EFFECT OF FAST CHILLING TEMPERATURE AND REFRIGERATED STORAGE DURATION ON LAMB QUALITY

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***Abstract*—The effect of fast chilling temperature (FCT) (0 ºC or -10 ºC) and refrigerated storage duration before splitting (RSD) (8 h or 24 h) on meat quality, was evaluated in 32 lamb carcasses of Rasa Aragonesa breed. FCT was applied for 90 minutes followed by 8 h or 24 h of storage at 0-2 ºC. pH, colour, lipid oxidation and texture were assessed in the muscle *Longissimus dorsi* displayed during 8 days. The results showed that display had less effect on the instrumental measurements of meat quality than the treatments evaluated, where texture was the main variable affected, being observed the highest C20 and C80 values at -10 ºC of FCT and 24 h of RSD. The interaction between the two fixed effects (FCT and RSD) was only significant in texture assessed by Warner-Bratzler test (Max Load).**

***Index Terms*—chilling temperature, instrumental meat quality, lamb, refrigerated carcass.**

I. INTRODUCTION

In Mediterranean countries, sheep breeding is much larger than in most other countries in the northern hemisphere (Sañudo, Sanchez, & Alfonso, 1998). Spain, France, Italy and Greece represented more than 55% of the European sheep and goat meat consumption in 2003 (FAOSTAT, www.fao.org).

The shelf-life of meat has always been of human concern since it is a perishable product. Refrigeration is the most common method of extending its shelf life (Medel & Sierra, 2001). Within conservation systems, the use of low temperatures has been widely used. Extended storage life is desirable because it facilitates the distribution of meat, (Scholdt, Jordaan, Krüger, Nortjé, & Naudé, 1992) and many consumers will pay a premium for prolonged freshness (Bailey, Jayas, Holley, Jeremiah & Gill, 1997). It is well documented that storage and subsequent ageing of meat at refrigerated temperatures *post-mortem* results in a significant improvement in tenderness (Koohmaraie, Seideman, Schollmeyer, Dutson, & Crouse, 1987; Koohmaraie, 1992). Cooling conditions of the carcasses can change variables of instrumental and sensory quality of the product. Besides, when carcasses are cooled quickly, they have the potential to be affected by cold-induced shortening or toughening (Savell, Mueller, Baird, 2004). Even an increase of 2º C in cooling temperature has been shown to produce significant changes on the quality of meat, specifically, the loss of weight, colour and texture (Muela, Sañudo, Campo, Medel, & Beltrán, 2010). The aim of this study was to assess the effect of fast chilling temperature and refrigerated storage duration before splitting on lamb quality.

II. MATERIALS AND METHODS

The study used 32 lamb carcasses of Rasa Aragonesa breed, a rustic breed that is reared for meat purpose in Aragón, Spain. Animals were reared intensively and fed with concentrate and cereal straw *ad libitum,* until they reached a fixed live slaughter weight (23-25 kg; no older than 90 days). Animals were slaughtered at an EU- licensed abattoir following standard protocols and carcasses were randomly selected among commercial lambs slaughtered on the corresponding slaughter date.

The experiment took place in the facilities of "Pastores Group", in an independent cold storage room. The relative humidity (RH) and environmental temperature (T) were controlled and monitored by four data logger *Testo 175-H2*, placed on the walls of the cold storage room at the same height as the carcasses. The lamb carcasses were divided in 4 batches. Each batch was composed of eight carcasses selected randomly (with a cold carcass weight of 11-13 kg). Thirty minutes after slaughtering, carcasses were cooled with a fast chilling system during 90 minutes. Half of the carcasses were chilled at 0 ºC and the other half at -10 ºC (FST). Then, 8 carcasses of each group were stored in refrigerated conditions (0-2 ºC, 85-90% relative humidity (RH), 0-0.2 m/s air speed) during 8 h or 24 h (RSD). Before splitting, carcass temperature was measured by inserting thermometer into *Quadriceps femoris* muscle. After this, the carcasses were quartered and transported to the meat quality laboratory of the Veterinary Faculty of Zaragoza, where the muscle *Longissimus dorsi* (LD) was dissected from the left side of the carcass and sliced according to the analyses requirements. The samples for colour measures and pH were stored on polystyrene trays covered with an air-permeable plastic film. Samples for texture analysis were vacuum-packaged, stored in refrigeration (2- 4 ºC) during 1, 4 and 8 days

and then, frozen and kept at -20 ºC until being analyzed. Samples for lipid oxidation were displayed only during 8 days and then frozen and stored at -20 ºC until being analyzed.

A portable *CRISON 507* pH-meter equipped with a penetrating electrode was used to measure the pH of the slices of the LD muscle at 1, 4 and 8 days of display. The colour was always assessed in the same slice at 1, 4, and 8 days of display, after 1h of blooming in the cranial portion of the LD. Final values were the average of three measurements. A portable *Minolta CR 200B* reflectance spectrophotometer with a standard illuminate D_{65} and a 10º standard observer, was used. Following the CIE-L*a*b* methodology (CIE, 1976). The colorimetric indices of chromaticity (C*) and hue (h*) were calculated.

Lipid oxidation was performed using the thiobarbituric acid-reactive substances method (TBARS) (Pfalzgraf, Frigg, & Steinhart, 1995). The lipid oxidation was measured at 8 days of display. Texture was measured with an Texturometer *Instron series 4301*, by a compression test in raw meat (load at compression at 20% and 80%) with a modified compression cell to avoid transversal elongation (Lepetit and Culioli, 1994) and by the Warner-Braztler (WB) device in heated meat (shear force). Samples were heated in their vacuum-sealed plastic bags in a 75 ºC water bath until the internal temperature of the meat reached 70 ºC. Instrumental texture assay requires muscle to be cut in parallelepipeds ($1cm^2$ cross section) parallel to the direction of the muscle fibre longitudinal axis. The texture was measured at 1, 4 and 8 days of display.

The effect of chilling temperature, the refrigerated storage duration before splitting and the time of display, on the parameters of meat quality was analyzed using SPSS 15.0 for Windows XP. Descriptive statistical analysis (mean and standard deviation) were computed for each parameter. To assess the statistical significance of the effects and any interactions, a general linear model (GLM) was used. When the main effect was significant, Duncan´s Multiple Range Test was applied, with the level for statistical significance set at $p \leq 0.05$.

III. RESULTS AND DISCUSSION

The significance of the main effects is showed in Table 1. In general, display had less effect on the instrumental measurements of meat quality than treatment and the interaction between the two fixed effects (FST and RSD) was only significant in texture assessed by Warner-Bratzler (Max Load). Treatment had a significant effect on pH, on colour parameters, on lipid oxidation and on texture assessed by compression test (C20 and C80) and by Warner-Bratzler test (Max Load). Display had a significant effect on pH, on h* (hue), and on texture analysis, compression and Warner-Bratzler.

pH was greater at 0 ºC/8 h than it was in the rest of treatments (Table 2), while pH was lower at 1 day of display than at 4 or 8 days. Chilling temperature and storage duration affected the surface colour, which could modify the colour perceived by observers (Ledward, 1985). Meat had the highest L* and C* values at 24 h of RSD, independently of 0 ºC or -10 ºC of FCT. The lowest values for these parameters were at 8 h of RSD and -10 ºC of FCT, respectively. However, only one colour variable was affected by display (h*), which showed a higher value at 8 days. On texture, the highest C20 and C80 values were observed at -10 ºC of FCT and 24 h of RSD. The effect of display showed that, at 1 day, C20 presented the biggest value and C80 the lowest one.

Table 3 shows the interaction between treatment and display for shear force (WB). It can be observed that the lowest values corresponding at 0 ºC of FCT and 24 h of RSD throughout display. The greatest values of toughness were observed at 8 h of RSD independently of FCT, probably due to cold-shortening. However, when the time of display was increased until 8 days, toughness was decreased. Also toughness decreased about 50% when splitting took place at 24 h instead of at 8 h. Some authors believed that muscles with values of 5 kg of shear force or less would be considered acceptably tender by the consumers (Shorthose, Powell & Harris, 1986). Other studies have shown that in lamb, toughness is maximum at 24 h post slaughtering and then becomes tender during *post-mortem* refrigerated storage because of ageing (Koohmaraie, Doumit & Wheeler, 1996). Differences were not observed on toughness between chilling temperature at -10 º C or 0 ºC, which could be interpreted as a big advantage by the industry because it is known that low temperatures decreases micro-organisms counts.

IV. CONCLUSIONS

The largest differences have been seen in texture. Splitting at 8 h would be less recommended than at 24 h because the cooked meat will be tougher. In the case of splitting 8 h after slaughtering, the meat should be consumed after 8 days of display to obtain an acceptable tenderness. Although toughness was not affected by chilling temperature (-10 ºC or 0 º C), it is recommended low temperatures to ensure food safety and maximize shelf-life.

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Table 1
Significance of the two main effects and their interaction for the instrumental meat parameters

Analysis		Significance level		
		Treatment (T)	Display (D)	T*D
pH		**	**	ns
Internal T[a] (before splitting)		ns		
Colour	L*	***	ns	ns
	h*	*	***	ns
	C*	***	ns	ns
TBARS (mg MDA/kg meat)		t		
Texture. Compression	C20	***	***	ns
	C80	***	***	ns
Texture. Warner-Bratzler	Max Load	***	***	*

ns=not significant; t≤0.1; *p≤0.05;**p≤0.01;***p≤0.001
T=FCT/RSD (fast chilling temperature/refrigeration storage duration)

Table 2

Effect of treatment (fast chilling system and refrigeration storage duration) and display duration (least square means ± S.E.) on the instrumental measurements of quality of lamb meat

Effect/variables[A]		Treatment (FCT/RSD)				Display		
		0 ºC/8 h	0 ºC/24 h	-10 ºC/8 h	-10 ºC/24 h	1 day	4 days	8 days
pH		5.81±0.07b	5.76±0.07a	5.75±0.05a	5.75±0.07a	5.74±0.06a	5.78±0.06b	5.78±0.08b
Internal T[a] (before spliting)		2.72±1.00	2.64±0.19	2.71±0.46	2.87±0.61	----------	----------	----------
Colour	L*	46.89±3.09b	49.02±1.91c	43.75±1.46a	48.80±2.72c	46.39±2.76	47.32±2.96	47.34±3.49
	h*	36.81±4.77b	35.55±3.46ab	34.77±4.39a	36.17±3.97ab	31.48±2.67a	36.70±2.58b	39.29±2.65c
	C*	17.03±1.66b	20.16±1.28c	14.13±1.83a	20.45±1.81c	17.70±3.27	18.23±2.84	17.90±3.13
TBARS (mg MDA/kg meat)		0.12±0.02ab	0.11±0.02ab	0.10±0.01a	0.13±0.04b	----------	----------	----------
Texture								
Compression	C20	5.49±1.88a	6.04±2.47ab	5.07±1.89a	7.27±3.24b	7.80±2.69b	5.43±2.17a	4.65±1.54a
	C80	39.97±11.78a	46.37±12.17b	37.26±12.02a	49.42±11.27b	36.02±9.13a	45.55±10.49b	48.39±14.54b

[A:] The parameters were meassured at 1 or 4 or 8 days of display (+ 8 h or 24 h)
C20 and C80: compression test at 20% and 80% of total compression; MDA: malonaldehyde; FCT/RSD (fast chilling temperature/refrigeration storage duration)
a,b,c: different letters in the same row indicate significant ($p \leq 0.05$) differences among means

Table 3
Least square means (±S.D.) of texture (WB) in terms of four different treatments and display

Effect/variable		Treatment (T)			
		0 ºC/8 h	0 ºC/24 h	-10 ºC/8 h	-10 ºC/24 h
Max Load (kg)	1 d	7.23±1.08by	4.32±0.73ay	7.07±2.37b	5.73±1.81aby
	4 d	7.34±0.73cy	2.50±0.50ax	7.47±1.07c	3.42±1.04bx
	8 d	5.52±1.00bx	2.72±0.95ax	5.85±1.44b	3.17±1.06ax

WB: Warner-Bratzler; SD: standard deviation
T=FCT/RSD (fast chilling temperature/refrigeration storage duration)
a,b,c: different letters in the same row indicate significant ($p \leq 0.05$) differences among means
x,y: different letters in the same column indicate significant ($p \leq 0.05$) differences among means