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ScienceDirect
Meat Science 79 (2008) 299–306
MEAT SCIENCE
www.elsevier.com/locate/meatsci

The protective effect of electrical stimulation and wrapping on beef tenderness at high *pre rigor* temperatures

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Received 11 April 2007; received in revised form 8 October 2007; accepted 8 October 2007

Abstract

A three factorial experimental design involving electrical stimulation (ES/NES), wrapping (wrapped/unwrapped) and *pre rigor* temperature (15 °C or 35 °C) was applied to 70 beef *M. longissimus lumborum* muscles to obtain a wide variation in shear force and drip loss. The shear force of all treatment groups decreased during ageing. As anticipated, wrapping and electrical stimulation had positive effects on shear force. However, high *pre rigor* temperature (35 °C) did not result in higher shear force values if the muscles were electrically stimulated, wrapped or both. The results suggested that electrical stimulation protects against the negative effects of high *pre rigor* temperatures. The drip loss of all treatment groups increased during ageing in a manner that was unrelated to treatment but was correlated to tenderness ($r^2 = 0.70$; $p < 0.0001$). It was concluded that the application of electrical stimulation, whatever the *pre rigor* temperature, protects beef from toughening through the prevention of *rigor* shortening and the avoidance of inhibition of ageing enzymes.

Keywords: Beef *longissimus*; Wrapping; Electrical stimulation; Drip; Tenderness; *Rigor* temperature

1. Introduction

Optimising processing parameters to produce beef of a defined quality for tenderness, drip and colour would be expected to be simple with the present knowledge that includes reduction of pre-slaughter stress, application of electrical stimulation, control of *pre rigor* temperatures and prevention of shortening.

Electrical stimulation is used to facilitate tenderisation (Devine, Hopkins, Hwang, Ferguson, & Richards, 2004), through acceleration of the *rigor* process so that detrimental effects of cold shortening through fast chilling and freezing are avoided. However electrical stimulation appears to have other roles so that even when cold shortening is avoided, there are still differences in tenderness at various times *post rigor* with different processes and times of application (Wahlgren, Devine, & Tornberg, 1997).

Unrestrained muscle will shorten at the onset of *rigor mortis* (Honikel, Roncales, & Hamm, 1983) being strongly dependent on the energy level in the muscle and the muscle temperature *post-mortem*. Locker and Hagyard (1963) found that so-called cold and warm shortening took place at *rigor* temperatures above and below approximately 15 °C. In general, the degree of shortening influences tenderness (Locker, 1960) and drip (Honikel, Fischer, & Hamm, 1980). A high degree of shortening is highly correlated with inferior tenderness and water holding capacity. Hence, prevention of shortening is essential to avoid toughening (Locker & Hagyard, 1963). One way of preventing shortening is by wrapping which has been applied successfully to prevent shortening and thus toughening (Devine, Wahlgren, & Tornberg, 1999; Sørheim et al.,

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doi:10.1016/j.meatsci.2007.10.002

2001; Hildrum, Nilsen, & Wahlgren, 2002; Sørheim & Hildrum, 2002).

To reduce drip (i.e. increase water holding capacity), it is generally accepted that low *pre rigor* temperatures are required (Rosenvold & Andersen, 2003). Much of this work is related to pork where a pale soft exudation condition occurs with a rapid pH fall at elevated *pre rigor* temperatures (Wismer-Pedersen, 1959). This is due to myosin denaturation (e.g. Penney, 1967; Stabursvik, Fretheim, & Froystein, 1984) with the consequent increase in drip and a reduced water holding capacity. The denaturation of myosin is temperature sensitive so that at low pH and high *pre rigor* temperatures water arises from myosin denaturation and subsequent changes as demonstrated in pork (Offer et al., 1989) with the mechanisms and kinetics being covered by Offer (1991) and Offer and Cousins (1992).

In beef things are less clear and there is often a presumed added factor of electrical stimulation so that an analysis of the sources of drip is particularly important as one needs to find optimum processes with least drip loss and most tender meat.

The following experiment was designed to obtain wide variation in meat tenderness and drip to study the effect of electrical stimulation, wrapping and *pre rigor* temperatures on meat tenderness, drip and their relationship.

2. Materials and methods

2.1. Animals and treatments

A total of 35 steers (18–24 months old, 190–220 carcass weight) were used in the experiment. Treatments including electrical stimulation (stimulation (ES)/no stimulation (NES)), wrapping (wrapped/unwrapped) and temperature (15 °C (15) or 35 °C (35)) were applied *pre rigor* to obtain a wide variation in subsequent meat tenderness and drip (Table 1). The NES steers ($n = 15$) were shot with a captive bolt and dressed as normal with the complete absence of any form of electrical stimulation; the ES steers ($n = 20$) were electrically stunned across the head (neck to nose for 3 s at 400–500 V at 2 A) and the current was then passed from neck to brisket (for 14 s of 450–550 V at 2.5 A), a procedure that removed post slaughter movement and induced cardiac arrest. The ES steers exited the stun box and further electrical stimulation was administered during bleeding by application of 80 V peak, 14.28 pulses s^{-1} for 30 s. At 30 min post slaughter, the left and right *M. longissimus lumborum* (LL) (approximately 4 kg each) from each steer were boned out and taken to the laboratory 800 m away.

Once in the laboratory, one of each of the paired LLs was tightly wrapped in four layers of polyethylene cling film. Then all the LLs were placed in water proof polyethylene bags. The wrapped and unwrapped LLs from 10 ES steers and 10 NES steers were placed in a water bath at 35 °C until *rigor mortis* was reached, and then placed in a water bath at 15 °C until equilibrated. The remaining LLs (wrapped and unwrapped from 10 ES steers and 5 NES steers) were placed in a water bath at 15 °C until equilibrated. All LLs were subsequently aged in a 15 °C room.

2.2. Measurement of pH and temperature

To determine the time of *rigor mortis* pH was measured in the ES and NES35 muscles every hour from 1 h post slaughter up to 10 h *post-mortem* using a Mettler Toledo pH meter with combination electrode. pH in the NES15 muscles was measured 1 h post slaughter and then every 2 h until 24 h *post-mortem*. *Rigor mortis* was defined as the time point when the pH fell below 5.55 for normal pH muscles and this was taken as the commencement of ageing. Therefore, the moment of *rigor mortis* was estimated with ±1 h precision in ES and NES35 muscles and ±2 h precision in NES15 muscles. Temperatures were measured with Dallas iButtons accurate to ±1 °C inserted in the muscle. In addition, spot temperatures were measured to find the time point when the muscles equilibrated to 15 °C prior to placement in the 15 °C room for ageing.

2.3. Shear force

Samples for shear force and drip measurements were collected at *rigor mortis* (0 ageing), and at the nominal following intervals: ~12 h post *rigor mortis*, ~24 h post *rigor mortis*, ~40 h post *rigor mortis*, ~70 h post *rigor mortis* and at ~90 h post *rigor mortis*; samples for different time points were cut adjacent to one another. The samples for shear force (~130 g) were immediately frozen and stored at −20 °C for subsequent shear force measurements. The meat was cooked from the frozen state in a 100 °C water bath until an internal temperature of 75 °C was reached (measured by a thermocouple). The cooked sample was

Table 1
The experimental treatments applied to each set of LLs from 35 animals (70 muscles)

Unwrapped						Wrapped					
Stimulated			Non-stimulated			Stimulated			Non-stimulated		
Treatment	*n*	*Pre rigor* temperature (°C)	Treatment	*n*	*Pre rigor* temperature (°C)	Treatment	*n*	*Pre rigor* temperature (°C)	Treatment	*n*	*Pre rigor* temperature (°C)
$ES_{unwrapped}15$	10	15	$NES_{unwrapped}15$	5	15	$ES_{wrapped}15$	10	15	$NES_{wrapped}15$	5	15
$ES_{unwrapped}35$	10	35	$NES_{unwrapped}35$	10	35	$ES_{wrapped}35$	10	35	$NES_{wrapped}35$	10	35