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RESEARCH ARTICLE

Effect of Rapid Chilling and Pelvic Suspension on Meat Quality of *Longissimus dorsi* Muscle of Lamb [1]

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Summary

The objective of this study was to examine the effect of rapid (RC) and conventional (CC) chilling with achilles (AS) and pelvic (PS) suspension on the meat quality of *M. Longissimus dorsi*. Twenty lamb carcasses were randomly allocated immediately prior to slaughter to the two experimental groups which were subjected to four different treatments. In the first group, carcasses were suspended from the Achilles tendon. Right sides (RC/AS; n=10) were rapidly chilled, while the left sides (CC/AS; n=10) were conventionally chilled. In the second group, the carcasses were re-hanged from the pelvic bone. Right sides (RC/PS; n=10) were rapidly chilled whilst the left sides (CC/PS; n=10) were conventionally chilled. Meat quality was evaluated by measuring the water holding capacity (WHC), cooking loss (CL), surface colour and shear force (SF). As a result, CC accelerated the rate of pH decline while RC increased the temperature decline. RC reduced CL and WHC values. PS had no impact on WHC, CL and color of steaks, but decreased the SF values on the 7th days of post-mortem. In conclusion; PS is a useful method for improving tenderness during storage period and the disadvantageous effect of RC on SF could be equalized by using PS.

Keywords: *Pelvic suspension, Meat quality, Rapid chilling, Tenderness, Lamb*

Hızlı Soğutma ve Pelvik Asılmanın Kuzulara Ait *Longissimus dorsi* Kasındaki Et Kalitesi Üzerine Etkisi

Özet

Bu çalışma, aşil tendosundan ve pelvis bölgesinden asma ile birlikte hızlı ve konvansiyonel soğutmanın *M. Longissimus dorsi*'nin et kalitesi üzerine etkisini incelemek için amaçlanmıştır. Yirmi kuzu karkası, kesimden hemen önce rastgele olarak iki deneysel gruba ayrılmış ve kesim sonrası dört faklı muameleye tabi tutulmuştur. İlk gruptaki karkaslar aşil tendosundan asılmıştır. Sol taraflar konvansiyonel olarak soğutulurken (CC/AS; n=10), sağ taraflar hızlı şekilde soğutulmuştur (RC/AS; n=10). Ikinci gruptaki karkaslar pelvik kemikten tekrar asılmıştır. Sol taraflar konvansiyonel soğutulurken (CC/PS; n=10), sağ taraflar hızlı şekilde soğutulmuştur (RC/PS; n=10). Et kalitesi su tutma kapasitesinin (WHC), pişirme kaybı (CL), yüzey rengi ve kesme kuvvetinin (SF) ile ölçülmesi ile değerlendirilmiştir. Sonuç olarak, RC sıcaklık düşüşünü arttırırken, CC pH düşüş oranını hızlandırmıştır. RC reduced pişirme kaybı ve su tutma kapasitesini azaltmıştır. Pelvik asılmanın su tutma kapasitesi, pişirme kaybı ve bifteğin rengi üzerine hiçbir etkisi yokken, SF değerlerini kesim sonrası yedinci günde azaltmıştır. Sonuç olarak, PS saklama periyodu boyunca yumuşaklığı geliştirmek için kullanışlı bir metoddur ve kesme kuvveti üzerinde RC'nin dezavantajlı etkisi pelvik asılma kullanılarak eşitlenebilir.

Anahtar sözcükler: *Pelvik asılma, Et kalitesi, Hızlı soğutma, Yumuşaklık, Kuzu*

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INTRODUCTION

Consumer acceptance of meat depends on quality characteristics such as tenderness, color and palatability attributes, which are influenced by a series of factors, ranging from physical and chemical to histological properties and meat-processing procedures [1-4]. Numerous techniques are currently used to improve meat quality. Chilling and suspension techniques are one of the effective applications worldwide [5,6]. During the first 24 h of post-mortem, the rate of temperature decline affects the bio-chemical and structure changes on the conversion of muscle to meat. The efficacy of temperature and pH on tenderization depend on the carcass chilling rate [7,8]. Nowadays, different applications of chilling processes are used in most parts of the world to reduce the problems associated with temperature/pH relationships. Rapid chilling (RC) appears more applicable system for extending the shelf life and reducing the evaporative loss of meat [6]. However, compared with conventional chilling regimes, application of RC has a risk of producing tough meat with a high shear force [9]. Therefore, it is important to control the meat temperature in order to improve the tenderness of meat concomitant with RC. Pelvic suspension (PS) has been shown to improve the tenderness in beef [10], lamb [11] and pork meat [12].

PS involves hanging carcasses from the *obturator foramen* shortly after slaughter and before the commencement of rigor [13]. The hind leg hangs vertically from the carcass reversing the effects on the muscles involved and the vertebral column is straightened [14]. The present study was aimed to investigate the concominant effects of RC and PS on the meat quality of *M. longissimus dorsi* (LD) of lamb.

MATERIAL and METHODS

The research protocol of the current study was approved by the Ethic Committee of the Istanbul University, Faculty of Veterinary Medicine (Approval number: 2004/078).

Animals and Experimental Design

Twenty lambs, averaging 11 months of age and overal live weight of 45 kg at slaughter were procured from Istanbul University, Faculty of Veterinary Medicine farm. The animals were transported to the slaughterhouse from nearby farm within 15 min for 1 day prior to slaughter. After a rest for 22-24 h, with only water available, animals were electrically stunned at 220-250 V, 1.0-1.3 A for 1-3 second, stunning tongs applied on both sides of the head. Following exsanguinations and evisceration, carcasses were halved by splitting through the vertebral column within approximately 25 min of postmortem.

Carcasses were randomly allocated immediately prior to slaughter to the two experimental groups which were subjected to four different treatments. In the first group, carcasses were suspended from the Achilles tendon. Right sides (RC/AS; n=10) were rapidly chilled (air temperature, -18±1°C; wind velocity, 2 m/s) for 6 h and then placed in a conventional chiller (air temperature, 2±1°C; wind velocity, 1 m/s) for 18 h, while the left sides (CC/AS; n=10) were conventionally chilled (air temperature, 2±1°C; wind velocity, 1 m/s). In the second group, the carcasses were re-hanged from the pelvic bone. Right sides (RC/PS; n=10) were rapidly chilled, whilst the left sides (CC/PS; n=10) were conventionally chilled. At 24 h of post-mortem, the longissimus muscle (LM) was removed from each half carcass after measuring pH and divided into two portions. Portions were vacuum packaged in Cryovac barrier bags (Cryovac Sealed Air Corp., New Jersey, USA) and stored at 2±1°C for up to 7 days post-mortem prior to the evaluating the water holding capacity (WHC), cooking loss (CL), shear force (SF), and instrumental colour (CIE *L**, *a**, *b**).

Meat Quality Measurements

The temperature and pH were monitored in the deep portion of the LM at approximately 1 h, 4 h, 8 h and 24 h post-mortem using a portable thermometer (Hanna HI 145) and pH meter (Hanna HI 8314) [15].

The percentage of free liquid was evaluated as a measure of WHC by the filter press method described by Hertog-Meischke et al.[16]. The outline area of the expressible juice and the meat film traced, and two areas were measured using AUTOCAD 2007 (Apso Ltd, UK). CL was calculated from the weight of samples taken before and after cooking.

SF of steaks was determined by measuring the force required to shear through a cooked sample at 2 and 7 days of post-mortem. Samples were cooked individually in a 100°C water bath (NB20, Nuve, Istanbul, Turkey) until an internal temperature of 75°C was reached. The cooked samples were stored in a refrigerator overnight and the pieces (2.5 cm thick) were removed parallel to the muscle fiber. The pieces were sheared by a Warner-Bratzler shear attachment mounted on an Instron Texture Analyzer (3343 model, Instron, UK) with a 50 kg load transducer and crosshead speed of 200 mm/min. An average of five sub-samples was accepted to be the SF value of the sample [17].

Meat colour was measured using a Color Flex Hunter Lab Colour Measurement System (Hunter Associates Laboratory Inc., Virginia, USA). Colour coordinates values which were refered as *L** for lightness, *a** for redness, and *b** for yellowness, were recorded at each analyzed day. Colour was evaluated using a diffuse illumination (D65 2° observer) with 8 mm viewing aperture and a 25 mm port size with the specular component excluded and readings were averaged. Colour values were obtained considering the average of five readings, performed in different location of the meat surface [18].

Statistical Analysis

Analysis of variance (ANOVA) was conducted for each variable to investigate the effect of chilling regime and suspension type on meat quality of lamb meat. The model used included the fixed effects of storage time, chilling rate and suspension conditions. Means of each characteristic, which were significantly different, were separated using Duncan's multiple range tests and significance of differences was defined as P<0.05 [19].

RESULTS

Changes of pH and temperature values obtained from carcasses are given in *Table 1*. According to the results, it was found that the pH values in RC were higher than CC. Differences among the results of the groups at 4 and 8 h were significant (P<0.001). Carcass temperature at 1 h was 37.44°C (P>0.05) and faster drop on the muscle temperature was remarkable after 4 h in both groups *(Table 1)*. The mean temperatures excepted after 24 h for RC were significantly lower than DC (P<0.05).

The effect of chilling conditions and suspension methods on WHC, CL and SF are presented in *Table 2*. RC reduced significantly CL and WHC (water expelled) values (P<0.001), and SF values were lower in CC carcasses than RC carcasses (P<0.001).

The effect of RC on colour parameters is summerazed in *Table 3*. RC significantly decreased *L** values (P<0.001) only at 2 day of post-mortem. There were no significant differences in *a** and *b** values between RC and CC carcasses. Additionally, colour parameters were not affected by using PS (P>0.05).

DISCUSSION

CC accelerated the rate of carcass pH decline. In the present study, the pH values in RC were higher than CC. Similar results in pH were reported by Li et al.[9] and Hopkins et al.[20]. At the end of the chilling process (24 h), the average pH values in the groups was 5.60 (P>0.05). Likewise, Bayraktaroglu and Kahraman [5] found that the values for ultimate pH were between the range of 5.3 and 5.7 for lamb carcasses.

In this study, carcass mean temperatures excepted after 24 h for RC were significantly lower than DC (P<0.05). Likewise, Janz et al.[21] indicated that RC increased the

Table 1. *Changes in the pH and temperature values of lamb meat*
Tablo 1. *Kuzu etinin pH ve sıcaklık değerlerindeki değişimler*

Attribute	Groups	n	Time (hours)			
			1	4	8	24
pH	RC	10	6.80±0.01	6.45±0.01^{a}	6.12±0.02^{a}	5.60±0.01
	CC	10	6.77±0.01	6.32±0.01^{b}	5.96±0.03^{b}	5.60±0.01
	P	20	NS	***	***	NS
Temperature (°C)	RC	10	37.44±0.06	16.37±0.03^{b}	12.33±0.04^{b}	2.59±0.06
	CC	10	37.44±0.07	20.61±0.04^{a}	17.41±0.03^{a}	2.52±0.07
	P	20	NS	***	***	NS

RC: *Rapid chilling,* ***CC:*** *Conventional chilling; * P<0.05, ** P<0.01, *** P<0.001*

Table 2. *Effect of RC and PS on the water holding capacity (WHC), cooking loss (CL), and shear force (SF) of lamb meat*
Tablo 2. *Kuzu etinin RC ve PS'nin su tutma kapasitesi (WHC), pişirme kaybı (CL) ve kesme kuvveti (SF) üzerine etkisi*

Attribute	Storage (days)	n	Groups				P
			RC/AS	RC/PS	CC/AS	CC/PS	
CL (%)	2	10	25.93±0.28^{bA}	25.87±0.13^{bA}	26.77±0.26^{aA}	26.59±0.30^{aA}	***
	7	10	23.94±0.14^{bB}	23.67±0.09^{bB}	25.52±0.14^{aB}	25.32±0.27^{aB}	***
	P	20	***	***	***	**	
WHC (%)	2	10	13.91±0.16^{bB}	13.90±0.13^{b}	14.10±0.11^{a}	14.09±0.17^{a}	***
	7	10	13.78±0.21^{bA}	13.77±0.21^{b}	13.95±0.17^{a}	13.87±0.21^{a}	*
	P	20	NS	NS	NS	NS	
SF (kgf)	2	10	3.94±0.10^{a}	3.85±0.10^{a}	3.73±0.14^{b}	3.33±0.15^{b}	***
	7	10	3.92±0.13^{a}	3.74±0.10^{b}	3.61±0.15^{b}	3.28±0.08^{c}	***
	P	20	NS	NS	NS	NS	

a, b, c: *Means within a row with different letters are significantly different (P<0.05);* ***A, B:*** *Means within a column with different letters are significantly different (P<0.05); * P<0.05, ** P<0.01, *** P<0.001*

Table 3. *Effect of RC and PS on color values*
Tablo 3. *RC ve PS'nin renk değerleri üzerine etkisi*

Attribute	Storage (days)	n	Groups				P
			RC/AS	RC/PS	CC/AS	CC/PS	
Lightness (*L**)	2	10	31.13±0.53^{b}	31.11±0.44^{b}	33.92±0.49^{a}	33.69±0.22^{a}	***
	7	10	35.94±0.99	36.38±0.73	36.71±0.45	36.65±0.34	NS
	P	20	**	***	**	***	
Redness (*a**)	2	10	12.42±0.89^{A}	13.42±0.52^{A}	11.77±0.91	12.71±0.59^{A}	NS
	7	10	10.50±0.23^{B}	10.61±0.30^{B}	10.38±0.27	10.63±0.37^{B}	NS
	P	20	*	***	NS	**	
Yellowness (*b**)	2	10	12.60±0.38	12.09±0.27^{B}	12.27±0.26^{B}	12.32±0.42	NS
	7	10	13.94±0.29	13.97±0.28^{A}	13.69±0.22^{A}	13.14±0.21	NS
	P	20	NS	**	**	NS	

a,b,c: *Means within a row with different letters are significantly different (P<0.05);* ***A, B:*** *Means within a column with different letters are significantly different (P<0.05) ; * P<0.05, ** P<0.01, *** P<0.001*

rate of temperature decline. Bendall [11] found that muscle temperature less than 10°C are susceptible to cold shortening when muscle pH less than 6.2 is reached and at 16°C cold shortening is less severe. In the present study, the temperature in RC and CC muscles were above 16°C at 4 h and 10°C at 8 h. It was implied that the chilling conditions had decreased the risk of cold shortening. In another study, Bowater [22] reported that beef and lamb carcasses must reach to the internal temperatures of 7°C after 24 h or before moving the carcass to the boning room.

Reduction in CL and WHC values because of RC is validated by earlier studies [9,23]. In another studies, it was concluded that RC had no effect on WHC and CL [24]. These differences may be originated from the different chilling temperature and wind velocity. PS had lower WHC and CL than AS at 2 and 7 days of post-mortem. However, no statistically significant differences were found (P>0.05) between the groups, which indicated that suspension methods had no impact on WHC and CL. Similar results were reported by Fisher et al.[25] and Claus et al.[26]. The results confirmed that WHC and CL depend on the ultimate pH value [27]. In contrary, Ahnstrom et al.[14] stated that PS significantly improved WHC by reducing the losses during storage. The differences could be attributed to the cooking method.

SF values were lower in CC carcasses than RC carcasses in the present study *(Table 2)*. The results showed that the temperature treatment has a powerful effect on tenderness. This is in agreement with previous studies [12,28]. However Li et al.[9] observed no significant difference between the chilling treatments. Differences may be due to variations in animal species and breed. On the other hand, SF values were lower in pelvic suspended carcasses, but significant differences were found only at 7 day post-mortem (P<0.001). Derbyshire et al.[29] stated that SF values were lower in pelvic suspended carcasses at aged for 7 day, but significant differences were found only at 24 h. Ahnstrom et al.[14] reported that PS reduced SF of *M. semimembranosus* from 67.7 to 53.3 N in bull carcasses.

No significant differences were observed in *a** and *b** values between RC and CC carcasses in this study, which showed similar findings with the reports of Bowling et al.[30] and Janz et al.[21]. Pearson and Dutson [31] also reported that a decrease of the free water on the cell surface give the meat darker appearance. On the other hand, no effect on *L** was found by several authors [32.33]. Additionally, colour parameters were not affected by using PS (P>0.05) *(Table 3)* similarly to those were found by Fisher et al.[25] and Claus et al.[26]. The similar colour values belong to PS and AS could be due to the same rate of pH decline at rigor.

The results of this study showed that CC accelerated the rate of pH decline and RC increased the temperature decline. PS had no impact on WHC, CL and colour of lamb meat. PS significantly decreased SF values only at 7 days of post-mortem. In conclusion, PS is a useful method for improving tenderness of LM during storage period and the disadvantageous effect of RC on SF could be equalized by using PS.

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