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Incidence of high pH in venison: implications for quality

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ABSTRACT

Muscle ultimate pH (pH_u) is known to influence eating quality, functional properties and safety in beef, lamb and pork. The extent to which muscle pH affects tenderness and the extent to which it can be "aged" out is different for lamb compared to beef and two studies have been carried out with venison in order to determine the implications for venison tenderness.

Longissimus thoracis et lumborum (striploin) muscles from nine carcasses which went prematurely into rigor ("stiff" carcasses) had higher mean pH than muscles from nine control carcasses (5.93 vs 5.61, SED = 0.091 at 2 days postmortem (PM); 5.83 vs 5.56, SED = 0.100 at 7 days PM; 5.81 vs 5.54, SED = 0.096 at 21 days PM). A typical quadratic relationship was observed between tenderness and pH which explained non-significant differences in tenderness between the stiff and control muscles. The tenderness-pH relationship for venison striploins assessed at 2 days after slaughter was typical of that reported for unaged beef and lamb in that muscles with pH in the range of 5.8-6.2 were tougher ($p < 0.05$) than normal (5.5-5.7) and high (> 6.2) pH muscles. The tenderness profile change after 7 and 21 days chilled storage at 4°C was similar to that reported for lamb in that all of the striploin samples tenderised to an acceptable level.

Ten intermediate pH (5.8-6.2)) *biceps femoris* (BF) muscles were tougher ($p < 0.05$) than ten normal pH (5.5-5.7) muscles at all times with chilled storage at 0°C for up to 6 weeks. The intermediate pH muscles that were frozen then thawed prior to assessment were significantly more tender than the chilled intermediate pH muscles, but still tended to be tougher than the normal pH muscles. Both the chilled and frozen intermediate pH muscles were significantly more variable in tenderness than the normal pH BFs.

Keywords: pH; venison; quality; tenderness; aging.

INTRODUCTION

It has been well established (Lawrie, 1985) that stress can result in an undesirable high pH condition known as dark-cutting or DFD (Dry, Firm and Dark). Up until very recently, no specific quality class existed for high pH meat in New Zealand, although a number of plants have, in the past, measured pH_u in an effort to identify and remove DFD carcasses from processing for long term vacuum packaged storage. The main objections to DFD meat are the colour and spoilage characteristics but the consistency and eating quality are also considered objectionable. The precise pH value at which a carcass is deemed DFD depends largely on processing and marketing factors but is in the range of 5.8 to 6.3, and, while there is a good relationship between pH_u and colour, most meat industries have moved to directly measure pH rather than relying on colour.

The studies reported here focus on the relationship between venison pH_u and tenderness since tenderness is regarded by many as the prime quality factor affecting consumer satisfaction, particularly so for venison. A relationship has been shown to exist between pH_u and tenderness in both beef and lamb, such that toughness increases as the pH_u rises to between 5.8 and 6.0, then reduces as the pH_u rises above 6.0. Prior to this work it was not known what the incidence of intermediate or high pH venison was and whether venison of intermediate pH would be of an acceptable tenderness level after aging. Stiff carcasses were investigated since Deer Slaughter Plant staff had noticed them and it was suspected that the carcass stiffness might have an influence on meat quality.

MATERIALS AND METHODS

Trial 1

Nine carcasses in a commercial deer slaughter plant (DSP) which were noticed by the meat inspector to be in premature rigor (stiff (rigid/inflexible/unbending) within 20 minutes of exsanguination instead of the normal 2-3 hours) were selected for study. Each prematurely stiff carcass was paired with a control (normal) carcass of similar weight in the same slaughter group and they were chilled next to one another in the same chiller. All carcasses used in this study were classed as Cervena (i.e. were from animals 3 years of age or less). Muscle pH values were measured as described by Pollard *et al.*, (1999). The striploins were removed in accordance with normal boning operation at approximately 24 hours postmortem (PM), vacuum packaged and chilled for 2-4 hours at 4°C prior to measurements of meat quality. The pH was determined again immediately after opening the vacuum-package in triplicate at three positions along the *M. longissimus thoracis et lumborum* (striploin or loin or ribeye muscle) and again on vacuum packaged portions after 2, 7 and 14 days (d) of chilled (4°C $\pm$ 0.5°C) storage. Tenderness was determined on steaks cooked via both the standard MIRINZ water-bath cooking technique and the grilling/broiling method of Cross *et al.*, (1978) then sheared using a MIRINZ tenderometer as described by Stevenson *et al.*, (1992).

Trial 2

Twenty Cervena-grade carcasses from a commercial DSP were selected based on the pH of the *M. biceps femoris* (BF). The animals were selected from three farms over three weeks (three different slaughter days). Ten car-

casses had normal pH (pH 5.5-5.7) and ten had pH in the "intermediate" pH range (pH 5.8-6.2) in the BF muscle. The two BF muscles were removed from each carcass at approximately 24 hours PM, in accordance with normal boning operation, vacuum packaged and chilled for 2-4 hours at 4°C. Each muscle was cut into seven 2.5 cm thick steaks and the steaks were stored at 0 ± 0.5°C for 0, 1, 3, 7, 14, 21 and 42 d. The steaks from one muscle (left and right hand side muscles were randomly assigned to this treatment) were chilled only and the steaks from the other muscle were subsequently frozen for 6 weeks after the initial chilling period. Tenderness was determined using the standard MIRINZ water-bath cooking technique and a MIRINZ tenderometer as described by Stevenson *et al.,* (1992). The frozen steaks were thawed by placing in a refrigerator at 2-4°C for 24 hours prior to cooking.

Statistical analysis

pH and log tenderness data from Trial 1 were analysed by ANOVA, with muscle within animal within pair as the block structure, and treatment (stiff versus control) by muscle, as the treatment structure. The relationship between log tenderness and pH was fitted by least squares quadratic regression, with separate intercepts for different days of storage. For Trial 2 log tenderness was analysed by ANOVA with side within animal as the block structure, and treatment (chilled or frozen), pH group (normal or intermediate), days of storage, and the interaction of all these terms, as the treatment structure.

RESULTS AND DISCUSSION

Trial 1

Mean pH was significantly higher for stiff than for control carcasses (Table 1). Three of the nine stiff carcasses had a mean pH above 6.0. The control carcass mean was within the expected range for normal venison carcasses (5.5 - 5.7). Although there appears to be a tendency for the muscle pH to decrease with time, this is confounded with position along the loin with the later time period samples being more posterior than the earlier time period samples.

The tenderness values from grilling and waterbath cooking were highly correlated (r = 0.842) but did not differ (P>0.05) in mean between the stiff and control carcasses (Table 2). However, there was considerably more variability in the tenderness of steaks from the stiff carcasses. Part of this non-significant result can be explained by the pH-tenderness relationship (Figure 1) for which the intermediate pH range steaks were the least tender and both the low pH and high pH steaks more tender. It was also found for the waterbath cooked steaks that the muscles from the control carcasses had a greater ratio of change in tenderness (2d/21d) than the stiff muscles (2.8 vs 2.0 respectively, SED = 0.28, p < 0.05). After 21 d ageing at 4°C these samples were able to reach an acceptable level of tenderness, in a similar manner to which lamb can be tenderised with ageing, although the steaks with moderate (5.8-6.0) pH tended to still be tougher than the normal and high pH steaks.

TABLE 1: Mean pH measurements for prematurely stiff vs normal carcasses.

Time	Location	Section	Stiff	Control	SED	Significance
24 hours	Carcass	Leg	5.85	5.54	0.087	**
		Loin	5.83	5.56	0.087	**
		Shoulder	6.03	5.80	0.087	**
	Loin Muscle	Lumborum	5.86	5.57	0.101	*
		Centre	5.84	5.59	0.101	*
		Thoracic	6.03	5.76	0.101	***
2 days	Loin Muscle	Centre	5.93	5.61	0.091	**
7 days	Loin Muscle	Centre	5.83	5.56	0.100	*
21 days	Loin Muscle	Centre	5.81	5.54	0.096	**

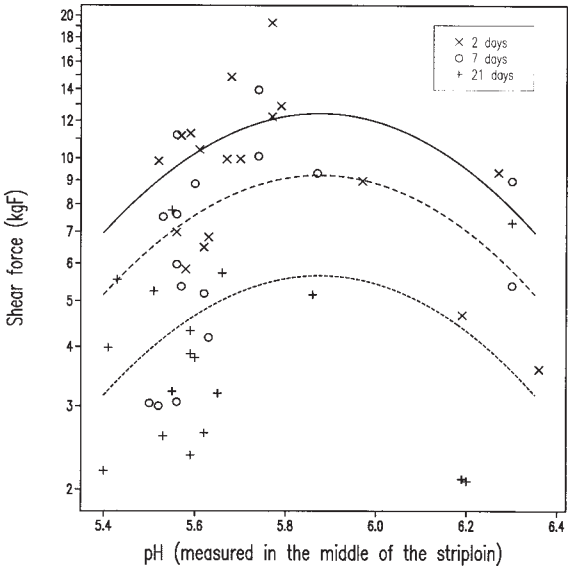
*** = p<0.001; **= p<0.01; * = p<0.05; n.s. = not significant. Leg = *biceps femoris*, loin = *longissimus thoracis et lumborum*, shoulder = *triceps brachii*.

TABLE 2: Mean tenderness measurements for prematurely stiff vs normal carcasses.

Time		Stiff	Control	SED	Significance
2 days	Waterbath	8.8	9.2	2.02	n.s.
	Grill	8.0	5.9	1.34	n.s.
1 week	Waterbath	7.7	5.3	1.20	n.s.
	Grill	6.9	5.3	1.32	n.s.
3 weeks	Waterbath	4.3	3.2	0.77	n.s.
	Grill	4.6	3.7	1.02	n.s.

*** = p<0.001; **= p<0.01; * = p<0.05; n.s. = not significant.

FIGURE 1: Relationship between pH and tenderness for striploins chilled at 4° C for different times; fitted quadratic curves for log(shear force) versus pH at 2 days (¾¾) 7 days(– – –), 21 days (———) of storage.



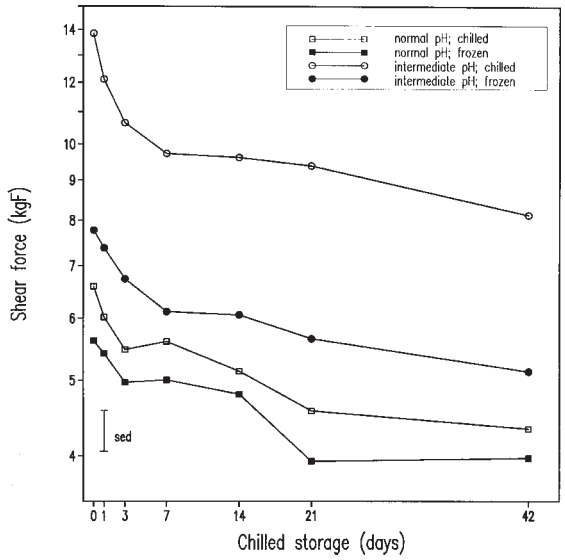
Watanabe *et al.,* (1996) and Devine (1994) reported that although meat of a moderate pH_u ages more slowly than both high and low pH_u meat, given enough time it eventually reaches the same tenderness. However, their work was conducted with meat held at 10-12°C, which ensured that aging was extremely rapid, whereas for meat held at 0°C the aging would be approximately one-seventh of that rate and at 4°C would be somewhat intermediate. It is likely that the venison studied here would have tenderised further at the faster rate if held at 10-12°C. However, 4°C is representative of the warmest temperature it is likely to be held at in commercial practice. Intermediate pH beef muscles tested by Simmons and Cairney (1997) were held at 4°C

and did not attain an AC & A standard of 8 kgF even after 49 days of aging. These findings indicate that intermediate pH venison tenderises faster than beef at 4°C, and probably tenderises as fast as lamb if they were held at the same temperature for ageing.

Trial 2

As shown in Figure 2, steaks from the chilled only intermediate pH BF muscles did not attain the AC & A standard of 8 kgF even after 42 days ageing. The steaks from the intermediate pH muscles that were frozen then thawed prior to assessment were more tender ($p<0.05$) than steaks from the chilled intermediate pH muscles, but still tended to be tougher ($p>0.05$) than the normal pH muscles. The normal pH and frozen intermediate pH muscles had mean tenderness levels that were below 8 kgF at all times and tenderised to highly acceptable levels (<6 kgF) within 1 day and 14 days respectively. Although it may appear from Figures 2 that freezing tenderises venison, we must caution against making that conclusion. Two of the animals had frozen muscles significantly tougher than chilled muscles and in this data set, one side of the carcass was significantly tougher than the other. It is suspected that the process of shackling only one leg prior to electrical stimulation may have led to one leg being consistently tougher than the other, although this information was not recorded, since this effect was not expected. There is also the possibility that the DSP personnel did not consistently shackle one side as opposed to the other. We believe that the shackling of only one leg is detrimental to venison quality, particularly in animals with intermediate pH muscles, and this issue needs further investigation.

FIGURE 2: Mean tenderness after chilled (0° C) and frozen (-20° C) storage for normal and intermediate pH biceps femoris muscle against chilled storage time.



Although some aspects of this study need to be confirmed (i.e. the leg side/shackling effect), it indicated that intermediate pH muscles perhaps should be frozen rather than chilled. This recommendation would be in harmony with recommendations that meat with elevated pH should be frozen rather than chilled for microbiological reasons.

CONCLUSIONS

Studies with other meats have shown that as meat pH increases from the ideal of 5.5 there are undesirable tenderness, texture, flavour, odour, colour, microbiology and hence, shelf-life and consumer acceptability consequences. These studies have confirmed similar outcomes for venison with regard to tenderness, and, it is considered highly likely that the other consequences will also occur. Further work is planned to investigate the appearance and shelf-life of venison with elevated pH.

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