Council Regulation (EC) No. 1/2005 of 22 December 2004 on the Protection of Animals During Transport and Related Operations and Amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No. 1255/97 [11].

2. Transportation of animals

The transportation and handling of animals are important issues of meat production systems. Animals intended for slaughter are subjected to stress by factors such as loading, transport, restraint, handling, unloading, adverse weather, hunger, thirst, and fatigue [12].

If animals are to be transported before being slaughtered, this should be performed in specially equipped vehicles under conditions guaranteeing their health and physiological needs. Transportation stress is inevitable [13,14]. During loading, transport, and unloading, the animals are in a new environment. This is something different, which is probably happening for the first time. It is something unfamiliar that causes stress during transport. Apart from the negative consequences of stress on animal welfare, it causes economic losses and poor meat quality [12,15]. Although transportation stress cannot be avoided, attempts can be made to minimize it.

Road transport in Bulgaria is mostly used for animals. Specialized vehicles and containers should be used for that purpose [8]. Every means of transport carrying live animals must meet certain basic criteria:

- Their design should provide complete safety for animals during loading, transport, and unloading;
- they should protect animals from injury and unnecessary stress, adverse climatic conditions, and prolonged exposure to noise and vibrations; and
- they should have no sharp edges, protruding objects, holes, or spaces facilitating injuries.

Vehicles intended for the carriage of animals must also be provided with a ventilation system, which:

- should be designed to operate continuously when the animals are in the vehicle, regardless of whether it is moving or not;
- should provide circulation of uncontaminated air;
- should maintain a temperature in the vehicle between 5 and 30 °C;
- should be equipped with an appropriate monitoring device; and
- can be adjusted depending on the temperature inside and outside of the vehicle.

Only identified and registered animals that are clinically healthy and prepared for traveling are transported if conditions for normatively defined care during the travel and at arrival are met. The duration of transportation of different animal species and categories is specified by an ordinance. Transport time should not exceed 8 h [10]. For short-distance transportation with a duration of up to 8 h, animals are provided only with drinking water. Duration of transportation could be longer only if the vehicle responds to some additional requirements.

The loading density for the transportation of lambs and sheep is specified in a legal act. It is stated that the loading density for road transport of shorn sheep and lambs under 55 kg is 0.2–0.3 m^2 per animal and 0.30–0.35 m^2 for those weighing more than 55 kg. Fleeced sheep weighing <55 kg require 0.30–0.40 m^2 and those weighing >55 kg require 0.40–0.45 m^2 [10].

Devices for loading and unloading, including the floor space (m^2/animal), should be designed in a way such that:

- should prevent injuries or suffering of animals and minimize the excitement and exhaustion at the time of shifts as well as ensure their safety. The surfaces must not be slippery; side protection devices must be fit to avoid the escape of the animals; and
- should be cleaned and disinfected easily.

During the loading and unloading of the animals, it is prohibited to:

- hit or kick the animals;
- exert pressure on any sensitive part of the animal's body in a way that may cause unnecessary pain or suffering; and
- lift or drag the animals by the head, ears, horns, legs, tail, or fleece or manipulate them in a way causing unnecessary pain or suffering.

After being transported to a slaughterhouse, the animals shall be unloaded as soon as possible after their arrival, and if not possible, they shall be protected from adverse weather conditions and provided with sufficient air exchange until unloading [11].

3. Stunning, slaughter, and bleeding of animals

Minimum requirements that minimize animal suffering during slaughter or killing are stipulated by a normative act [8]. These requirements are to be observed during:

· unloading, moving, preslaughter lairage and preparation, fixing and stunning, and slaughter or killing.

After unloading at the slaughterhouse, the animals enter the slaughterhouse premises only if they will be immediately slaughtered. When the slaughter is not done immediately, the animals are accommodated for rest in pens or paddocks protecting them from adverse climatic events. These premises should meet the following requirements:

· the flooring should not allow slipping and injury to the animals and should be easily cleaned and disinfected;

· provision of ventilation conditions adequate to the expected temperatures and humidity;

· appropriate facilities for tying the animals; and

· provision of space for each animal to stand upright, to lie down, and to turn around without difficulties.

According to the same normative act, the following conditions must be met during accommodation of animals on the premises for resting/relaxing:

· all animals are provided with drinking water in a suitable waterer and those that will be slaughtered after more than 24 h should receive moderate amounts of food at appropriate intervals in a way providing access to food to each animal;

· if the animals are tied, this should be done in a way allowing them to lie down without difficulties;

· animals that may injure one another by reason of species, gender, or age are accommodated in separate pens/paddocks or sheds;

· protection against adverse climatic conditions should be ensured, and in humid and very hot weather, measures should be taken to cool the animals by appropriate means; and

· the duration of preslaughter rest is up to 4 h for transportation distances up to 80 km, and for distances over 80 km it is up to 12 hours.

It was found that animals slaughtered after a 12-h stay in a slaughterhouse experienced less stress compared to lambs slaughtered immediately upon arrival [16]. This was probably because preslaughter rest permitted animals to calm down and rest before being slaughtered.

After the animals have rested from the travel, they are moved into the slaughter premises. Before slaughter, the animal must be stunned to eliminate pain, stress, and discomfort from the procedure. Animals are not stunned if exsanguination is not possible immediately after slaughter; stunning represents rendering animals unconscious until death [8]. The main goal of stunning is to render the animal immobile and unconscious in order to feel no pain [1].

There are three main stunning techniques: percussive, electrical, and gas stunning. In sheep, mainly electrical and percussive stunning are practiced (http://www.agrowebcee.net/fileadmin/subnetwork/awsee/fawbg/Narachnik-FAO-redactir-1.pdf).

3.1. Gas stunning

This is an expensive method and therefore not frequently used.

3.2. Percussive stunning

This is done by means of a pistol with a stun bolt gun. The method works using the principle of the gun: a trigger pull pushes a short bolt to the outside. The latter penetrates the skull, causing concussion of the brain via brain damage or increased intracranial pressure. The stun bolt gun is perhaps the most universal stunning tool as it is appropriate for use in cattle, pigs, sheep, and goats; moreover, it is compact and easy for transportation. A very important prerequisite for efficient stunning is the proper positioning of the gun. In sheep it is placed at the uppermost point of the head, in the direction of the jaw joint (Figure 1) (http://www.agrowebcee.net/fileadmin/subnetwork/awsee/fawbg/Narachnik-FAO-redactir-1.pdf).

3.3. Electric stunning

This method is very suitable for stunning pigs, sheep, and goats. Presuming that electric stunning leading to unconsciousness is a humane slaughtering method, this procedure is the most widely spread technique for the stunning of animals [17]. Electric stunning also has the advantage of low noise levels during application. On the contrary, the use of a stun bolt gun produces much noise during the shot. This may result in additional stress of other animals waiting at the slaughterhouse. Electric

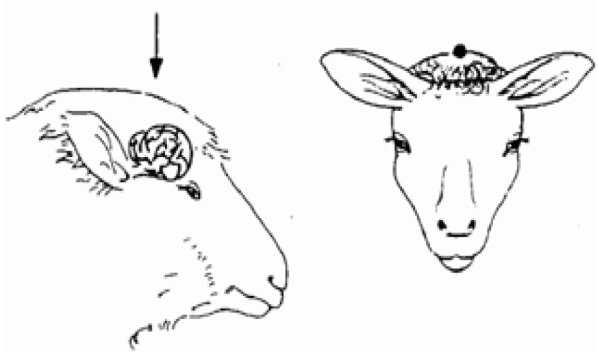

Figure 1. Site for stunner placement for sheep.

stunning uses an alternating current with low voltage applied through the electrodes of the stunning device (Table). Electric stunning causes an epileptic state of the brain in two stages: tonic seizure followed by clonic seizure (Table). If exsanguination does not follow these two stages, the animal regains consciousness. As the animal's brain is small, the electrodes should be placed accurately in a stable manner on both sides of the skull (Figures 2 and 3). During the epileptic state of the brain, the nervous system of the animals is blocked; they are unconscious and do not feel pain. The unconsciousness state should last long enough to perform exsanguination, so that the animal will die of brain anoxia (complete lack of oxygen in the brain) (http://www.agrowebcee.net/fileadmin/subnetwork/awsee/fawbg/Narachnik-FAO-redactir-1.pdf).

Electric stunning is performed in compliance with the following requirements [8]:

· the electrodes of the stunning device are placed in a manner to embrace the animal's skull and to provide efficient passing of the current through the brain;

· to improve electroconductivity, excess wool or hair coat is shaved, and the skin of the head is moistened with water;

· the animal is bled as soon as possible after being stunned in a way allowing for rapid and complete bleeding out; and

· bleeding is done before the animal regains consciousness by cutting the carotid arteries or blood vessels from which they originate.

4. Postmortem changes in meat

After slaughter, several processes with substantial significance for its quality take place in meat [18,19]. One of the main criteria for meat quality is the ultimate pH of the muscles, determined by glycogen depletion and postmortem accumulation of lactic acid [20]. The processes occurring in meat postmortem are interrelated. The most important among them are as follows:

4.1. Postmortem rigidity (rigor mortis)

This is characterized by muscle rigidity. The muscles are stiff and firm [21]. Such muscles are hardly salt cured and are not appropriate for cooking**.** Even the bouillon after cooking such meat is cloudy.

The cause of rigor mortis is the interruption of oxygen flow to muscles; hence, biochemical events occur in an anaerobic environment and as a result glycogen is rapidly degraded [22].

Complete rigor mortis takes different amounts of time depending on animal-specific features and environmental conditions [23]. At 4 °C stiffness of carcasses of small ruminants occurs after 12–16 h. It develops more rapidly in muscles of young animals and more slowly in muscles of fattened animals. Rigor mortis is most pronounced in skeletal muscles, and it is less perceptible or almost imperceptible in smooth muscles.

4.2. Meat ripening

Aging or ripening of meat lasts several (3–14) days [19,24,25]. During ripening, physicochemical changes are observed, resulting in the improvement of organoleptic properties. Meat assumes a pronounced flavor and taste, with higher water-holding capacity, and it becomes more tender and juicy [23,26]. Meat tenderness is facilitated by postmortem proteolysis activated by proteolytic enzymes (calpains) and is inhibited by proteolytic inhibitors (calpastatin) [19,27,28].

Table. Recommended electric current parameters and stunning time and duration of stunning phases in animals.

Parameters	Value
Duration of phases electrical stunning Tonic Clonic Recovery	 10–20 s 15–45 s 30–60 s
Loss of brain function bleeding methods Chest stick Full cut Half cut	 4.5 s 14 s 70 s
Recommended currents for stunning and killing animals Stun (head-only) Kill (applied to heart)	 1.0 A 1.0 A
Approximate electrical resistance of animals to stunning current Electrode position Resistance (ohms)	 Across the head, light fleece cover 150–1000

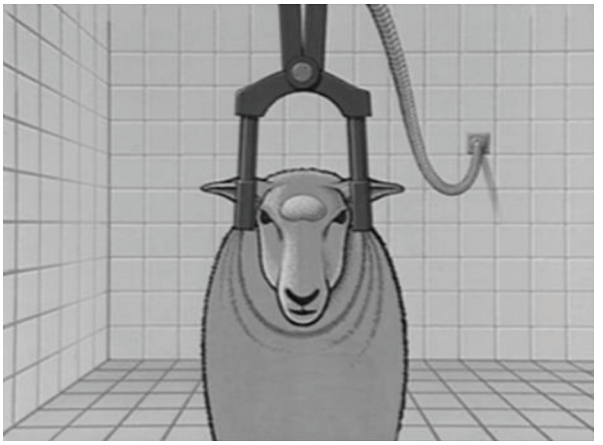

Figure 2. Electrode position for sheep (front view).

Figure 3. Electrode position for sheep (side view).

4.3. Postmortem glycolysis

The energy for muscle activity of live animals is provided by muscle glycogen. The glycogen content of muscles in healthy rested animals is high (http://www.agrowebcee.net/fileadmin/subnetwork/awsee/fawbg/Narachnik-FAO-redactir-1.pdf). After slaughter, the blood circulation in the body is interrupted; hence, the delivery of oxygen and nutrients to muscles and muscle fibers also is. Metabolic processes already occur in an oxygen-free environment and muscle glycogen is converted into lactic acid [22]. As lactic acid is not transported along with the circulation to the liver and the heart, it remains in the muscles and this results in a reduction of pH from usual values of 7.00–7.40 in live animals to about 5.40–5.70. Lactic acid is necessary to produce tender meat with good taste and good color.

If the animal experiences stress before and during slaughter, glycogen is depleted, and the lactic acid formed in meat postmortem decreases [29]. This has a serious negative impact on meat quality. Therefore, during preslaughter handling, animals should not be subjected to stress and injuries in order to preserve unnecessary muscle glycogen depot depletions.

Another important issue is the good rest of animals during the 24-h preslaughter period. This creates conditions for the restoration of the muscle glycogen of slaughtered carcasses to the highest extent. Maximum high muscle glycogen levels are important to obtain a maximum lactic acid level in meat. This acid gives meat the ideal pH_{24} value, which is lower than 6.20. If the measured pH_{24} is higher than 6.20, this indicates that the animal was stressed or ill before being slaughtered. The lactic acid in muscles delays the replication of bacteria contaminating the carcass during slaughter and washing. These are the bacteria responsible for meat spoilage during storage. Therefore, the meat produced from animals under transport or slaughter stress has a shorter shelf life due to spoilage (http://www.agrowebcee.net/fileadmin/subnetwork/awsee/fawbg/Narachnik-FAO-redactir-1.pdf).

4.4. Cold shortening of meat

This is a problem of veal and lamb during the cooling of carcasses [30] with great impact on meat tenderness [31–33]. During the cooling of carcasses, the sarcoplasmic reticulum surrounding the myofibrils is stimulated by low temperatures (temperatures of <10–15 °C) and releases Ca^{2+} near the myofibrils [34,35]. In the presence of sufficient adenosine triphosphate amounts, Ca^{2+} provokes muscle contractions by forming permanent transverse bridges between actin and myosin. Because of these contractions, the length of the muscle sarcomeres is reduced. Muscles containing large amounts of red oxidative muscle fibers are more prone to cold shortening.

Intensively reared animals produce carcasses with thicker layers of subcutaneous fat due to the high-energy rations and restricted locomotion. The thick subcutaneous fat isolates the carcass and delays its postmortem cooling This results in the prevention of cold shortening of muscles [36] and increases the postmortem activity of proteolytic enzymes, leading to better meat tenderness.

5. Effect of preslaughter handling on meat quality

Preslaughter handling of animals includes loading, transport, and unloading; preslaughter rest; and stunning and bleeding. Because of these manipulations, animals probably experience fear, hunger, thirst, physical injuries, and fatigue, which ultimately has a negative impact on health, welfare, and meat quality [14,37,38]. All animals are under certain stress before slaughter, which could be detrimental for meat quality [39,40].

Stunning methods could have an adverse effect on carcass quality and on meat. That could be manifested

visually as hemorrhages, skin burns in sheep, bone fractures, etc. [1]. In a study conducted on pigs, it was determined that the application of electric stunning with a current of 1.27 A, a constant voltage of 220 V, and a frequency of 50 Hz caused the appearance of spine fractures and hemorrhages in leg areas and spinal muscles [41].

The effect of short-distance road transportation during hot days on live weight, physiological response, and meat quality in Omani sheep at 5 and 12 months of age was investigated [42]. According to the authors, live weight losses were 1.09 and 1.52 kg for animals at 6 and 12 months of age. Transported animals had considerably higher levels of cortisol, epinephrine, and norepinephrine in both age groups compared to nontransported animals. This is because stress is an evitable consequence of the transportation of animals from the farm to the slaughterhouse [38]. It causes changes in the immune system mainly due to physiological changes [43].

Transportation of animals also had a substantial effect on meat quality. Meat pH and cutting force were significantly higher in animals transported before slaughter. Color coordinates L*, a*, and b* were lower in transported versus nontransported animals [44]. Moreover, lambs transported for 5 h gave lower slaughter yields and water-holding capacity of meat versus those transported for 30 min [45].

The results from another report demonstrated that the transportation of animals on nonasphalt roads had a considerable influence on physiological and hematological parameters of stress [46]. Lambs that had traveled on nonasphalt roads had substantially higher blood cortisol and glucose concentrations. This probably resulted from vibrations of the vehicle due to road bumps. What is more, the meat of lambs transported on nonasphalt roads had higher ultimate pH values and higher tenderness values compared to the meat of lambs having traveled on pavement roads [47].

The effect of preslaughter rest duration (0, 3, 6, 12 h) on meat quality has been investigated [48]. It was found that slaughter weight losses and liver glycogen contents decreased parallel to the duration of stay at the slaughterhouse. The authors found that with a preslaughter stay of up to 3 h, meat pH and tenderness parameters were the highest, while those for the color coordinate b* were the lowest. Based on experimental results, the authors suggested that lambs should not be slaughtered immediately after their arrival at the slaughterhouse.

Another study compared the effects of different stunning techniques in lambs [49]. The animals were divided into 3 groups: those from the first group were submitted to electric stunning and those from the second group to carbon dioxide stunning, while the rest were slaughtered without stunning. Meat quality was assessed through pH, meat color (L*, a*, b*), cooking losses, and cutting force. At postslaughter hour 24, the highest meat pH was established in lambs that were not stunned before slaughter, while the lowest pH values were observed in lambs stunned with CO_2. The latter group also had more tender meat than those either stunned with an electric current or not stunned at all. In general, preslaughter stunning did not exert any effect on meat color or cooking losses. A similar conclusion was expressed by other authors as well [50], having found that at postslaughter hour 24, there were no considerable differences in meat quality due to stunning methods.

6. Conclusion

Preslaughter handling of animals is associated with their transportation to the slaughterhouse, their stay, and preslaughter preparation. Stress and injuries of animals induced by improper preslaughter handling are probably the two most essential criteria determining animal welfare.

In Bulgaria there are adopted laws and regulations governing animal husbandry (in particular sheep breeding) and the requirements for carrying out preslaughtering procedures. Compliance with these requirements greatly reduces stress. The exposure of animals to stress and injuries before slaughter should be avoided as they lead to deterioration of the quality of the produced meat. If the animals suffer from stress before and at the time of slaughtering, glycogen is depleted and lactic acid formed in meat after slaughter decreases. If lactic acid levels in meat are low, this influences the ultimate meat pH. It was found that stress and injuries of lambs before slaughter resulted in higher meat pH and hence shorter shelf life. Furthermore, the produced lactic acid delays the proliferation of bacteria that contaminate the carcass; therefore, its lower concentration results in faster spoilage of meat.

Stunning is important for the welfare of lambs. Its main goal is to render the animal unconscious before slaughter, a state in which it feels no pain. It was also shown that meat quality was influenced by both stunning and nonstunning applications and the technique used (percussive, electric, or gas stunning).

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