PE8.28 Retail colour display life of chilled lamb – impact of electrical stimulation and chilling 312.00

Katja Rosenvold (1) katja.rosenvold@agresearch.co.nz, E Wiklund(1), ,
(1)AgResearch MIRINZ, New Zealand

Abstract—Twenty percent of New Zealand lamb is exported chilled making up 46% of the value of lamb exports. Chilled lamb products are typically vacuum-packed straight after deboning and then stored and transported at -1.5°C and subsequently repackaged in consumer packages containing high levels of oxygen (> 70% O2) for retail display. This study explored the impact of electrical stimulation and different pre rigor on retail colour display life of lamb which had been vacuum-packaged for seven weeks prior to repackaging into consumer packages. It showed that electrical stimulation protected against toughening at both high (42°C) and low (5°C) pre rigor temperatures. Further, electrical stimulation had not effect on retail colour display life of lamb which had been vacuum-packed for seven weeks prior to retail display in high oxygen modified atmosphere. A high pre rigor temperature did significantly reduce the retail colour display life however it is unlikely that the colour differences found between the 5°C, 15°C and 25°C loins were sufficiently large to be important from a consumer perspective.

Index Terms—lamb, chilling, electrical stimulation, retail colour display life

I. INTRODUCTION

EPORT of meat from Australia and New Zealand – primarily to Europe – started with the development of refrigeration in the late 1800s. The first frozen shipment of meat from Australia to the UK took place in 1880. In 1882, the first consignment of frozen carcasses was shipped from New Zealand. It took three months to arrive in the UK and only one of the 4,931 mutton, beef and pork carcasses was rejected [1]. More impressively, the carcasses sold for approximately twice the price of what it would have fetched on the domestic market [2]. The New Zealand sheep meat export was focused around the trade of whole frozen carcasses until well into the mid 1980s [3]. The late 1960s saw the introduction of new hygiene and inspection requirements for two of the country's major markets. The US Wholesome Meat Act and the EC's Third Country Veterinary Directive set out strict standards for the ante and post mortem management of livestock destined for the respective markets. Necessary upgrades to meet these standards were progressively introduced through the 1970s and 1980s, and the largest impact of these upgrades was the capacity for processors to shift into chilled meat for export [3]. Today 20% of New Zealand lamb is exported chilled making up 46% of the value of lamb exports. Chilled lamb products are typically vacuum-packed straight after deboning and then stored and transported at -1.5°C. The time it takes for the product to reach overseas markets ensures that the product is very tender. Another import attribute of these products is the shelf life which is determined by the microbial spoilage and the colour stability of the meat in the consumer package – the latter is also referred to as retail colour display life. In 1993, the shelf life of chilled lamb products was stated to be no more than 63 days including the seven days from cutting to consumption [4]. However, since then practices have been improved and today the claimed storage shelf life is much longer (77+ days). In addition, meat distribution has changed; nowadays chilled lamb products will often be repackaged into consumer packages with modified atmosphere at central packaging operations. Only limited research has been carried out exploring the retail colour display life of chilled lamb which is vacuum-packaged and subsequently repackaged in consumer packages containing high levels of oxygen (> 70% O2). Although some studies have investigated processing effects (stimulation and chilling) most studies have altered both the electrical input and the chilling regime simultaneously. Hence it is difficult to distinguish which of the two process steps are causing the observed effects. However, there is little evidence that electrical stimulation alone affects the retail colour display life of chilled beef and lamb (i.e. meat which has been vacuum-packed and stored prior to retail display) [5-7] with the exception of the results by Van Laack and Smulders [8] which were slight although unlikely to be significant from a consumer perspective and Ledward et al. [9] who found electrical stimulation to negative effect the colour stability of chilled beef. But it does appear that chilling rate has a significant impact on retail colour of chilled beef as shown by Harris et al. [10]. This study explored the impact of

different processing conditions – electrical stimulation and different pre rigor temperatures – on retail colour display life of lamb which had been vacuum-packaged for seven weeks prior to repackaging into consumer packages using a design by which is was possible to distinguish between the effect of stimulation and chilling.

II. MATERIALS AND METHODS

Twenty lambs (mix of females and castrates) were slaughtered at the AgResearch Ruakura abattoir, Hamilton, New Zealand, on the same slaughter day. Both M. Longissimus dorsi (loins) from the 20 lambs (totaling 40 loins) were allocated to eight different treatments in a split plot design. The 8 treatments comprised two different factors: i) pre rigor temperature: 5°C, 15°C, 25°C or 42°C which were randomly allocated to animals; and ii) electrical stimulation: (80 V peak, 14.28 pulses s-1 for 30 s) 15 minutes post mortem (ES) or no stimulation (NES) which were randomly allocated to the two loins from each animal. The lambs were stunned with a captive bolt gun, slaughtered and dressed. One loin was removed from each carcass immediately before (NES) and the other immediately after (ES) electrical stimulation. Five lambs (five ES and five NES loins) were allocated to each of the four pre rigor temperatures. Random allocation of left and right loins to electrical stimulation as well as lambs to pre rigor temperatures was applied. After removal from the carcass, each loin was wrapped individually in cling film to prevent shortening, and then transported in insulated boxes to the MIRINZ laboratory, stored at 15°C until 1 h post mortem when they were put in plastic bags and immersed in water baths at 5°C, 15°C, 25°C or 42°C until rigor mortis was reached. Rigor mortis was defined as the time point when the pH fell below 5.60 for normal pH muscle or when the pH ceased to fall for muscle with elevated pH values. pH was measured - using a Mettler Toledo pH meter with a combination electrode (Mettler Toledo Inlab 427; Mettler Toledo Inc, Columbus, Ohio, US) – every hour from 1 hour post mortem until rigor mortis was reached. When rigor mortis was reached the loins were chilled down to and stored at -1.5°C until 2 days post mortem and then vacuum-packed and stored at -1.5°C for 7 weeks. After seven weeks of vacuum-packed chilled storage at -1.5°C, the loins were removed from the vacuum-packs and cut into four 3-cm thick samples which were butterflied and randomly allocated to retail display for 3, 6, 7 and 8 days. Randomly, one of these samples was allocated to the 0 day colour measurement, which was measured after 2 hours blooming at 2°C. The loins were packaged (individual packages for each retail display time) in 80% O2/20% CO2 modified atmosphere stored at 4°C under fluorescent light until the package was opened and the colour was measured using a Hunterlab Miniscan (Hunter Associates Laboratory, Reston, VA, USA). The average of three measurements across the surface was used. Shear force was measured seven weeks post mortem. The samples were cooked from the frozen state in a 100°C water bath until an internal temperature of 75°C was reached (measured with a thermocouple). The cooked sample was immediately placed in an ice-water slurry and when cool, 10 mm x 10 mm cross section samples (n = 10) were sheared using a MIRINZ tenderometer. Data were analysed using the ANOVA directive of GenStat [11].

III. RESULTS AND DISCUSSION

First, it was checked whether any of the loins had pH values above 5.80 when rigor mortis was reached as any such loins would be removed from the data set prior analysis, as the colour stability from these loins may interfere with the conclusion of this study as the formation of metmyoglobin is pH dependent [12]. All the loins had pHrigor mortis values below 5.80, and the mean values are shown in Table 1. Electrical stimulation is applied as part of the slaughter process to accelerate rigor mortis before chilling to avoid meat toughening caused by cold shortening [13] as cold shortening may take place if the muscle temperature falls too quickly while the energy level (pH) in the muscle is still high [14]. In this study, electrical stimulation resulted in a significant fall in pH ($p < 0.001$) with pH1 h values of 6.28 for stimulated and 6.68 for non-stimulated loins. Further rigor mortis was reached earlier post mortem in muscles which were electrically stimulated, and the time to reach rigor mortis increased with decreasing pre rigor temperature (Table 1). Shear force - measured in the loins after seven weeks of vacuum-packed storage - did not differ between electrically stimulated and non-stimulated 15°C and 25°C loins and were considered to be tender with shear force values below 60 N [15]. Further, electrical stimulation protected against toughing at both high (42°C) and low (5°C) pre rigor temperatures and the loins were equally tender to the 15°C and 25°C loins. This result is in agreement with recent findings

in beef [15]. Colour was measured in the loins after they had been stored under vacuum for 7 weeks at -1.5°C to simulate ideal storage and shipping conditions. Seven weeks were chosen as this is the average time it takes for New Zealand chilled lamb products to reach the European market allowing time from boning to loading onto the ship, transport and distribution in the receiving market prior to repackaging into retail packages. The retail colour display life was followed for eight days after the loins had been retail packaged with 80% O2 and 20% CO2 by measuring the L*-value (lightness), a*-value (redness) and b*-value (yellowness) (Figure 1). The colour of the loins changed significantly over the eight days the samples were followed with $p < 0.001$ for all three colour values. Electrical stimulation did not result in any significant differences in either L*-value ($p = 0.26$), a*-value ($p = 0.16$) or b*-value ($p = 0.15$), indicating that electrical stimulation has no impact on the colour stability of lamb which has been vacuum-packed for an extended prior to retail packaging in high oxygen modified atmospheres. The four pre rigor temperatures – simulating different chilling regimes – resulted in significant differences in L*-value ($p < 0.001$), a*-value ($p = 0.050$) and b*-value ($p < 0.003$). The L*-value decreased with decreasing pre rigor temperatures with the exception that there was no difference between the 5°C and 15°C loins. For the a*-value, there was an interaction between pre rigor temperatures and storage time ($p = 0.019$), which was primarily caused by the a*-value being higher in the 25°C loins on day 3, and the a*-value of the 42°C loins decreasing considerably faster from day 6 to day 8 compared to the other three treatments. Similar to the L*-value, the b*-value decreased with decreasing pre rigor temperatures, with only small difference between the 5°C and the 15°C loins. Hence, overall there was no effect of electrical stimulation on the retail colour display life of lamb loins which had been vacuum-packaged and stored at -1.5°C for seven weeks prior to retail packaging. Similarly, although different pre rigor temperatures induced a significant difference in retail colour display this was primarily caused by the 42°C pre rigor temperature. It is unlikely that the colour differences between the 5°C, 15°C and 25°C loins are sufficiently large to be important from a consumer perspective. Hence, the findings in this study support the evidence [5-7] that electrical stimulation has only limited effect on retail colour display life of chilled lamb. However, it is acknowledged that electrical stimulation improves meat colour at grading, whereas its effect on retail colour display life of fresh meat seems more uncertain [16]. The limited difference between the pre rigor temperatures of 5°C, 15°C and 25°C – essentially representing different chilling rates - were unexpected as it had previously been found that chilling rate would have had a larger impact on the retail colour display life of chilled beef [10]. The impact of storage temperature on retail colour display life of chilled lamb was investigated in a separate study [17].

IV. CONCLUSION

This study showed that electrical stimulation protected against toughening at both high (42°C) and low (5°C) pre rigor temperatures. Further, electrical stimulation had not effect on retail colour display life of lamb which had been vacuum-packed for seven weeks prior to retail display in high oxygen modified atmosphere. A high pre rigor temperature did significantly reduce the retail colour display life however it is unlikely that the colour differences found between the 5°C, 15°C and 25°C loins were sufficiently large to be important from a consumer perspective.

ACKNOWLEDGEMENT

This study was funded by AgResearch's Research and Capability Fund. The project team is gratefully acknowledged: Steffen Dalgaard, Pete Dobbie, Nick Penney, Emma Fraser-Smith and Adam Stuart.

REFERENCES

1. Robinson, D., No news is good. A History of New Zealand's Meat Hygiene Service 1898-2002. 2006, Wellington, New Zealand: Steele Roberts Ltd.

2. McCrystal, J., ed. A long Season: The Centennial History of AFFCO New Zealand. 2004, KUKUPA Press: Wellington, New Zealand.

3. McDermott, A., et al., The Key Elements of Success and Failure in the NZ Sheep Meat Industry from 1980-2007. 2008, Agmart.

4. Bell, R.G., Whys and hows of handling chilled New Zealand lamb. 1993: Hamilton, New Zealand. p. 58.

5. Channon, H.A., S.R. Baud, and P.J. Walker, Modified atmosphere packaging improves retail display life of lamb cuts with variation between loin and knuckle. Australian Journal of Agricultural Research, 2005. 45(5): p. 585-592.

6. Unruh, J.A., et al., Effects of low-voltage electrical stimulation during exsanguination on meat quality and display colour stability. Meat Science, 1986. 18(4): p. 281-293.

7. Moore, V.J. and O.A. Young, The effects of electrical stimulation, thawing, ageing and packaging on the colour and display life of lamb chops. Meat Science, 1991. 30(2): p. 131-145.

8. van Laack, R.L.J.M. and F.J.M. Smulders, Colour stability of bovine Longissimus and Psoas major muscle as affected by electrical stimulation and hot boning. Meat Science, 1990. 28(3): p. 211-221.

9. Ledward, D.A., et al., The colour and colour stability of beef Longissimus dorsi and Semimembranosus muscles after effective electrical stimulation. Meat Science, 1986. 16(4): p. 245-265.

10. Harris, M.B., et al., Immersion chilling: Revised Chilling Regime and updated Process Economics. 1999: Hamilton, New Zealand.

11. Payne, R.W., et al., eds. GenStat Release 11 Reference Manual, Part 1 Summary. 2008, VSN International: Hemel Hempstead.

12. Mancini, R.A. and M.C. Hunt, Current research in meat color. Meat Science, 2005. 71(1): p. 100-121.

13. Davey, C.L. and B.B. Chrystall, Conditions for an efficient post-mortem electrical stimulation. Ann Technol Agric, 1980. 29: p. 547-561.

14. Locker, R.H. and C.J. Hagyard, A Cold Shortening Effect in Beef Muscles. Journal of the Science of Food and Agriculture, 1963. 14: p. 787-793.

15. Rosenvold, K., et al., The protective effect of electrical stimulation and wrapping on beef tenderness at high pre rigor temperatures. Meat Science, 2008. 79(2): p. 299-306.

16. Renerre, M., Review: Factors involved in the discoloration of beef meat. International Journal of Food Science & Technology, 1990. 25: p. 613-630.

17. Rosenvold, K. and E. Wiklund, Retail colour display life of chilled lamb – impact of storage temperature, in 55th ICoMST. 2009: Copenhagen, Denmark.

Table 1 $pH_{rigor\ mortis}$, time to reach *rigor mortis* and shear force measured seven weeks *post mortem* for loins which were either electrically stimulated (ES) or non-stimulated (NES) and subjected to *pre rigor* temperatures of 5°C, 15°C, 25°C and 42°C (Standard error of means: $pH_{rigor\ mortis}$ = 0.025, time to reach *rigor mortis* = 1.2 h and shear force = 6 N).

	ES	NES	Stim	Temp	Stim *Temp
$pH_{rigor\ mortis}$					
5°C	5.59	5.60			
15°C	5.53	5.56	0.35	0.003	0.41
25°C	5.51	5.56			
42°C	5.50	5.47			
Time to reach *rigor mortis* (h)					
5°C	22.9[c]	25.8[c]			
15°C	11.0[b]	14.4[b]	0.007	< 0.001	0.58
25°C	7.3[a]	11.2[b]			
42°C	4.2[a]	4.9[a]			
Shear force seven weeks *post mortem* (N)					
5°C	53[a]	80[b]			
15°C	42[a]	48[a]	< 0.001	0.001	0.014
25°C	37[a]	40[a]			
42°C	51[a]	86[b]			

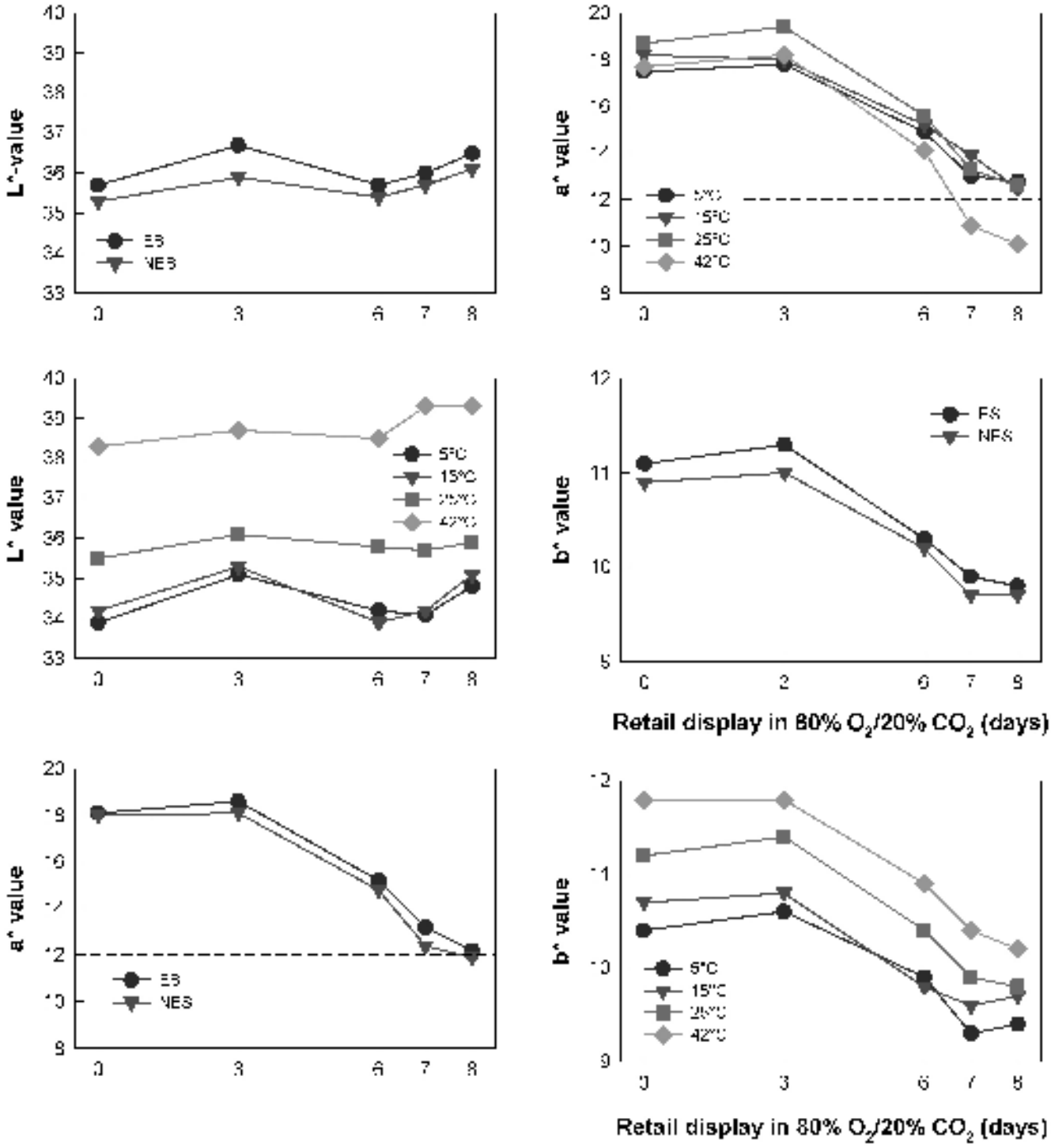

Figure 1. Colour measured as L*-value, a*-value and b*-value in loins which were either electrically stimulated (ES) or non-stimulated (NES) and subjected to pre rigor temperatures of 5°C, 15°, 25°C and 42°C, deboned and vacuum-packed for seven weeks prior to retail packaging with 80% O2 and 20% CO2.