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THE INTERACTION OF CHILLING RATES, INCLUDING HOT-BONING, AND ELECTRICAL STIMULATION ON THE COLOUR AND COLOUR STABILITY OF FRESH AND AGED BEEF CUTS ON RETAIL DISPLAY

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INTRODUCTION

Colour of meat and fat, and fat distribution are the most important factors influencing the appearance, and hence acceptability, of the product to the consumer when a retail purchase is made.

Rapid pH and slow temperature decline post-mortem affect the initial colour and the colour stability of meat (Taylor *et al.*, 1981). These conditions exist in the deep parts of many beef carcasses which are electrically stimulated (ES).

Ledward *et al.* (1986), Hunt *et al.* (1986) and MacDougall and Allen (1986) reported on the lack of colour stability of some cuts from electrically stimulated carcasses. Claus *et al.* (1984) reported that hot-boning negatively affected colour stability. However, Taylor *et al.* (1981), van Laack and Smulders (1990) state that faster and more uniform chilling of hot-boned meat may help reduce protein denaturation and enzyme inactivation. Since both the metmyoglobin (MMb) reducing activity and enzymic consumption of oxygen remain high in hot-boned meat, its colour stability may be improved. High enzymic consumption is said to have a negative effect on colour stability (O'Keefe and Hood, 1982) and may be responsible for the darker meat usually associated with hot-boned meats.

Claus *et al.* (1984) observed that the undesirable dark colour of hot-boned meat could not be redressed by the use of ES. Van Laack and Smulders (1990) stated that changes in chroma and hue indicated that hot-boned (*m.longissimus thoracis* (LD) but not *psoas major* (PM)) samples had slightly higher colour stability than cold-boned, blast-chilled, controls.

The objective of this study was to produce a set of carcass processing and chilling procedures that optimise meat colour and colour stability of the resultant meat on display.

MATERIALS AND METHODS

Sixteen young steers, (<18 months old; carcass weight 180 to 210kg; P8 fat depth 4 to 16mm) were slaughtered four per day. The sides were allocated to one of the following treatments:
(1) non-ES, slow side chilling (to a deep butt temperature of 20°C in 24 hours) and cold-boned, (CB);
(2) non-ES, blast chilling (air temperature -20°C, air velocity 1.5 to 3mps for three hours then air temperature of 2°C for 21 hours) and cold-boned (BC);
(3) no-ES, hot-boned, ice water cooled for 24 hours, (HB);
(4) high voltage ES, hot-boned and ice water cooled, (ESHB).

Four muscles (LD, PM, *m.semimembranous* (SM) and *adductor* (Add)) were removed at 24 hours (CB) or at 1.5 hours post-mortem. Sides were held at 20°C for one hour before hot-boning. The muscles were cut in half, weighed and each half was vacuum-packaged in a low permeability, shrinkable bag. All the vacuum-packaged, hot-boned muscles were held in the ice water for 24 hours and then all cuts were placed, according to a randomised allocation, into cartons labelled "fresh" and "aged". The "aged" samples were stored for four weeks at 0°C before opening and steaks were prepared and displayed.

At four days post-slaughter, the "fresh" samples were removed from the bags, weighed and the pH and FOB values were determined. Four slices (15mm thick) were removed from each muscle and an additional slice (15x15x4mm) was prepared with one long axis parallel to the fibre direction. The slices (4) were then prepared for retail display on styrene trays and overwrapped with permeable PVC film. These packages were then bloomed in a dark room at 0°C for 2 h and then placed into a forced-air display cabinet for seven days. Philips 93, 36W, fluorescent tubes were used for illumination (1000lux, 12 hours a day). The meat temperatures were 2 to 4°C with the lights on and 0 to 2°C with them off.

A "squash plate" (MacDougall and Taylor, 1975) was prepared from the thin slice and placed in the display case. After six hours, 1, 2, 3 and 7 days the widths of the oxymyoglobin (MbO) layer from the edge towards the centre of the slice and the metmyoglobin (MMG) ring were measured using a magnifying glass and a ruler.

After the trays had been in the display cabinet for two and six hours, 1, 2, 4, 5 and 7 days, the CIELAB Lightness (L^*), a^* & b^* values and Chroma (C^*), and hue (h^*) were recorded (Minolta CR 2000, 8mm aperture, D65 lamp). With each SM slice, measurements were made in two zones; in the outer (or darker) section of the SM, called the OSM, and in the inner (or lighter) section, called the ISM. Four measurements were taken for each slice of the LD, PM and Add, (SM had eight) and hence 16 measurements were obtained for each muscle. Meat colour was also assessed subjectively using AUS-MEAT colour chips.

RESULTS and DISCUSSION

The meat quality attributes of sarcomere length, Fibre-optic probe, Warner-Bratzler initial yield and peak force were as expected for meat from the four experimental treatments listed above. All the aged hot-boned steaks had a Warner-Bratzler peak force less than 5kg; this is of acceptable tenderness to Australian consumers. All the non-ES, hot-boned meat had lower FOP values than the ES hot-boned or cold-boned meat.

Meat Colour

Australian consumers (Kingston *et al.*, 1985) prefer to purchase meat which has a light, cherry red colour (AUS-MEAT colour score 1) while Japanese consumers (Powell, 1993) prefer a slightly darker cherry red (AUSMEAT colour score 2 and 3). The AUSMEAT in-chiller assessment was introduced to the Australian Industry in 1991 and rates meat colour on a scale from 1 to 9. It also assesses chilled carcasses for fat colour, marbling and other meat quality attributes and is modelled on the Japanese meat grading system. For economic reasons, the Australian processing industry would like to introduce hot-boning. However, it is well documented (Claus *et al.*, 1984) that meat from hot-boned carcasses,

whether electrically stimulated or not, is so dark in colour that it would be unacceptable to local and overseas customers.

However, this work has shown, that the colour of the bloomed steaks (Tables 1 and 2) from the hot-boned primals, aged for four weeks, was almost identical to that of the steaks prepared from the "fresh" cold-boned joints. This is the first report to document the production of light red coloured steaks obtained from aged hot-boned primals. The initial colour of fresh steaks from the hot-boned primals (LD, PM, OSM & ISM and Add.) aged four days, was dark red (4 to 7 AUSMEAT colour score). The colour of these steaks was rated as two or three after four weeks of ageing.

Samples with a cherry red colour had an OMG layer, in a squash plate, 3 to 4mm thick while in those with a dark red colour it was only 1 to 1.5mm thick. The thickness of the OMG layer for aged, hot-boned, LD and PM steaks varied from 2 to 2.8mm, sufficient for the colour to be perceived as light red.

Colour stability

Since the PM has very poor colour stability and a rapid rate of glycolysis, it was expected that the individual and combined effects of the various treatments would be most evident in this muscle.

In Table 3 the chroma and changes in chroma over three days for the cold- and hot-boned steaks are listed. The changes in chroma for the steaks at day three for the hot-boned steaks (LD, OSM, ISM and Add), are about 30% less than that for the cold-boned steaks. The difference for the PM is about 10%. Thus hot-boning and rapid cooling of the primals resulted in a substantial improvement in the colour stability of the steaks prepared from the aged primals. Presumably the high rate of glycolysis of the PM limited improvements in its colour stability.

From previous results (Powell, 1978) it was expected that per cent weep from the hot-boned treatment would be less than that of the cold-boned treatment. No difference was observed.

If the Australian industry introduced hot-boning, a procedure for the production of acceptable table meats would be to effectively stimulate all carcasses, hot-bone one hour after stimulation, cool the primals promptly at 0°C, carton and then age the material for four weeks.

CONCLUSIONS

Hot-boned meat, aged for four weeks, yields steaks which have acceptable, light red colour, and rapid cooled hot-boned meat (ES and/or non-ES) improves the colour stability of steaks in retail display.

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Table 1. AUSMEAT colour score* of the retail packages when first placed into display case.

Muscle	non-ES cold-boned	non-ES blast chill cold-boned	non-ES hot-boned	ES hot-boned
LD				
fresh	2	6	5	3
aged	2	2	3	3
PM				
fresh	2	4	7	3
aged	2	2	3	2
OSM				
fresh	3	4	5	3
aged	2	2	5	3
Add				
fresh	2	4	5	3
aged	2	2	3	3

* The higher the number, the darker the colour:
1=a very light, cherry red
9=dark bluish red

Table 2. Oxygen penetration* into meat (mm) after six hours at 5 °C in the squash plate.

Muscle	non-ES cold-boned	non-ES blast chill cold-boned	non-ES hot-boned	ES hot-boned
LD				
fresh	4.3	2.1	0.8	1.6
aged	4.8	2.6	2.8	2.8
aged-fresh	0.5	1.0	2.0	1.2
PM				
fresh	2.0	1.5	1.2	1.3
aged	2.0	2.1	2.2	2.3
aged-fresh	0.0	0.6	1.0	1.0

* Oxymyoglobin width, measured from edge towards centre.

Table 3. Mean Chroma and change in Chroma during retail display of steaks from the cold- and hot-boned treatments.

Time in days	Slow & fast chill cold-boned*		ES & non-ES hot-boned**	
	Chroma	Change in Chroma	Chroma	Change in Chroma
Aged sirloin (LD) steaks				
0.2	22.6	-	19.1	-
1.0	21.8	0.8	18.7	0.4
3.0	20.4	2.2	18.0	1.0
Aged fillet (PM) steaks				
0.2	24.7	-	22.6	-
1.0	22.1	2.6	20.6	2.0
3.0	18.3	6.4	17.4	5.2
Aged outer topside (OSM) steaks				
0.2	23.3	-	20.9	-
1.0	21.8	1.5	20.0	0.9
3.0	19.0	4.3	18.2	2.7
Aged inner topside (ISM) steaks				
0.2	25.3	-	23.6	-
1.0	22.7	2.6	21.4	2.2
3.0	19.0	6.3	19.1	4.5
Aged adductor (Add) steaks				
0.2	23.9	-	22.8	-
1.0	21.7	2.2	20.7	2.1
3.0	17.1	6.8	18.5	4.3

* Mean Chroma from fast chill was marginally superior to slow chill but not significant.
** Mean Chroma for ES and non-ES hot-boned steaks were not different.