PE4.88 Ageing Prior to Freezing Improves the Colour of Frozen-Thawed Beef and Venison 311.00

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***Abstract* — This study tests the hypothesis that the colour of frozen meat can be improved by ageing the meat prior to freezing. Beef *M. semimembranosus* (SM), and beef and venison *longissimus dorsi et lumborum* (LDL) were each divided into four portions and assigned to four ageing times: 0 (48 h post-mortem), 1, 3 and 9 weeks prior to freezing, thawing and analyses. Meat was brighter red with ageing time prior to freezing ($P < 0.01$). The improvement in the brightness and redness of meat with ageing was more evident in beef than in venison. Hue angle did not change with ageing in SM ($P > 0.05$) but increased (meat became browner) in LDL. The increase was more evident in venison relative to beef. Result in this study proves the hypothesis that the colour of thawed meat can be improved by ageing the meat prior to freezing. Ageing was more beneficial to the colour of beef than venison. The implications of the results have been discussed.**

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***Index Terms*— Ageing, beef colour, freezing, venison colour.**

I. INTRODUCTION

Color is an important attribute affecting the decision by the consumer at the point of purchase whether to buy meat on retail display or not [1]. Meat color is affected by a number of factors including freezing and frozen storage. The superior color of chilled meat over frozen meat could be due to the latter losing more color pigments in thaw exudates [2] or as a result of the destruction of the mitochondrial enzyme system during freezing and subsequent storage. The poorer color and color stability of thawed meat could be one reason this meat currently fetches a lower price relative to chilled meat. This study was designed to test the hypothesis that ageing of meat prior to freezing will narrow or eliminate the difference in quality between chilled-never-frozen and AC&A (accelerated conditioned and aged) meat that is frozen within 48 h of slaughter [3].

II. MATERIALS AND METHODS

Two separate studies were conducted to determine the effect of ageing prior to freezing on the color of meat: (A) Used beef *M. semimembranosus*, (B) Compared beef and venison *M. longissimus dorsi et lumborum*. The meat samples were collected according to the following protocols:

A. Beef M. semimebranosus (SM)

Twelve young bulls (age 2-3 years) were included in the study. The animals were slaughtered according to standard procedure at a New Zealand beef export processing plant. All carcasses at this plant are hot-boned within 1 h post-mortem [4]. Meat samples (both SM muscles from each animal) were collected at boning and then transported chilled to AgResearch MIRINZ, stored at 10°C until in *rigor* and then transferred to 2°C. At 2 days post-mortem, the topsides were cut in half and the resulting four sub-samples from each animal were weighed and then randomly assigned to one of the following four treatments: 1 = chilled storage at -1.5°C for 9 weeks, 2 = frozen storage at -18°C for 9 weeks, 3 = chilled storage at -1.5°C for 1 week then frozen storage at -18°C for 8 weeks, 4 = chilled storage at -1.5°C for 3 weeks then frozen storage at -18°C for 6 weeks.

B. Beef & venison M. longissimus dorsi et lumborum (LDL)

Eight young bulls (age 2-3 years) and eight red deer (*Cervus elaphus*) stags (< 2 years) were included in the study. The bulls were slaughtered according to standard procedure at a New Zealand beef export processing plant. All carcasses at this plant are hot-boned within 1 h post slaughter [4]. The deer were slaughtered according to standard procedure at a New Zealand specialised deer slaughter facility approved for export. The deer carcasses were kept for approximately 6 hrs post-mortem at 10°C and then chilled down to 1°C. Carcasses were boned out 1 day post-mortem.

The beef samples (left-side LDL muscles) were collected at hot-boning and transported chilled to AgResearch MIRINZ, stored at 10°C until in *rigor* and then transferred to 2°C. Venison samples (left-side LDL muscles) were collected at boning 1 day post-

mortem and transported chilled to AgResearch MIRINZ.

At 2 days post slaughter, all LDL samples (beef and venison) were cut into four pieces and the 4 sub-samples from each animal were weighed and then randomly assigned to one of four treatments; 1 = chilled storage at -1.5°C for 9 weeks, 2 = frozen storage at -18°C for 9 weeks, 3 = chilled storage at -1.5°C for 1 week then frozen storage at -18°C for 8 weeks and 4 = chilled storage at -1.5°C for 3 weeks then frozen storage at -18°C for 6 weeks.

All frozen samples were thawed at 2°C for 48 hours after the 9 weeks storage period.

C. pH

pH of the samples was measured after the 9 week storage period by inserting a calibrated pH probe (Mettler Toledo MP 125 pH meter with an Inlab 427 probe) directly into the meat. Duplicate readings were taken for analysis of each sample.

D. Colour

One steak (2 cm thick) was cut from each sub-sample, tray overwrapped with an oxygen permeable plastic film and allowed to bloom for 3 h at 1-2ºC before colour was measured using a Minolta Colour Meter (Minolta Colourimeter (Minolta Camera Co., Ltd, Japan). CIE L* (lightness), a* (redness) and b* (yellowness) values were measured (D65, 10º) through the package film at three random locations on each steak, averaged and Hue angle (arctan b/a) and saturation $(a^2 + b^2)/0.5$ were calculated [5]. Each steak was measured on days 0, 1, 3 and 7 of simulated retail display.

E. Statistical analysis

The designs for both studies were randomised block. The first study consisted of 12 animals. The two SM muscles from each animal were divided into two parts and the subsamples from each animal were allocated to the 4 conditioning times so that treatments and positions were as balanced as possible. For all data, the only significant positional effect was 'end of muscle', so data were analysed using the ANOVA directive of GenStat [6]. The second study consisted of 8 stags and 8 bulls. Both LDL muscles from each carcass were excised and each divided in 2 pieces. The 4 subsamples from each animal were then allocated to the ageing times. One animal was excluded from the analysis due to high pH. Data were analysed using the REML directive of GenStat [6]. Both species were included in the same analysis for all data.

III. RESULTS AND DISCUSSION

1. Effect of specie and ageing time prior to freezing on the pH of beef and venison LDL

The pH of beef LDL was significantly higher ($P < 0.001$) than the venison (Table 1). Ageing time prior to freezing had no effect on the pH of beef and venison (Table 1). pH is a good indicator of the colour of meat. Although beef and venison statistically differ in pH, numerically the difference in pH is small and may not translate into any significant effect on the colour difference between the meats. The lack of difference in the pH of the meat from all the three muscles with ageing time (Table 1) also means there is unlikely to be any effect of pH related variations in waterholding capacity on the colour of the meats.

2. Effect of ageing time prior to freezing on the colour and colour stability of beef SM

Consumers judge the acceptability of meat colour by how bright red the meat looks on display, and a strong correlation exist between redness (a*), hue angle and consumer colour acceptability [7]. Hue angle is also a good indicator of colour stability of meat on display.

Regardless of muscle type or specie, in this study meat colour became lighter and yellower with ageing time prior to freezing (data not shown). The increase in lightness could be due to lipid oxidation considering pH did not differ with ageing time [8].

Beef SM became brighter red – higher a* and chroma values – ($P < 0.01$) with the increase in ageing time prior to freezing (Figure 1a and b). The increase in redness with ageing could be due to the diminished mitochondrial respiration and reduced oxygen consumption with long term post-mortem storage under vacuum [1]. Ageing time had no effect on the hue angle (an indicator of brownness) of beef SM (Figure 1c), in other words, there was no difference in browning between the samples that were frozen at different times post-mortem to those samples that were chilled and never frozen. However, when only the frozen samples were compared, beef SM were less brown (lower hue angle) with the increase in ageing time prior to freezing. It appears that for beef SM, 3 weeks of ageing prior to freezing is sufficient to eliminate the negative impact of freezing on meat browning relative to chilled-never-frozen meat.

Beef SM became less red, duller, and browner with extended display storage in the dark (Figures 1a, b & c). The reduction in the metmyoglobin reducing activity of meat with storage and/or the increase in

lipid oxidation in the samples could be the reason for the colour deterioration with the longer display storage time [9, 10]. The deterioration of meat colour on display in retail cabinets is one of the limiting factors for the merchandising and the central packaging of meat

3. Effect of ageing time prior to freezing on the colour and colour stability of beef and venison LDL

Venison was brighter red (higher a* and chroma) than beef on the first day of simulated retail display and then became less red and duller at longer display times (Figure 2a and b). Venison was browner relative to beef throughout display (Figure 2c). The overall poorer colour (duller, lower redness and more brown) of venison relative to beef could be because the higher enzymatic activities of venison compared to beef resulted in venison losing its metmyoglobin reducing activity, oxidising faster than beef and thus losing its colour faster as a consequence [11].

Beef and venison LDL linearly ($P < 0.001$) became brighter red with the increase in time the muscles were aged prior to freezing (Figures 2a and b). The increase was more evident and more linear in beef than in venison, as by the third day of display storage there was virtually no effect of ageing on the redness and brightness of venison while significant differences were observed in beef (Figures 2a and b). LDL colour display life reduced (meat became browner, hue angle increased) with the increase in the length of ageing time prior to freezing ($P < 0.001$) (Figure 2c). The reduction was more obvious in venison relative to beef. No difference was observed in hue angle in beef LDL with ageing longer than a week prior to freezing while a linear difference was observed in venison. Based on the observation in previous studies [7, 12] that indicate a* values of 12 and Minolta hue angle of 19-25° as the cut off points for the acceptability of venison and beef respectively, the display life even in the dark was only 3 days for venison while beef remained acceptable for a week.

IV. CONCLUSION

Within the parameters of this study, the colour of thawed beef and venison improved by ageing the meat prior to freezing. The length of time of ageing should be ≥3weeks for beef and 1-2 weeks for venison. The outcomes in this study has the following implications for the meat industry: (1) the colour of frozen meat can be improved by the ageing of the meat prior to freezing; (2) venison should be aged for a shorter period and frozen earlier than beef to optimize its colour; and (3) the significant difference observed between beef and venison in the effect treatments in the current study had on the meat from the two species strongly suggest specie-specific tailoring of process inputs is required for beef and venison by meat processors if the colour of these meats is to be optimised.

ACKNOWLEDGEMENT

The authors would like to thank the meat processing plants involved in the survey for their support and assistance in connection with collection of the samples and John Waller for statistical analysis of the data. Funding for this project was provided by the New Zealand Foundation for Research, Science and Technology (contract number C10X0708).

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Table 1. pH of beef and venison as affected by ageing time prior to freezing

Muscle/specie	Ageing time (weeks)				
	0	1	3	9	*P*-value
Beef SM	5.62	5.63	5.62	5.64	0.8
Beef LDL	5.74	5.77	5.79	5.76	0.2
Venison LDL	5.49	5.52	5.48	5.51	0.2

P = Statistical significance; SM & LDL = *M. semimembranosus* and *M. longissimus dorsi et lumborum* respectively

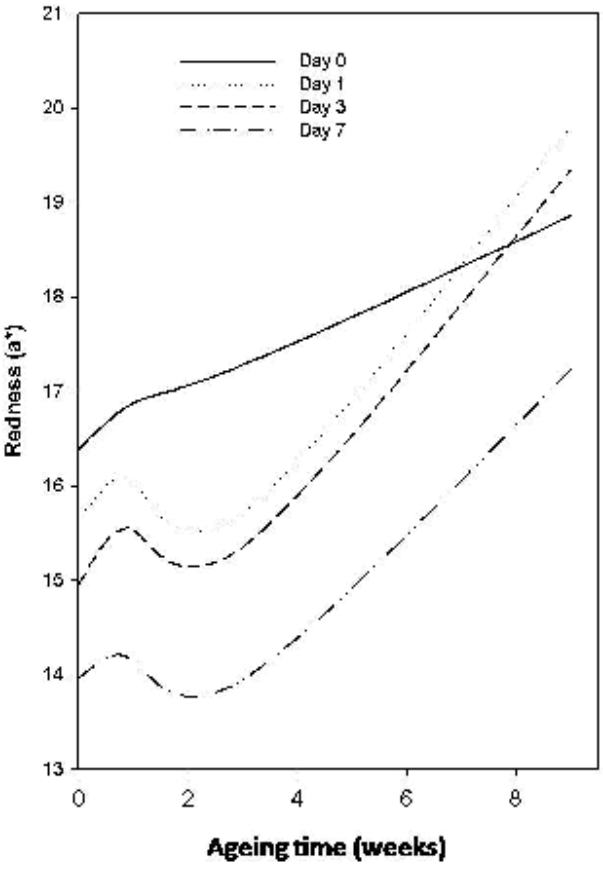

Fig. 1a. Changes in the redness of beef *semimembranosus* with time of ageing

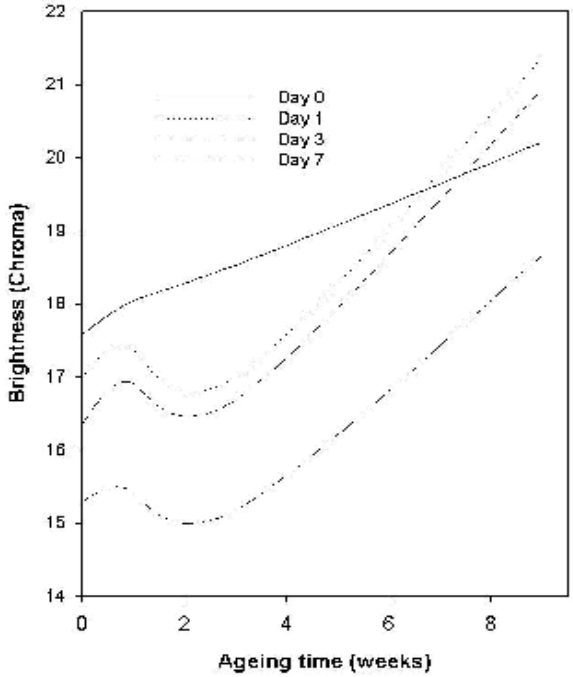

Fig. 1b. Changes in the brightness of beef semimembranosus with time of ageing

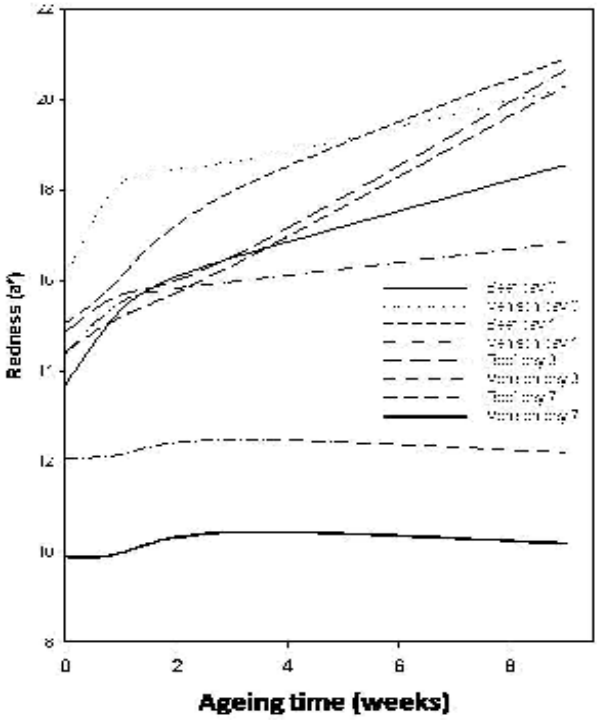

Fig. 2a. Changes in the redness of beef and venison with time of ageing

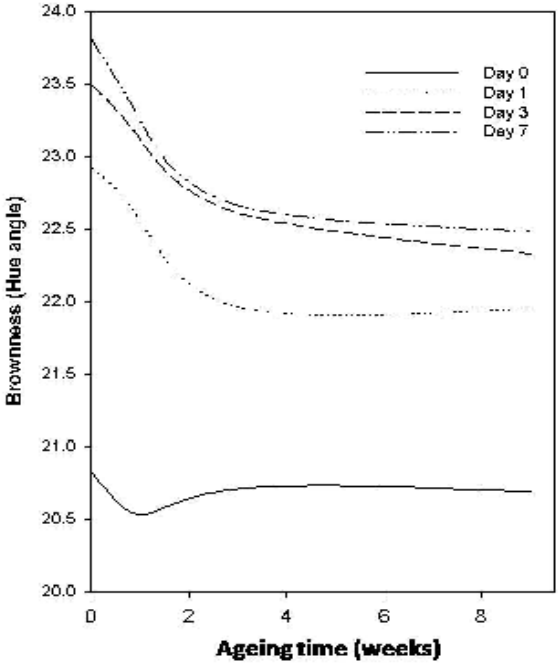

Fig. 1c. Changes in the brownness of beef semimembranosus with time of ageing

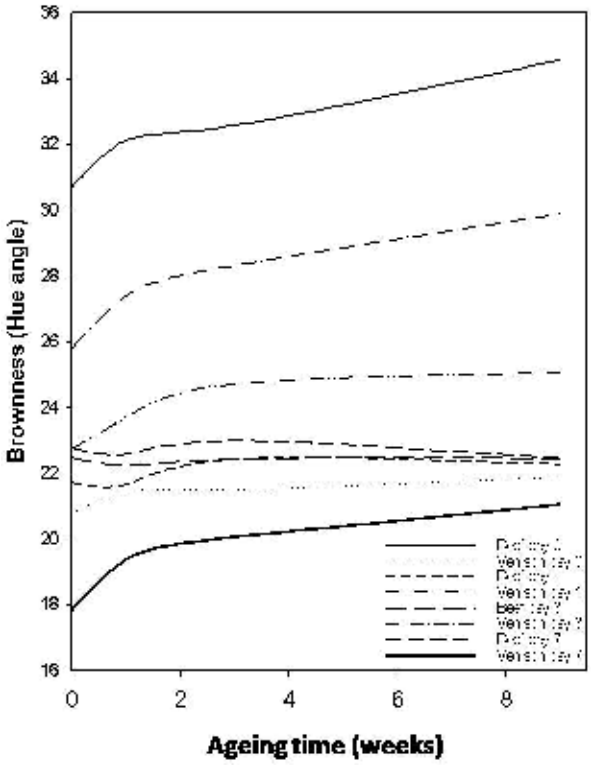

Fig. 2c. Changes in the brownness of beef and venison with time of ageing

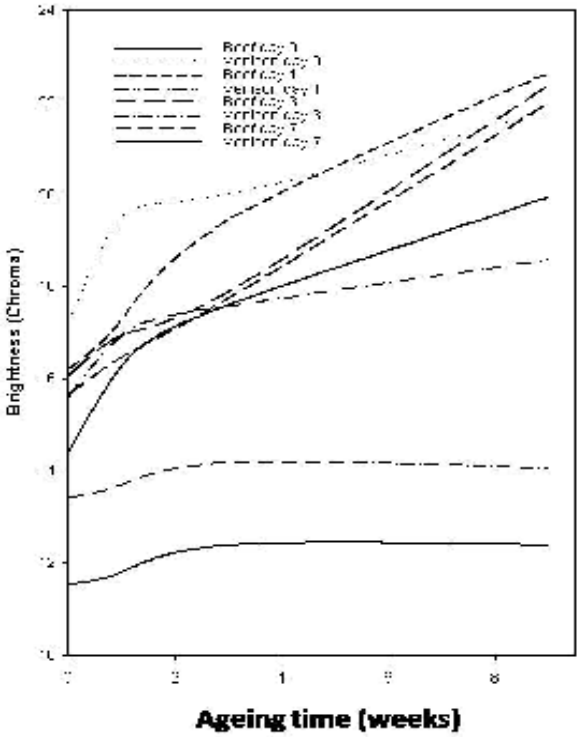

Fig. 2b. Changes in the brightness of beef and venison with time of ageing