



Retail colour display life of chilled lamb as affected by processing conditions and storage temperature

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ABSTRACT

This study explored the impact of i) processing conditions (electrical stimulation and *pre rigor* temperatures), and ii) storage temperature prior to retail display on the colour stability of lamb which had been vacuum-packaged for seven weeks before retail packaging in high-oxygen modified atmosphere (80% O₂/20% CO₂). A high *pre rigor* temperature (42 °C) reduced colour stability while differences in colour stability between *pre rigor* temperatures of 5 °C, 15 °C and 25 °C were limited. It was not affected by electrical stimulation, and did not interact with *pre rigor* temperature. In contrast, an increase in the storage temperature from the ideal temperature of −1.5 °C to 2 °C significantly decreased the colour stability of lamb loins. Even one week at 2 °C at the end of the storage period had a substantial negative impact on the retail colour display life. The variability in colour increased over time, and the variability increased more for the temperature abuse treatments.

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1. Introduction

Export of meat to Europe from Australia and New Zealand began when new refrigeration technology was developed in the late 1800s. In 1880, the first frozen shipment from Australia to the UK took place. In 1882, the first consignment of frozen carcasses was shipped from New Zealand to the UK. The consignment took three months to arrive but of the 4931 carcasses (mutton, beef and pork), only one was rejected (Robinson, 2006) and the meat was sold for approximately twice the price it would have fetched on the domestic market (McCrystal, 2004). Until the mid 1980s, New Zealand sheep meat export continued to concentrate on the trade of whole frozen carcasses (McDermott, Saunders, Zellman, Hope, & Fisher, 2008). Freezing preserves the quality at the time of freezing, where tenderisation may not have been completed.

However, in the late 1960s, new hygiene and inspection requirements were introduced for two of New Zealand's major markets. The US Wholesome Meat Act and the EC's Third Country Veterinary directive set out strict hygiene and inspection standards for the *ante* and *post mortem* management of livestock for the US and UK markets. The upgrades which were necessary to meet these standards were progressively made through the 1970s and 1980s. The most important result of these upgrades was that meat processors were able to change to exporting chilled meat (McDermott et al., 2008). The advantage of

chilled meat is improved tenderness, which is achieved during the extended transport period. This, coupled with the fact that most chilled meat is from the higher value parts of the carcass, leads to the perception that chilled meat is superior to frozen meat. In 2010, 26% of New Zealand lamb was exported chilled, and it returned 36% of the value of lamb exports.

Typically chilled lamb products are vacuum-packed straight after deboning and then stored and transported, ideally at a temperature of −1.5 °C. The period of storage and transportation, which could be as long as ten weeks at this temperature, ensures that the product is very tender. Besides tenderness, another important attribute of chilled lamb products is shelf life which is determined by microbial spoilage and colour stability of the meat (also referred to as 'retail colour display life') in the consumer package. In 1993, the total shelf life of chilled lamb products was no more than 63 days (Bell, 1993) but since then, practices have been improved and today, the storage shelf life are often claimed to be longer than 77 days.

Only limited studies have been carried out on the retail colour display life of chilled lamb which has been vacuum-packaged, stored for an extended period and subsequently repackaged into consumer packages containing oxygen levels higher than 70% O₂ (Channon, Baud, & Walker, 2005; Kim, Frandsen, & Rosenvold, *in press*), and it is not known to what extent the slaughter process (electrical stimulation and chilling) and storage temperatures affect the retail colour display life.

Although some studies have investigated the effect of the slaughter process on meat colour, often, both the electrical input and the chilling regime were altered simultaneously making it difficult to distinguish which of the two different process steps

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caused the observed effects. There is little evidence that electrical stimulation alone affects the retail colour display life of chilled beef and lamb (i.e. meat that has been vacuum-packed and stored for an extended period prior to retail display) (Channon et al., 2005; Moore & Young, 1991; Unruh, Kastner, Kropf, Dikeman, & Hunt, 1986). Electrical stimulation shortens the time to reach *rigor mortis*, thereby influencing the *rigor* temperature. However, some exceptions were colour differences found by van Laack and Smulders (1990) which were minor and unlikely to be important to the consumer and Ledward, Dickinson, Powell, and Shorthose (1986) who found that electrical stimulation negatively affected the colour stability of chilled beef.

Storage conditions also impact retail colour display life. An increase in storage temperature has a marked effect (second only to the effect of the age of meat *post mortem*) of reducing the colour stability (O'Keefe & Hood, 1981) so that seemingly small differences in display temperature conditions have a significant effect on metmyoglobin formation (Ledward et al., 1986).

This paper describes two trials that were conducted to explore i) the impact of processing conditions (electrical stimulation and *pre rigor* temperatures), and ii) the impact of storage temperature prior to retail display in high-oxygen modified atmosphere (80% O₂/20% CO₂) on the retail colour display life of lamb which has been vacuum-packaged for seven weeks prior to repackaging into consumer packages.

2. Materials and methods

2.1. Processing conditions trial

2.1.1. Animals and treatments

Twenty lambs (mix of females and castrates) were slaughtered at the AgResearch Ruakura abattoir, Hamilton, New Zealand, on the same day. Both *M. longissimus dorsi* (loins) from the 20 lambs (a total of 40 loins) were allocated to eight different treatments in a split plot design. The eight treatments comprised of two factors: i) *pre rigor* temperature: 5 °C, 15 °C, 25 °C or 42 °C which were randomly allocated to animals; and ii) low voltage electrical stimulation: (80 V peak, 14.28 pulses s⁻¹ for 30 s) 15 min *post mortem* (ES) or no stimulation (NES) which were randomly allocated to the two loins from each animal.

2.1.2. Slaughter procedure and sampling

The lambs were stunned with a captive bolt gun, slaughtered and dressed. The loin assigned for NES was removed from each carcass immediately before electrical stimulation and the other loin immediately after electrical stimulation (ES). 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 muscle shortening, and then transported in insulated boxes to the 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 5.55 for normal pH muscle or when pH ceased to fall for muscles with elevated ultimate pH values. The loins were then chilled down to and stored at -1.5 °C until 2 days *post mortem* when 5-cm thick samples were taken for initial colour and tenderness measurements. The remainder of the loins were vacuum-packed and stored at -1.5 °C for seven weeks.

After seven weeks storage, the loins were removed from the vacuum-packs and cut into four 3-cm thick samples which were butterflied to obtain a meat surface sufficiently large for Hunter lab measurements (3 cm aperture) and randomly allocated to retail display for 3, 6, 7 and 8 days. Randomly, one of these samples was also

used for the 0 day colour measurement, which was measured after 2 h blooming at 2 °C. The samples for subsequent retail colour display measurements were placed (individual packages for each retail display time) on polystyrene food grade trays (Plix FST75, 19 cm × 14 cm × 1.2 cm; Auckland, New Zealand), and put in a shrinkable bag (BB7L, 30 by 39 cm/ an oxygen-transmission rate of 20 cc O₂/1 cm³/m²/24 h at 23 °C and a water-vapor transmission rate of 10 cc/m²/24 h at 23 °C; Cryovac Sealed Air Corporation, Hamilton, New Zealand), and packaged to a high-oxygen modified atmosphere (HiOx-MAP; 80% O₂/20% CO₂, Certified Standard within ± 2%, BOC GASES; Hamilton, New Zealand). The packaging was accomplished by using a Securepak 10 Controlled Atmosphere Packaging Machine (Securefresh Pacific, Auckland, New Zealand) by applying vacuum, then flushing the package with the gas mixture, and sealing. Then, the loins were displayed at 4 °C for up to 8 days under continuous fluorescent natural white light.

2.2. Temperature abuse trial

2.2.1. Animals and slaughter procedure

Fifty-seven lambs were slaughtered on the same day at the AgResearch Ruakura abattoir, Hamilton, New Zealand. The lambs were electrically stunned, slaughtered and dressed and then electrically stimulated at 15 min *post mortem* using low voltage electrical stimulation (80 V peak, 14.28 pulses s⁻¹ for 30 s). The carcasses were then placed in a chiller following the normal chilling procedure of the abattoir (10 °C). Approximately 6 h *post mortem* the short loins (20 cm) were removed from the carcasses and placed in a chiller in the laboratory at 10 °C until 15 h *post mortem*, when the temperature was decreased to 4 °C. At 24 h *post mortem*, colour, tenderness and water-holding capacity were determined in the posterior end of the right-hand side loins while the anterior end of the right-hand side loins and the entire left-hand side loins were vacuum-packed, allocated to their specific storage treatments and stored for seven weeks.

2.2.2. Treatments

The loins were randomly allocated to three different storage treatments: i) -1.5 °C for 7 weeks and 1 day (control), ii) 2 °C for 7 weeks and 1 day (long term temperature abuse) and iii) -1.5 °C for 6 weeks and 1 day 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 be referred to in entire weeks in this paper.

After seven weeks of storage, the loins were removed from the vacuum-packs and cut into five 3-cm thick samples which were butterflied to obtain a meat surface sufficiently large for Hunter lab measurements (3 cm aperture) and randomly allocated to retail display for 3, 5, 6, 7 and 8 days. Randomly, one of these samples was also used for the 0 day colour measurement, which was measured after 2 h blooming at 2 °C. The samples for subsequent retail colour display measurements were packaged (individual packages for each retail display time) in 80% O₂/20% CO₂ modified atmosphere stored at 4 °C under fluorescent light until instrumental colour was measured to determine retail colour display life.

2.3. Meat quality measurements

2.3.1. pH

pH was measured using a Mettler Toledo pH meter with a combination electrode (Mettler Toledo Inlab 427; Mettler Toledo Inc, Columbus, Ohio, US). In the Processing Conditions Trial, pH was measured every hour from 1 h *post mortem* until *rigor mortis* was reached and again 48 h *post mortem*. In the Temperature Abuse Trial pH was measured at 24 h *post mortem*.

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