USE OF POST-SLAUGHTER TECHNOLOGIES TO ENHANCE HEAVY LAMB MEAT QUALITY: pH RESPONSE AND VARIATION

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Abstract – The aim of this study was to determine if use of post-slaughter technologies can modulate pre-rigor pH-temperature dynamics in order to enhance meat quality of heavy lambs produced in Quebec. Market heavy lambs were selected at the abattoir and assigned to four treatments in a 2 × 2 design: electrical stimulation (ES) or not (NES) and normal (+) or slow (-) chilling. Slow-chilled carcasses stayed warmer during the first 12 h postmortem ($P > 0.0001$) to attain thereafter the same temperature as normally chilled ones. They also had a lower pH between 2 and 12 h ($P < 0.05$). Stimulated carcasses had a lower pH than NES throughout the first 24 h postmortem ($P < 0.0001$), but ultimate pH (pHu) was similar ($P = 0.6709$). Grouping of carcasses based on their temperature at pH 6.0 showed that NES in both chilling procedures are susceptible to cold-shortening. Stimulation reduced this risk and enabled 60% of the carcasses to reach pH 6.0 between 10 and 35°C. However, variation of pH response was important, showing that application of ES to manage pH-temperature needs more research. Moreover, 16.7% of all carcasses had pHu > 5.8 and their color was affected (L^*, a^* and b^*; $P > 0.0001$).

Key Words – Chilling rate, Electrical stimulation, pH and temperature declines.

I. INTRODUCTION

Among all production factors, post-slaughter processes have the most important impact on lamb tenderness [1], with chilling and aging period being critical points. In Quebec, most heavy lambs (carcass weight > 20 kg) are slaughtered in multi-species abattoirs designed to chill beef, veal or pork carcasses. A recent study showed that tenderness of the meat from heavy lambs produced and processed in Quebec could be enhanced by ES, mostly through cold shortening reduction [2]. Temperature of lamb carcasses at pH 6.0 has been shown to affect tenderness and eating quality, with 18-25°C being the window recommended by the Australian Sheep Meat Quality program [3-5]. Electrical stimulation is considered a tool to reach this pH-temperature window, prevent cold shortening and accelerate aging. The aim of this study was to determine if use of post-slaughter technologies can modulate the pre-rigor pH-temperature dynamics in order to enhance meat quality of heavy lambs produced in Quebec. In this part of the study, pH response and variation are presented.

II. MATERIALS AND METHODS

Between June and August 2010, 128 male market lambs (hot carcass weight = 22.3 ± 0.2 kg) were selected at a commercial abattoir over 8 slaughter days (16 lambs/d) and assigned to one of 4 treatments (32 lambs/treatment) in a 2 × 2 design:
NES+ = No ES and normal chilling;
ES+ = ES and normal chilling;
ES- = ES and slow chilling;
NES- = No ES and slow chilling.
Each ES carcass was hung by the hind legs and electrical stimulation was applied for 30 sec via a neck clip and a rectal probe using a commercial low-voltage system (21 V RMS; 0.25 A; Jarvis, Model ES-4, Middletown, CT). Both ES and NES carcasses were pelted, dressed, weighed and transferred to one of two chilling rooms, according to the treatment, within 25 min. The average room temperature in the normal chilling treatment was 1.2 ± 0.9°C. In the slow chilling treatment, carcasses were chilled for 3 h at 9.3 ± 0.8°C before normal chilling, in an attempt to reach pH 6.0

between 18-25°C, as determined in preliminary tests. Temperature and pH decline were monitored on the left *longissimus lomborum* (*LL*) muscle at 0.75, 2, 3, 6, 12 and 24 h. At 24 h postmortem, carcasses were cut into primal cuts (shoulder, loin, leg and flank) and left and right racks were vacuum-packed and assigned to 3 or 8 d of aging at 4°C before being frozen at -20°C. Ultimate pH (pHu) was measured at 48 h on the left short loin (*LL*) maintained at 4°C. Color measurements (*L**, *a** and *b**) were taken on the freshly cut and oxygenated surface of thawed racks with a colorimeter (Chroma Meter CR-300, Minolta Co., Ltd., Osaka, Japan). Carcasses were grouped according to their temperature at pH 6.0. Carcasses with pHu higher than 5.8, an abnormal value related to the dark, firm and dry (DFD) meat quality defect, were grouped separately.

The data were analyzed using the MIXED procedure of SAS (SAS Institute Inc. Cary, NC). DFD-like carcasses were removed from the analyses of temperature and pH decline. The model included slaughter day, ES and chilling treatment, postmortem time and interactions as fixed effects. Observations of postmortem time were considered as repeated measures. The model for the analysis of color included group.

III. RESULTS AND DISCUSSION

As expected, temperature decline was the same for ES and NES carcasses in both chilling procedures ($P = 0.7255$). Therefore, the data from these two treatments are combined in Figure 1a. A time × chilling interaction was observed ($P < 0.0001$) as slow-chilled carcasses (ES- and NES-) were warmer during the first 12 h, but had similar temperatures to normally chilled carcasses thereafter.

Electrical stimulation effectively depleted ATP, lowering pH by 0.59 units at 45 min postmortem, compared to NES, resulting in a pH of 6.16. This response to low-voltage ES is in accordance with previous results obtained with the same system [2], although only half the ES time was required in the present study (30 sec vs 60 sec). Genetic and pre-slaughter factors could be responsible for this difference, as lambs were randomly selected at the abattoir instead of having been chosen from the same crossbred and raised under the same conditions, as in Pouliot *et al.* [2].

There was a time × stimulation interaction for pH ($P < 0.0001$) owing to the lower pH of ES carcasses throughout the first 24 h postmortem ($P < 0.0001$), combined with an equivalent pHu in both ES and NES ($P = 0.6709$; Figure 1b). A time × chilling interaction was also found ($P < 0.0001$) owing to the faster pH decline of slow-chilled carcasses between 2 and 12 h ($P < 0.05$), independent of the common 45 min pH measured in both chilling treatments ($P = 0.1755$). The pH tended to remain lower at 24 h ($P = 0.0673$) between chilling procedures, but this difference disappeared at 48 h ($P = 0.7941$). This result can be explained by a faster rate of glycolysis and pH decline under warmer conditions [6, 7], as slow-chilled carcasses were warmer during the first 12 h.

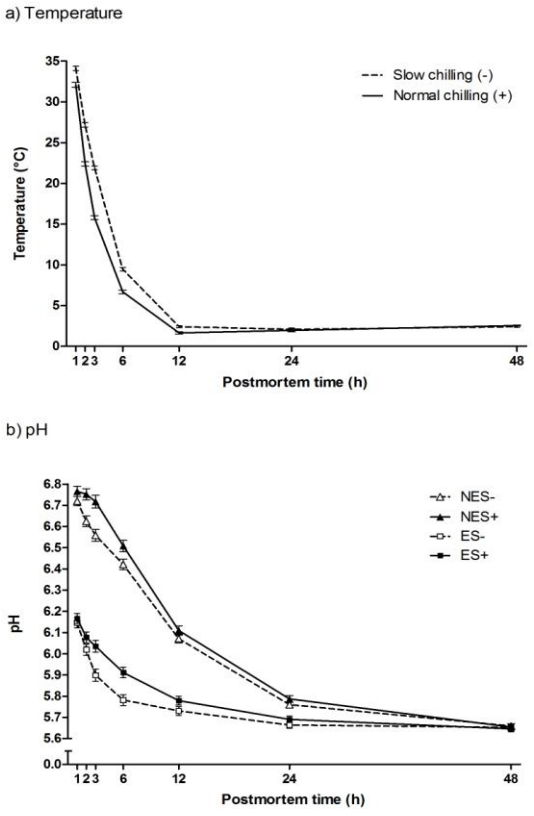

Figure 1. Temperature (a) and pH (b) decline of lamb carcasses (n = 105) according to electrical stimulation (ES) or not (NES) and normal (+) or slow (-) chilling.

Grouping of carcasses based on their temperature at pH 6.0 and also DFD-like pH provided insightful information (Table 1). An important proportion of carcasses (16.7%) had a

pHu higher than 5.8 irrespective of treatment, indicating that some pre-slaughter practices in Quebec are not optimal for meat quality. More research is needed to further explore this problem, which is reported for the first time. Almost all NES carcasses, under both chilling procedures, reached pH 6.0 below 10°C (Table 1), making them susceptible to cold-shortening [8]. In fact, they reached 10°C at pH 6.4-6.5, indicating that there is still significant amount of ATP in the muscle at a temperature where calcium sequestration is reduced. Comparable results have been reported by Pouliot et al. [2].

Some ES carcasses were below 10°C at pH 6.0, indicating that ES can reduce the incidence of cold-shortening but not completely prevent it. Moreover, the distribution of ES carcasses between the pH-temperature groups showed an important variation in response to ES in the lamb population. Some carcasses reached pH 6.0 too fast, above 35°C, which could potentially induce defects such as PSE-like condition [9], rigor shortening or poor aging due to fast autolysis of calpains [10, 11]. This was due to an over-response to ES for these carcasses, causing a huge drop in pH following stimulation: at 45 min postmortem they had almost reached a pH of 6.0 (data not shown). The incidence seems to be more important in slow chilling conditions where glycolysis could be accelerated. This indicates that response variability to ES between animals, slaughter days and chilling temperatures is important and complicates the use of ES. On the other hand, almost 60% of the ES carcasses in both chilling procedures reached pH 6.0 between 10 and 35°C (Table 1), a window of carcass temperature where most defects are prevented [12]. However, less than half of this number was in the recommended pH-temperature window (18-25°C) of the Australian Sheep Meat Quality program (Table 1). Better results have been obtained in Australia using a different stimulation system and protocol [5, 13].

Meat from carcasses classified in the DFD-like group differed in terms of *L**, *a** and *b** with DFD-like meat being darker, with reduced redness and yellowness (Table 2), confirming that their pHu was high enough to influence color quality. On the other hand, meat from carcasses that reached pH 6.0 above 35°C did not present the PSE-like characteristics in terms of color and was comparable to the > 10°C and < 35°C group.

IV. CONCLUSION

NES heavy lamb carcasses chilled too rapidly, making them susceptible to cold-shortening. Slow chilling as applied in this study was not useful in reducing the risk of cold-shortening, neither did it allow more ES carcasses to reach a desirable pH-temperature window. Electrical stimulation did reduce the risk of cold-shortening; however, the variation in pH response, probably due to heterogeneity in terms of genetics, rearing and feeding of lambs and pre-slaughter conditions, demonstrates the need for further optimization and research on post-slaughter technologies for the improvement of heavy lamb meat quality.

Table 1 Carcass distribution into pH-temperature groups according to electrical stimulation (ES) or not (NES) and normal (+) or slow (-) chilling

	Non-stimulated (NES)		Electrically Stimulated (ES)	
	Normal chilling (+)	Slow chilling (-)	Normal chilling (+)	Slow chilling (-)
Total	31	32	32	31
DFD-like (pHu > 5.8)	7	4	5	5
Temperature at pH 6.0				
≥ 35°C	0	0	1	5
> 10°C and < 35°C	0	1	18	20
> 18°C and < 25°C	*0*	*0*	*9*	*6*
≤ 10°C	24	27	8	1

Table 2 Color parameters of lamb meat at 3 d of aging according to pH-temperature groups

		Temperature at pH 6.0				*P*-value	
	DFD-like	≥ 35°C	> 10°C and < 35°C	≤ 10°C	SEM	Group	DFD vs others
n	21	6	39	60			
Color							
L*	34.8	40.7	38.6	37.9	1.1	< 0.0001	< 0.0001
a*	10.8	13.5	13.3	12.6	0.5	< 0.0001	< 0.0001
b*	5.3	9.0	8.1	7.5	0.4	< 0.0001	< 0.0001

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