PE8.29 Retail colour display life of chilled lamb – impact of storage temperature 313.00

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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 storage temperature (long term or short term compared to ideal storage conditions (-1.5°C) – on retail colour display life of lamb which had been vacuum-packaged for seven weeks prior to repackaging into consumer packages. It showed that retail colour display life of chilled lamb was significantly decreased when the storage temperature was increased from the ideal temperature of 1.5°C to 2°C for vacuum-packed lamb loins prior to retail display in high oxygen modified atmosphere. Even short term temperature abuse (one week at 2°C) at the end of the seven weeks storage period had a large negative impact on the retail colour display life. This illustrates that failure to maintain ideal storage temperatures throughout the supply chain (storage, transport, wholesale, retail) can significantly reduce retail colour display life.

Index Terms—lamb, retail colour display life, storage temperature

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 that has been vacuum-packaged for transport and subsequently repackaged in consumer packages containing high levels of oxygen (> 70% O2), but it is generally known, that apart from age of meat post mortem, increasing storage temperature has the most marked effect on reducing colour stability [5] and that seeming small differences in display conditions has a marked effect on metmyoglobin formation [6]. This study explored the impact of storage temperature (long term or short term compared to ideal storage conditions (-1.5°C) – on retail colour display life of lamb which had been vacuum-packaged for seven weeks prior to repackaging into consumer packages.

II. MATERIALS AND METHODS

Fifty-seven lambs were slaughtered on the same day at the AgResearch Ruakura abattoir, Hamilton, New Zealand. The lambs were randomly allocated to three different storage temperature treatments: i) -1.5°C for 7 weeks and 1 days (control), ii) 2°C for 7 weeks and 1 days (long term temperature abuse) and iii) -1.5°C for 6 weeks and 1 days followed by 2°C for 1 week (short term temperature abuse). For clarity, storage in vacuum-package for 7 weeks and 1 day and 6 weeks and 1 day, respectively, will in this paper be referred to in entire weeks. The lambs were electrically stunned, slaughtered and dressed followed by electrical stimulation (80 V peak, 14.28 pulses s^{-1} for 30 s) 15 minutes post mortem. The carcasses were then placed in a chiller following the normal chilling procedure of the abattoir. Approximately six hours post mortem the loins were removed from the carcasses and placed in a chiller at 10°C until 15 h post mortem, when the temperature was decreased to 4°C. At 24 h post mortem the loins were vacuum-packed and allocated to their specific storage temperatures. pH was measured 24 h post mortem using a Mettler Toledo pH meter with a combination electrode (Mettler Toledo Inlab 427; Mettler Toledo Inc, Columbus, Ohio, US). Retail display colour was measured after chilled storage according to the three storage temperature treatments described above. The loins were removed from the vacuum-packs and cut into five 3-cm thick samples which were butterflied and randomly allocated to retail display for 3, 5, 6, 7 and 8 days. The loin samples were packaged (individual packages for each retail display time) in 80% O_2/20% CO_2 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. Data were analysed using the ANOVA directive of GenStat [7].

III. RESULTS AND DISCUSSION

Three different storage regimes were used in this study: i) control where the loins were stored at -1.5°C for seven weeks simulating ideal storage conditions, ii) long term temperature abuse where the loins were stored at 2°C for seven weeks simulating the storage conditions had been to high both during storage at the abattoir, during transit and at the wholesaler prior to retail packaging and iii) short term temperature abuse where the loins were stored at -1.5°C for six week and one week at 2°C simulating that the wholesaler in the importing country stored the loins at less than ideal conditions. Three loins from the control group, and one loin from each of the long and short term temperature abuse groups had pH24 h above 5.80 and were removed from the data set prior to analysis, as the colour stability from these loins may interfere with the conclusion of this study as the formation of metmyoglobin is pH dependent [8]. When these five loins were removed from the data set there was no difference in pH24 h between the three treatment groups (Table 1).

Table 1 pH24 h measured in loins from control, long term temperature abuse and short term temperature abuse treatments.

	Control	Long term	Short term	SEM	p-value
n	16	18	18		
$pH_{24\,h}$	5.47	5.47	5.48	0.033	0.97

Colour was measured in the loins after they had been stored under vacuum for seven weeks. 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% O_2 and 20% CO_2 by measuring the L*-value (lightness), a*-value (redness) and b*-value (yellowness) (Figure 1). While the three storage treatments did not result in any overall significant differences in L*-value ($p = 0.43$), it appeared that the L*-value in the loins exposed to short term temperature abuse increased more rapidly from day 5 onwards compared to the other two treatments, and this difference was significant on day 7 between the loins exposed to short term temperature abuse and the control loins. Further, the L*-value did not change significantly during the retail display period ($p= 0.10$). In contrast the a*-values did change during the retail display period ($p < 0.001$). The storage treatments also had a significant effect on a*-value ($p = 0.013$) with the a-values of the loins exposed to long term temperature abuse being significantly lower than the control loins from day 5 to day 7, while the loins exposed to short term temperature abuse were in-between the two other treatments. On day 7, the a*-

value of the loins exposed to long term temperature abuse was below the acceptability limit of 12 [9] – and was also significantly lower than that of the loins exposed to short term temperature abuse. The acceptability of 12 was originally determined in venison however there is no similar estimate for lamb, but it was evaluated that this limit would also give an acceptable indication for lamb and was applied in this study. On day 8, there were no differences between the three treatments, and they were all at or below the acceptability limit. The b*-values decreased during the retail display period ($p < 0.001$), but the storage treatments had no significant effect on the b*-values. Overall, the colour stability of the control loins was better than in the loins exposed to long term temperature abuse, whereas it was intermediate in the loins exposed to short term temperature abuse. This result support previous findings that increased storage temperature has a large impact on retail colour display life [5, 6]. The results discussed above is based on mean values, however in the purchase situation the consumer will not take an average approach, but will reject meat products which do not have acceptable colour at the time of purchase. Hence, the a*-value distribution was investigated for each day the retail colour display was measured and is shown for day 3 and day 7 in Figure 2. On day 3 the variation is identical, for each treatment, i.e. the a*-values were spread over five colour units. In contrast, on day 7 the variation has increased considerably with the values spreading over ten colour units. In addition, although the 18 loins exposed to short temperature abuse had an average a*-value of 13.0, six of these were below the acceptability limit. For the 18 loins exposed to long term temperature abuse eight loins were below the acceptability limit. Even for the control loins, two fell below the acceptability limit. The percentage of samples with a*-values below the acceptability limit for the entire retail display period is shown in Table 2.

Table 2 Percentage loins with a*-values below the acceptability limit (< 12) from control, long term temperature abuse and short term temperature abuse treatments.

	Control	Long term	Short term
3	-	-	-
5	-	-	6%
6	-	17%	17%
7	13%	44%	33%
8	69%	56%	56%

The implication of the observed distribution is that although the average a*-value of both the control loins and loins exposed to short term temperature abuse is acceptable at seven days retail display, the retailer would have to decrease the shelf life of ideally treated lamb products to six days in order to minimise the variation in colour display life and thereby minimise consumer rejection at purchase. Further, if the lamb products had been exposed to both long and short term temperature abuse the shelf life would have to be reduced to five days or possibly even shorter as one of the loins exposed to short term temperature abuse was below the acceptability level on day 5. This latter result illustrated that even if the processing company manages to store and transport lamb products at ideal temperatures (-1.5°C), the wholesaler and retailer can significantly reduce the retail colour display life to similar levels as lamb products which had been stored and transported under less than ideal conditions. The impact of storage temperature on retail colour display life of chilled lamb was investigated in a separate study [10].

IV. CONCLUSION

This study showed that retail colour display life of chilled lamb was significantly decreased when the storage temperature was increased from the ideal temperature of 1.5°C to 2°C for vacuum-packed lamb loins prior to retail display in high oxygen modified atmosphere. Even short term temperature abuse (one week at 2°C) at the end of the seven weeks storage period had a large negative impact on the retail colour display life. This illustrates that failure to maintain ideal storage temperatures throughout the supply chain (storage, transport, wholesale, retail) can significantly reduce retail colour display life.

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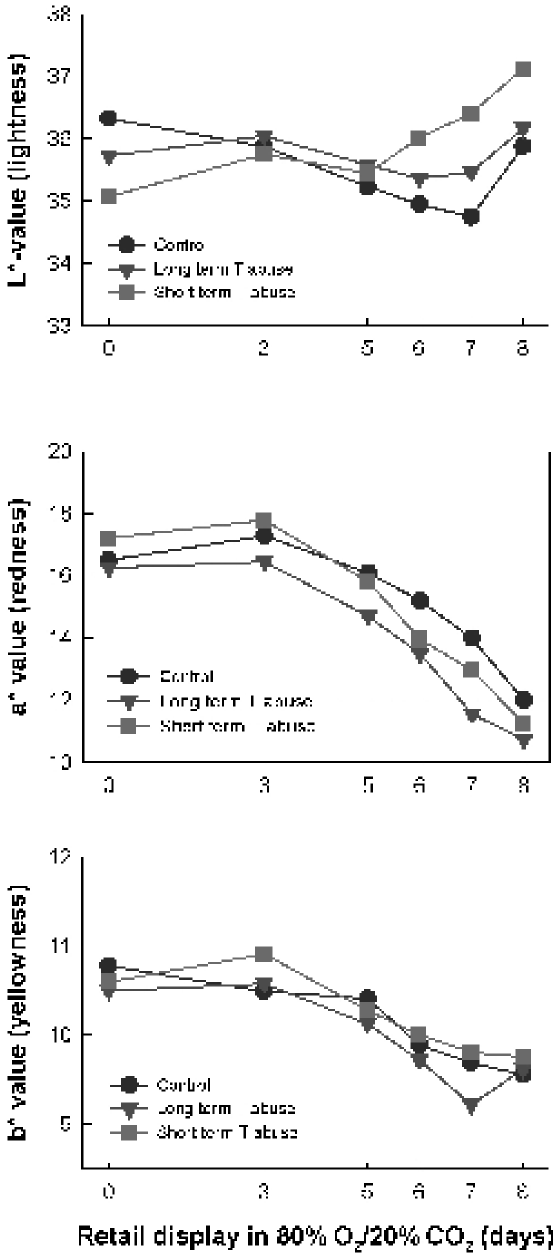

Figure 1 Colour measured as L*-value, a*-value and b*-value in lamb loins which were vacuum-packaged and stored at either at -1.5°C for 7 weeks (control), 2°C for 7 weeks (long term temperature abuse) or -1.5°C for 6 weeks and 2°C for 1 week (short term temperature abuse) prior to retail packaging with 80% O2 and 20% CO2.

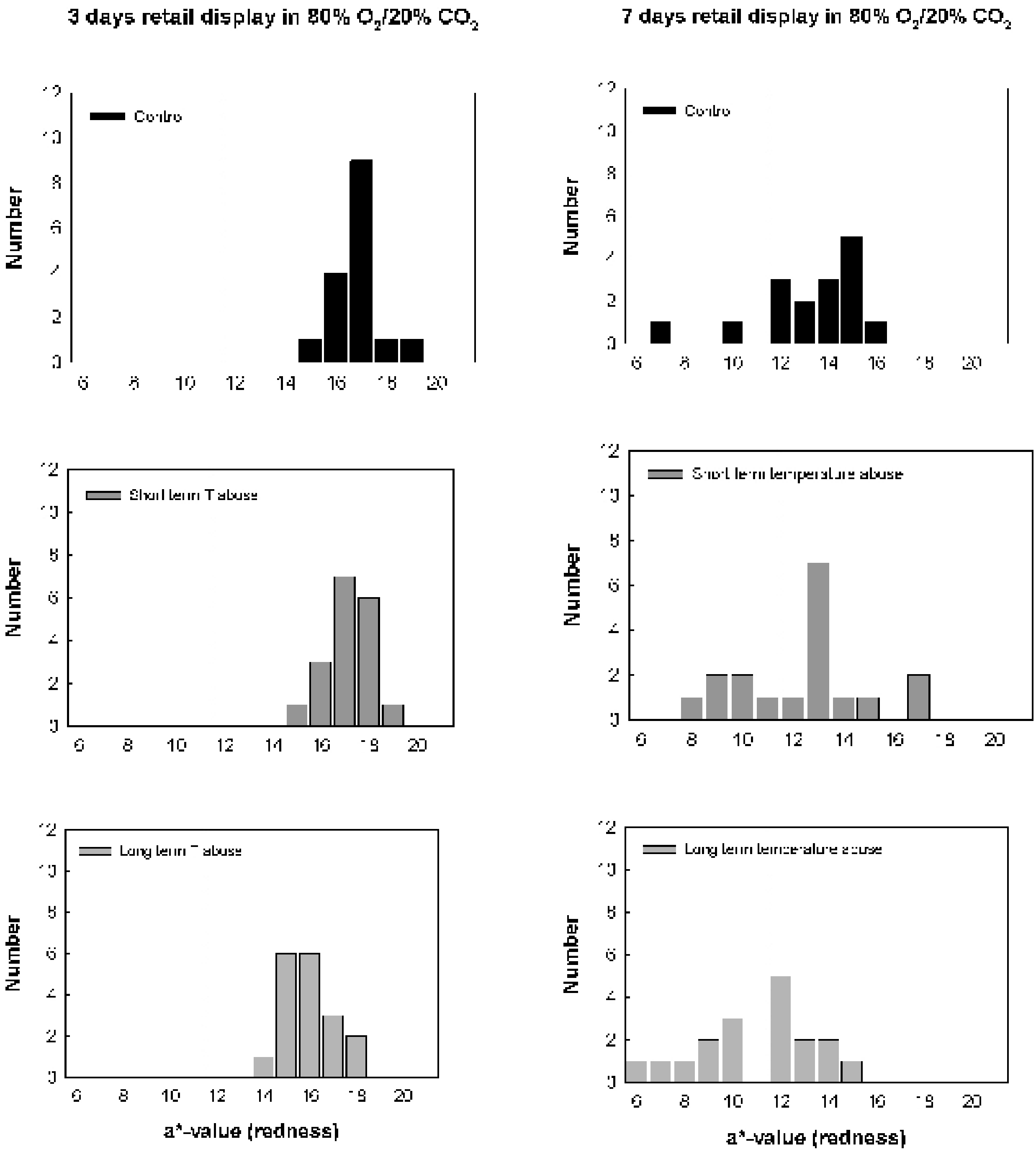

Figure 2 Distribution (number) of a*-values after 3 and 7 days retail display for lamb loins which were vacuum-packaged and stored at either at -1.5°C for 7 weeks (control), 2°C for 7 weeks (long term temperature abuse) or -1.5°C for 6 weeks and 2°C for 1 week (short term temperature abuse) prior to retail packaging with 80% O2 and 20% CO2.