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INITIAL CHILLING RATE AS A PREDICTOR OF THE COLOUR OF MUSCLES AS THAWED MEAT

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Background

New Zealand hot-boning plants bone out carcasses within 45 min of slaughter, well before they enter rigor. For the manufacturing trade, the meat is then packed into cartons and frozen to -18°C within 48-72 hours of slaughter. As the carton cools, the boxed, hot-boned meat enters rigor. The rate at which a muscle goes into rigor is affected by temperature and muscle fibre type. The rate of chilling of boxed hot-boned beef in commercial plants can now be precisely logged or predicted.

Objectives

This study was designed to investigate the combined effect of rigor temperature and muscle type on the pH and colour of manufacturing beef and to use the data to develop an equation for predicting the colour of thawed beef.

Methods

Heifers were captive bolt stunned and processed, with no electrical immobilisation or stimulation, at a commercial meat plant. Carcasses were halved. The *semitendinosus* and *biceps femoris* muscles were removed from each side approximately 45 min after slaughter and transported to the laboratory where further preparations took place. Before storage at the different rigor temperatures began, the *biceps femoris* was trimmed to match the thickness and length of the *semitendinosus*. The pH and temperature of the muscles were measured, and the muscles were then weighed, individually sealed in a vacuum bag without vacuum, and submerged in water baths maintained at 0, 10 and 35°C. The samples held at 35°C were removed from the water bath after they went into rigor (6 hr, determined by pH measurements) and transferred to a 4°C chiller where they were held while the other samples held at lower temperatures went into rigor. All muscles were in rigor by 24 hr. The samples were then vacuum packed and were immediately frozen to -18°C and kept at that temperature for one month. After storage the muscles were thawed unexposed to air for 72 hr at 1°C and analyses were carried out.

The pH and temperature of the muscles were measured at 0 (approximately 1 hr post-mortem), 1, 3, 6, 12 and 24 hr after waterbath entry. pH, sarcomere length and colour of fully bloomed samples (Young *et al.*, 1998) were measured as described in Farouk and Swan (1998). The design was a balanced incomplete block, with two rigor temperatures per animal. A smooth curve was fitted to the graphed data by S-Plus using the Loess procedure described by Cleveland (1979). The best-fit line was fitted to the data by S-Plus using least-squares linear regression.

Results and Discussion

As expected, the pH of the muscles fell with time post-mortem at all holding temperatures. The rate of pH fall was significantly faster in *semitendinosus* (ST) muscles compared to *biceps femoris* (BF). The rate of pH fall during the first 12 hours of the process for both muscles was compared with the rate of cooling, as determined by the temperature drop in the first hour (Figure 1). At faster cooling rates (initial rate 12 to 27°C/hr), the pH fell at a rate of 0.07 ± 0.02 pH units/hr; at slower cooling rates (initial fall 3 to 5°C/hr), the rate of pH fall was 0.23 ± 0.04 pH units/hr. These data indicate that the rate at which glycolysis proceeded in the muscles was not affected by the rate of cooling between 12 and 27°C/hr.

Hunter ***L**, a**** and ***b**** values of thawed samples (lightness, redness and yellowness respectively) for both ST and BF muscles tended to increase with increasing rigor attainment temperature ($P<0.001$) (Data not shown). There was no difference in redness between ST and BF, although ST muscles has more red muscle fibres (Hertzman *et al.* 1993); and ST muscles were yellower than BF muscles. The present results agree with the results of a previous study in which a similar effect of temperature on colour was observed in ST muscles (Farouk and Swan, 1998).

Hue angle increased (indicating decreased colour stability) with increasing rigor attainment temperature ($P<0.001$). We previously observed a similar effect of rigor temperature on the colour stability of *semitendinosus* muscles stored frozen for one month (Farouk and Swan, 1998). The colour of BF muscles was more stable (hue angle was lower) than the colour of ST muscles ($P < 0.001$) (Data not shown). The faster rate of glycolysis in ST might have denatured the muscle myoglobin and/or the metmyoglobin reducing enzymes, resulting in a less-stable colour in ST muscle compared to BF.

Colour parameters were plotted against the rate of cooling, as determined by the temperature drop in the first hour (Fig. 2), and a linear regression line was fitted to the data. The following models describe the colour relationships shown in Figure 2:

L^* = 41.5 - 0.31 x Initial rate of temperature fall, °C/hr
+ 3.3 if muscle is ST
(r^2 = 0.66, residual standard error = 2.0) (1)

a^* = 17.9 - 0.11 x Initial rate of temperature fall, °C/hr
(r^2 = 0.22, residual standard error = 1.6) (2)

b^* = 8.7 - 0.14 x Initial rate of temperature fall, °C/hr
+ 1.9 if muscle is ST
(r^2 = 0.72, residual standard error = 0.9) (3)

Hue angle = 25.8 - 0.23 x Initial rate of temperature fall, °C/hr
+ 5.2 if muscle is ST
(r^2 = 0.71, residual standard error = 2.0) (4)

The relationship was poorer for Hunter a^* values compared to other colour parameters. However, because the data from the present study mirrored trends in data obtained in a previous study, the models in eqs 1-4 can be used with a certain degree of reliability.

Conclusions

Results of this study demonstrated that the chilling rate of muscles early during rigor development can be a good indicator of the colour and colour stability of the muscles as meat after frozen storage for one month.

Pertinent literature

Cleveland, W.S. (1979) *J. American Stat. Assoc.* **74**, 829-836.
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Hertzman C., Olsson, U. and Tornberg, E. (1993). *Meat Sci.* **35**, 119-141.
Young, O.A., Priolo, A., Simmons, N.J. and West, J. (1998) *Meat Sci.* (**In Press**).

Acknowledgements

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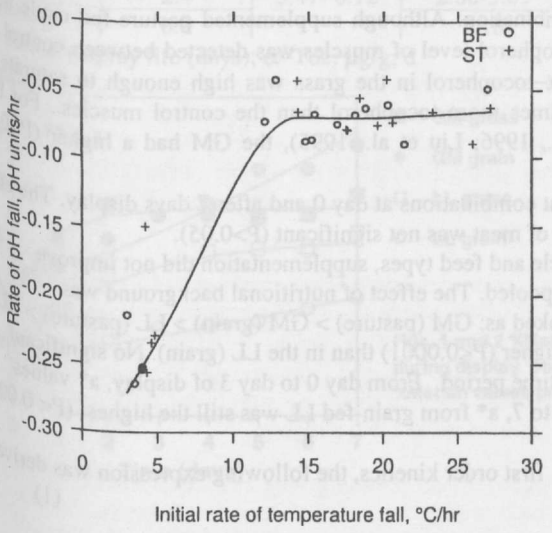

Figure 1.
Rate of pH fall as a function of the initial cooling rate.

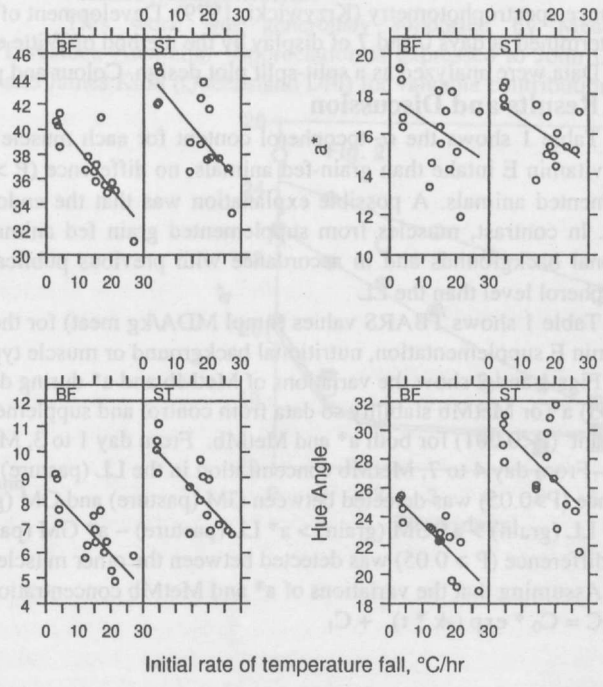

Figure 2.
Effect of initial cooling rate over the first hour on colour parameters.