Obtaining tender meat by rapid chilling of light lamb carcasses

I. JAIME, J.A. BELTRAN, P. CEÑA and P. RONCALES

Dep. Producción Animal y Ciencia de los Alimentos. Facultad de Veterinaria. Universidad de Zaragoza. 50013 Zaragoza. Spain.

SUMMARY : Lamb carcasses of animals aged either 2,5-3 months (light) or about 5 months (heavy) were exposed immediately after slaughter to three different refrigeration conditions: rapid chilling, chilling and conventional refrigeration. In all cases carcasses were aged thereafter for seven days at 4°C. Sensory overall tenderness was higher in muscles from light carcasses at the first day of aging. At this time meat from carcasses held under conventional refrigeration conditions showed the highest tenderness scores. Meat toughness increased as treatment temperature decreased, due to cold shortening. After seven days of aging, an increase of meat tenderness was evident, both in light and heavy carcasses. The degree of tenderization was similar for the three different conditions within each type of carcass. The sole exception was that of light lamb carcasses exposed to rapid chilling, in which the rate of temperature decrease during the first few hours post-mortem was the fastest. Following this latter treatment meat underwent the highest softening, reaching tenderness scores similar to those given to the meat from conventionally refrigerated carcasses.

INTRODUCTION : In the past years the relationship between muscle shortening and meat toughness as well as the occurrence of cold shortening by exposure of muscles to low temperatures prior to rigor onset have been extensively studied (Locker, 1960, Locker and Hagyard, 1963, Marsh and Leet, 1966, Honikel et al., 1983). Thus a direct relationship between toughness and shortening produced by chilling of carcasses in pre-rigor conditions has been reported both in beef and lamb (Herring et al., 1965, Marsh et al., 1974).

However, experiments carried out on excised lamb muscles (Jaime et al., 1989) suggested that besides the toughening effect of muscle shortening, the rate of decrease of internal muscle temperature might be a factor which could influence to a greater extent tenderness of meat, even if muscle has undergone a high degree of shortening.

The experiments reported in this work were designed to determine the effect of post-mortem temperature conditions on lamb meat from intact carcasses, especially concerning rapid chilling of carcasses in an attempt to reproduce a rate of decrease of temperature as fast as it occurred in isolated muscles.

MATERIAL and METHODS : The animals used in this work were lambs aged either 2,5-3 months or about 3 months. These produced light carcasses in the weight range 9,5-12,5 Kg (as most usually consumed in Spain) or heavy carcasses of 16 to 20 kg (as usual in most european countries).

Ten carcasses of each weight were exposed to three refrigeration conditions which included: 1) rapid chilling, 2) chilling and 3) conventional refrigeration. 1. Carcasses were kept in a cold room with an air temperature of - 4°C for 5 hours and later at 0°C until 24 hours. 2. Chilling: carcasses were kept at 0°C for 24 hours. 3. Conventional refrigeration: after a period of 45 min at 2°C, carcasses were kept at 4°C until 24 hours post-mortem (h pm). Temperature was monitored by termocouples inserted into the centre of the loin (Longissimus dorsi muscle) and pH was measured with a penetration probe electrode throughout rigor mortis development.

At 1, 4 and 7 days pm, a section of every loin was excised from the carcasses. Samples were taken from this section for pH and water holding capacity determination. pH was determined in a homogenate of 3 g of muscle tissue in 20 ml distilled water with a Crison pH-meter and a combined glass electrode. Water holding capacity (WHC) was determined using a press method according to Grau and Hamm (1957). Values obtained at 1, 4 and 7 days for both parameters were averaged and used as mean for aging.

Sarcomere measurement. At 48 h post-mortem small cubes of about 3 g taken from Longissimus dorsi muscle were fixed by inmersion for 1 h in glutardialdehyde (2,5% in phosphate buffer pH 6,5). Four bundles of 2-3 fibers were removed from them, and the lengths of ten consecutive sarcomeres were measured in 10 randomly selected fibre fragments using a phase contrast microscope at 1000X magnification.

Tenderness evaluation. Overall tenderness was evaluated at 1 and 7 days pm by a semi-trained taste panel composed of ten members. Sensory scores were rated on a 9-point scale; 9 denoted extremely tender and 1 denoted extremely tough. Evaluation samples consisted of 0,7 cm thick loin steaks, trimmed of visible connective tissue and fried with very little oil on a frying pan to an internal temperature of 70°C (cooking method most frequently used in Spain). Steaks were cut in four sections and two of them, selected at random, presented to each panel member for evaluation.

RESULTS and DISCUSSION : Light and heavy lamb carcasses exposed to the three refrigeration conditions could be included into three groups according to the significant differences found in their rate of decrease of internal temperature of Longissimus dorsi muscle (Figure 1). Since the rate of decrease was affected both by temperature of conditioning and size and fat coberture of the carcass, group 3 was constituted only by light carcasses exposed to rapid chilling (- 4/0 °C) with a decrease of 36,3 °C in the first five h pm. Group 2 was composed of light and heavy carcasses exposed to chilling (0°C), as well as heavy carcasses rapidly chilled since their characteristics determined a slower decrease of internal temperature than in light carcasses. Finally, group 1 consisted of both light and heavy carcasses exposed to conventional refrigeration.

The effects of temperature treatment and type of carcass on meat tenderness are shown in Table 1. Sensory tenderness was lower in Longissimus muscle from heavy carcasses, probably due to the characteristics of connective tissue which seemed to lend to a higher toughness as age of animals increased (Lawrie, 1985). At the first day of aging the highest tenderness scores corresponded to the carcasses with a slower rate of decrease of temperature. Meat toughness was higher in carcasses included in groups 2 and 3 with a faster rate of decrease of temperature pm. As seen in Table 2 muscles from the two types of carcasses underwent a cold shotening of about 20%, quite similar for both rates of temperature decrease. The occurrence of cold shortening, even though the presence of intact skeletal attachments, and concomitant toughening have been reported in beef (Herring et al., 1965, Watt and Herring, 1974) and in lamb carcasses (Marsh et al., 1968, McCrae et al., 1971).

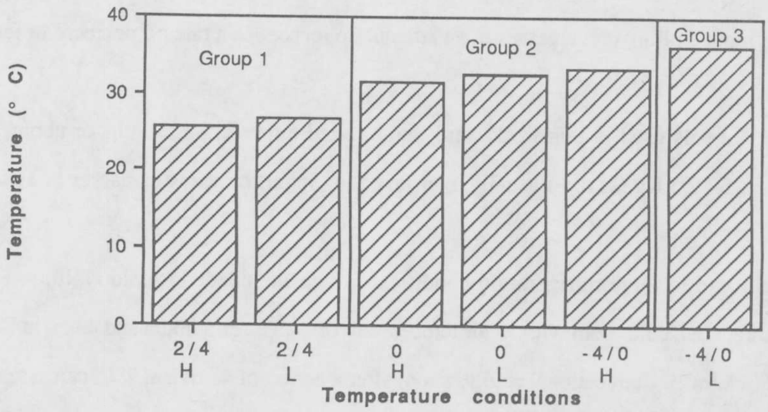

Figure 1.- Decrease of internal temperuture of lamb longissimus dorsi muscle in the first 5 hours postmortem. H: heavy carcasses, L: light carcasses. Temperature conditions as described in Material and Methods. Temperature decreases did not differ significantly within a group, significant difference was found between groups ($P<0.05$).

After seven days of aging tenderness increased significantly, independently of the refrigeration conditions used after slaughter (Table 1). In carcasses held under conventional conditions meat achieved high tenderness scores, equal for both light and heavy carcasses since the increase of sensory tenderness was higher in the oldest lambs, as was already shown by Jaime et al. (1989). The increase of tenderness scores between first and seventh days of aging was similar for chilling and conventional conditions within each type of carcass, i.e. for shortened and unshortened muscles. In contrast to the widespread opinion that cold shortening interfere with or even prevent meat tenderization throughout aging, meat of a considerable tenderness was obtained at seventh day of aging from carcasses exposed to chilling.

Table 1.- Overall tenderness panel scores on a 9-point scale (9 denoted extremely tender and 1 denoted extremely tough) at first and seventh day of aging for lamb meat from carcasses held under three different refrigeration conditions. **

	2/4 °C		0 °C		- 4/0 °C	
	H*	L	H	L	H	L
First day of aging	3,7±1,0 a	5,0±0,8 b	3,1±0,8 c	4,4±0,9 d	3,2±0,7 c	4,3±1,0 d
Seventh day of aging	7,1±0,9 a	7,1±0,7 a	6,4±0,7 b	6,4±0,7 b	6,4±0,8 b	7,1±0,6 a
Increase between 1st and 7th day of aging	3,4	2,1	3,3	2	3,2	2,8

*Type of carcass: H heavy carcasses, L: light carcasses.
**Mean values not followed by the same letter within a row are significantly different ($p < 0.01$).

This result agreed with Sheridan (1990), who found that after 7 days of storage ultra-rapid chilled lamb meat was as tender as that from carcasses which had been conventionally chilled at 4 °C for 24 hours. In our work meat from carcasses held under rapid chilling conditions showed a degree of tenderization even higher than carcass which suffered only chilling, the former achieving the same sensory tenderness at 7th day of aging than conventionally refrigerated carcasses. Meat from these carcasses included in the group 3 with a rapid decrease of temperature showed a similar behaviour to that found in a previous work in isolated muscles exposed to drastic refrigeration (Jaime et al., 1989).

Table 2 evidentiates differences found between fast chilled muscle and those included in group 2 according to their rate of temperature decrease. This results might at least partially explain the different degree of tenderness achieved by fast chilled meat after seven days of aging, even though the scores at first day of aging were similar in both cases within each carcass type. Muscles which suffered the fastest chilling showed a slower decrease of pH , differing significantly ($P<0,05$) of the pH fall of muscles from carcasses held under less drastic temperature conditions.

Table 2.- pH, water holding capacity and sarcomere shortening for lamb meat from carcasses held under three different refrigeration conditions*

	2/4 °C		0 °C		- 4/0 °C	
	H[a]	L	H	L	H	L
Rate of pH decrease[b]	1,05±0,1 a	0,95±0,07 a	1,04±0,08 a	1,05±0,09 a	0,78±0,08 b	0,62±0,12 c
pH (mean for aging)	5,57±0,07 a	5,63±0,08 a	5,58±0,07 a	5,64±0,06 a	5,60±0,14 a	5,78±0,08 b
Sarcomere shortening (%)	4,9	2,5	14,8	22,75	21,8	25,3
WHC (mean for aging) [c]	27,0±2,6 a	27,7±1,9 a	27,8±1,9 a	29,0±2,7 a	27,1±2,0 a	24,5±2,8 b

a Type of carcass: H heavy carcasses, L: light carcasses
b Units of pH decrease in the first 15 hours post-mortem
c Water holding capacity expressed as water released from 100g of meat .
* Mean values not followed by the same letter within a row are significantly different ($p < 0.01$).

A great importance is given by Marsh et al. (1987) and Smulders et al. (1990) to the effect of glycolytic rate on toughness of meat . At 48 h pm the correlation of panel tenderness on sarcomere length was remarkably high in the slow glycolysers, but negligible in those of faster pH decline (Smulders et al., 1990). In that work muscles with a pH at 3 h pm under 6,3 were considered fast-glycolysing muscles.In our work even muscles with the fastest pH decline should be included in the slow-glycolysers category. Therefore, the observed influence of cold shortening on meat tenderness at first day of aging agreed with Smulders et al. (1990) who found that tenderness was very highly dependent on shortening in slow-glycolysing muscles. An increase of meat tenderness throughout aging was shown by Marsh et al. (1987), who reported that the aging effect was lower as glycolytic rate increased. This would suggest that a slower pH decline in the fastest chilled muscles could have an advantageous effect, contributing indeed to the high tenderness found at seventh day of aging. A higher release of calcium from sarcoplasmic reticulum was found in isolated muscles held at low temperature (0°C) comparing to muscles held under not so low temperatures (> 4°C) (Jaime et al. 1989). The effect of a higher pH throughout aging, in addition to the high calcium level could determine a higher proteolytic activity of calpain and therefore a more intense tenderization.

On the other hand, the high pH and WHC in meat from carcasses held under rapid chilling conditions could exert an influence on the sensory evaluation of tenderness, determining that meat was perceived as more tender by panellists. Meat from these carcasses had a higher water holding capacity than in any other treatment, which could explain in part the high tenderness scores obtained for this treatment, since juiciness perception was not discriminated from overall tenderness by panel members.

CONCLUSIONS : Unaged meat from lamb carcasses exposed to low temperatures post-mortem exhibited a considerable toughness, due to cold shortening. However, when meat was aged for 7 days it underwent a remarkable tenderization, especially intense in rapidly chilled carcasses. Meat from these carcasses achieved in fact tenderness scores similar to those of meat from carcasses in which temperature treatment did not induce cold shortening. This effect appeared to be related to a slower rate of post-mortem pH decrease induced by very low temperatures.

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