PE4.89 Stunning and chilling methods and tenderness of lamb meat in Iceland 316.00

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***Abstract*—The aims of the survey were to study the influence of stunning methods, electrical stimulation, chilling practices and aging on pH, temperature, colour and shear force of lamb meat.**
Abattoir were divided into a head/head stunning, head/back stunning and head/back/stunning/electrical stimulation groups. (HH, HB, HBE) Stunning, bleeding and chilling practices were recorded. pH and temperature were measured during chilling of carcases before freezing. *M. longissimus thoracis et lumborum* (LL) was sampled from ten 15 kg carcases in seven visits for analyzing colour and texture of unaged meat. LL muscles of ten 12-13 kg and ten > 18 kg carcases were also sampled in two abattoirs to study the effects of 4 days aging at 4°C and carcass weight on shear force of the meat.
Capillary haemorrhages and blood splash were more notable in abattoirs using HH stunning method. Stunning methods influenced pH. pH in LL when entering the chill room after slaughter was lower in muscles of lambs stunned with the HB than the HH method and lowest in the HBE group.
Stunning methods influenced the shear force of the meat. It was lowest in HBE muscles and highest in HH muscles but short times from slaughter in two abattoirs complicated the comparison of stunning methods. ES and aging for 1 day produced LL muscles with very low shear force (30-40 N) that was unaffected by carcass weight and aging for 4 days. 4 hours chilling before freezing produced LL with higher shear force (50-85 N) affecting lighter carcases more that the heaviest carcases and 4 days aging reduced shear force to the same levels as in the ES muscles.
The most important conclusion from the survey is that electrical stimulation and 1 day aging produce fully tenderized loin muscles with economic benefits for the abattoirs in less weight loss of carcases during chilling, cutting and deboning and longer shelf life and consistent quality.

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Index Terms- Stunning, chilling, lamb meat, tenderness

I. INTRODUCTION

Stunning methods, electrical stimulation, chilling rate and chilling time can influence the quality of lamb meat. Killing lambs with a bolt pistol was the common practice in Iceland for many years but now all lambs are stunned with an electrical shock before bleeding. This is compulsory and in accordance with an EU directive (1). Stunning with electrical shock during slaughter has been claimed to increase haemorrhages and blood splash in lamb meat (2). The European Food Safety Organization has both in 2004 and 2006 published scientific reports and opinion on the killing of slaughter animals (3,4). The Veterinary Institute in Norway did the same in 2007 (5). There results of studies and advice in relation to methods, equipment and it‘s settings, working procedures can be found. There are also guidelines about methods and correct work procedures at the Humane Slaughter Association homepage (6).

If electrical stunning is performed correctly the animal should lose consciousness and any sense of pain. Here the current is decisive. Meat animals must be unconscious before they are bled to death. In practice it means that sticking must be carried out within 15 seconds from stunning. Guidelines in Iceland also say that bleeding must be continued for at least 30 seconds before commencing with the next steps in the process. Electrical currents after stunning have been reported to improve bleeding in slaughtered animals (7).

Concerns about increased risk of cold shortening of lamb meat in Iceland are based the two facts, the first being stricter demands on chilling rates and temperatures and the second being increased slaughter per day in the remaining abattoirs in the country that in worst cases could exceed the chill room storage capacity for lamb carcasses leading to shorter times from slaughter to freezing.

pH and temperature at the onset of *rigor mortis* are used to monitor and ensure the tenderness of lamb meat. The least contraction of muscle occurs when the temperature is between 14 and 19°C in the beginning of *rigor mortis*. Lower and higher temperatures lead to more contraction and tougher meat (8,9). The reference values used in this study were based on the pH/temperature window developed by Meat Standards Australia(MSA)(10) based on the results of Locker and Hagyard (9) but also on the results of Pearson and Young (11) who concluded that for cold shortening to occur the muscle pH had to be greater than 6.0 and the muscle temperature to be less than 10°C at the onset of *rigor mortis*. Heat shortening can in some cases also lead to increased toughness (12,13). The MSA reference values for cold shortening are temperature lower than 12°C and pH above 6. And for the heat shortening the values are 35°C and pH below 6.

Electrical stimulation is used in commercial abattoirs to improve meat quality by ensuring rapid *rigor mortis* so that cold shortening is avoided when meat is cooled below 10 °C. The degree of stimulation needs to be reproducible and defined as there are wide ranges of stimulation parameters used (14), and in some cases electrical stunning and low voltage immobilization can substitute for a defined stimulation procedure(15). Medium voltage electrical stimulation has been tested and implemented in lamb slaughterhouses in Australia. 87% of the carcasses reached pH 6,0 at temperatures between 12-35°C, the guidelines set by MSA and 43 % by the guidelines set by the Australian Sheep Meat Eating Quality (SMEQ) program(16). Electrical current applied skin on carcasses soon after stunning and sticking increased blood release and reduced shear force of the meat (17).

The aims of the survey were to study the influence of stunning methods, electrical stimulation and chilling practices on the texture of LL from lamb carcasses from abattoirs in Iceland.

II. MATERIALS AND METHODS

Six abattoirs of the eight lamb abattoirs in Iceland were in the study. They were all visited once during the slaughter season except one that was visited twice. They were divided into three groups:

- Abattoirs using head only stunning (HH)
- Abattoirs using head to back stunning (HB)
- Abattoir using head to back stunning and medium voltage electrical stimulation (HBE)

Stunning and bleeding

The stunning and bleeding of about 100 lambs was monitored each time. Type of stunners, strength and time of the current, time from stunning to sticking and the time from sticking to decapitation were measured and recorded.

Sampling for pH, temperature, colour and texture analysis

Ten approximately 15 kg carcasses of EU grade R2 (average carcass weight of Icelandic lambs) were selected in each abattoir. In addition ten light (12-13 kg) and ten heavy carcasses (<18 kg) were selected in two abattoirs to study the influence of carcass weight and aging for four days on the quality of the meat. One of them used head/back stunning, electrical stimulation and fast chilling for 22 hours before freezing. The other used fast chilling but only for 4 hours before the carcases were frozen.

The carcasses followed normal chilling and freezing procedures and chilling times in the abattoirs. If they varied during the day, then the procedure risking more that the carcasses would fall outside the pH/temperature window was selected.

pH and temperature

Core temperatures in loin, leg and forequarter and pH in LL were measured automatically in one 15 kg carcass in each abattoir. pH and temperature was measured at regular intervals in LL of the carcasses that were sampled for texture analysis using Ebro thermometers and Knick Portamess® 913 X pH-meters with a electrode of the model SE 104.

Colour and texture

Saddles were cut from the carcases and vacuum packed at the normal time of freezing in the abattoirs and blast frozen at -24°C. The left side of the saddle was vacuum packed and frozen at the normal time but the right side was vacuum packed and aged for 4 days at 4°C before freezing in the abattoirs with the light, normal and heavy carcases. The samples were kept in a freezer at -24°C for 4-7 weeks before they were analyzed for colour and texture. Then the samples were thawed at room temperature overnight and muscle LL cut out of the saddles. Colour was measured on raw muscle before shear force analysis. The colour of the muscle was measured with a Minolta colourmeter (type CR-300, Japan). The L*, a*, b* system was used.

Texture Analyser-XT2i from Stable Micro System in England was used to measure shear force. Shear force was measured after heating (waterbath at 75ºC) until a 70ºC internal temperature was reached, cooling for 30 minutes in running tap water and storage at 4ºC until tested. Samples were subjected to the shear test, at right angles to the muscle fibre axis, using a Warner-Bratzler device with a triangular shaped hole in the shear blade.

Statistical analysis

Analysis of variance (ANOVA) was used to calculate the effects of stunning methods, abattoirs, chilling and aging on texture, pH and colour of the meat.

III. RESULTS AND DISCUSSION

Table 1 summarizes the conditions in abattoirs in the survey. Medium voltage electrical stimulation was used in abattoir 4. Three of the abattoirs used head to head stunning methods and three the head-back method. The work procedures in all the abattoirs complied with the guidelines set by the veterinary authorities in Iceland. Bleeding was done by sticking in four abattoirs and by throat cutting in two of them. Time from the sticking until the head was removed was from 15 seconds to 4 minutes. Capillary haemorrhages and blood splash were more notable in abattoirs using the HH stunning method. Chilling time before freezing ranged from 4-22 hours.

Table 1. Conditions in the abattoirs in the survey

	Head	**Head/ back**	**Head/ back/ el.stim.**	**P**
N	40	20	10	
pH entering chiller	7,00±0,19	6,64±0,15	6,46±0,12	<0,001
pH after thawing	5,61±0,10	5,70±0,12	5,52±0,0	<0,001
L*	35,6±2,9	35,0±3,1	37,6±2,5	
a*	18,4±2,9	18,6±2,3	19,8±1,8	
b*	7,50±2,8	7,59±2,6	8,21±1,7	
Shear force (N)	53,0±14,3	51,0±12,3	30,1±6,7	<0,001

The temperature in the carcases when they were put in the blast freezer was from 4-22°C. The final temperature before freezing in the deep leg was from 3°C to 20°C and 3- 17°C in the forequarter and 3-15°C in the loins of the 15 kg carcases

Chilling was very fast in three abattoirs. One of them used electrical stimulation. Cold shortening is a problem in the other two abattoirs with one using HH and the other using HB stunning, that can easily be solved with electrical stimulation. Freezing pre rigor meat was a problem in one abattoir using HH stunning that can be solved either by electrical stimulation or by increasing the chilling time before freezing.

pH, colour and shear force of unaged meat

Table 2 shows the influence of stunning methods on pH, colour and shear force

	Head	Head/ back	Head/back/ Electrical stim.
No of abattoirs	4	2	1
Procedures	OK	OK	OK
Bleeding	Sticking/ Throat cut	Sticking	Sticking
Head removal, in	0,3-4,3	0,3-4,0	0,5
Blood emptying	Comments	OK	OK
Chilling time, hr.	4-22	6-21	22

Table 2. Influence of stunning methods on pH, colour and shear force of *m. longissimus thoracis et lumborum* (LL) from 15 kg Icelandic lamb carcases.

Stunning methods influenced pH in the meat. pH when entering the chill room after slaughter was lower in muscles of lambs stunned with the HB method than the HH method. And it was lowest where electrical stimulation was also used. There was also a significant pH difference in muscles after thawing that can be explained by very short chilling times before freezing in two abattoirs in the HH and HB groups. Stunning methods did not influence colour of the meat but shear force was highest in the HH meat and lowest in ES muscles ($p<0,001$) but too short times from slaughter to freezing in two abattoirs cannot be excluded as a confounding factor in groups HH and HB.

Figure 1 shows the distribution of shear force in all the unaged samples of LL in this study. Only about 35% of the samples can be considered tender and about 50% are above above 50 N and tough.

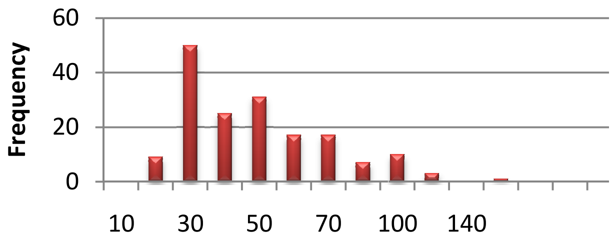

Figure 1. Shear force (N) distribution of cooked samples (n=170) *m. longissimus thoracis et lumborum (12-20 kg carcass weight)*

Shear force of aged meat

Shear force of the ES muscles aged for 1 day and 4 days before freezing is shown in figure 2. The most interesting results are that the one day aged muscles seem to be fully tenderized and the shear force values are quite low. The difference between weight groups was not statistically significant.

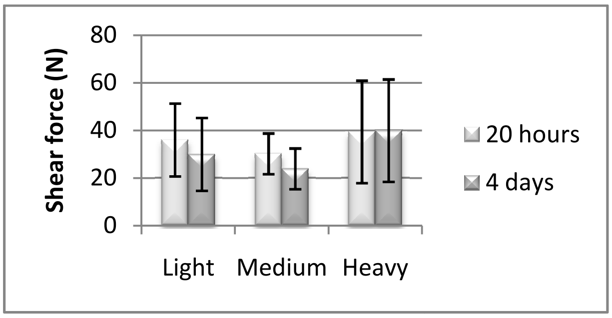

Figure 2. Shear force of cooked *m. longissimus thoracis et lumborum* aged for 1 and 4 days from electrically stimulated carcases of different carcass weights

Figure 3 shows the shear force of the LL muscles from the lambs from an abattoir not using electrical stimulation and where the carcases were put in a blast freezer after only 4 hours chilling.
The shear force of the LL muscles aged for 4 hours was significantly higher in the lightest muscles than in the muscles in the other weight groups ($p<0,001$). There was a great improvement in tenderness with significantly lower shear force after 4 days aging ($p<0,001$). The shear force was significantly higher ($<0,05$) in the unaged LL muscles from the light and medium carcases than in the ES muscles. This difference disappeared after 4 days aging.

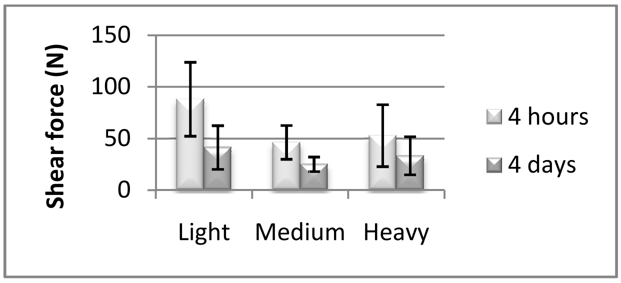

Figure 3. Shear force of cooked *m. longissimus thoracis et lumborum* aged for 4 hours or 4 days from carcases of different carcass weights.

IV. CONCLUSION

Carcases of lambs stunned with electrical shock are most of the time bled properly. But there were more comments on both capillary haemorrhages and insufficient bleeding when the head stunning method was used. But the time from bleeding until the head was removed from the lambs was also shortest in the abattoirs using the head stunning method. This complicated and makes the comparison of stunning methods less accurate.
Chilling was very fast in three abattoirs. One of them used electrical stimulation. Cold shortening is a problem in the other two abattoirs that can easily be solved with electrical stimulation. Freezing pre rigor meat was a problem in one abattoir that can be solved either by electrical stimulation or by increasing the chilling time before freezing.
The most interesting conclusion from the survey is that medium voltage electrical stimulation, fast chilling and 1 day aging produce fully tenderized LL muscles. This mean economic benefits for the abattoirs in less weight loss of carcases during chilling, cutting and deboning and longer shelf life and consistent and high quality.

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