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Sources of variation in the ultimate pH of *M. longissimus* from prime steers

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ABSTRACT

The ultimate pH (pH_{ult}) of beef is an important quality determinant, that can be affected by pre-slaughter muscle glycogen concentrations. The two trials reported here evaluated relationships between pre-slaughter conditions and behaviour of mobs of steers processed at Manawatu Beef Packers Limited and the subsequent incidence of high-pH beef. Trial 1 involved 405 2- and 3-year steers in 12 mobs, with a mean (±sd) carcass weight of 341.2 (±28.2)kg. Cattle were held for either c. 3h prior to slaughter (1/2 of each mob) or c. 27h. Mean carcass weight was lower for the 27h-mobs ($P < 0.01$), but the extra 24h holding time had no effect on mean pH_{ult}, bruising score, carcass fat depth, or meat colour. The percentage of carcasses with a $pH_{ult} > 6.0$ varied from 0 to 27%, but was not closely related to any of the pre-slaughter conditions monitored (eg. feeding levels, conditions during yarding, loading and transport, weather conditions, and conditions at the plant). Animal temperament on a mob basis was also unrelated to the incidence of high-pH. For Trial 2, 776 steers in 34 mobs (carcass weight = 335.0±29.9 kg) were evaluated. Mob means for pH_{ult} ranged from 5.38 to 6.27 (mean = 5.82), but neither the mean pH_{ult} nor the proportion of pH_{ult} values below 5.8 or 6.0, was closely related to animal age, carcass bruising scores, or pre-slaughter assessments of animal temperament. Greater electric probe use during unloading decreased the percentage of pH_{ult} values below 6.0. ($P = 0.03$). It is concluded that the incidence of high-pH beef from a mob is usually determined by a range of factors, no one of which was dominant in these trials.

Keywords: Ultimate muscle pH; carcass quality; holding time; animal temperament.

INTRODUCTION

The ultimate pH (pH_{ult}) of beef is of considerable practical concern because of implications for a range of key quality characteristics. Thus, with increases above a "normal" value of 5.5 to 5.6 for *M. longissimus thoracis et lumborum* (LT) towards a maximum value of about 7.0, beef colour darkens, the flavour becomes more bland and less acceptable, cut surfaces appear more dry due to an increased water holding capacity, and shelf life declines (Tarrant 1989). Because of these effects the usual aim for prime beef is for a pH_{ult} of LT close to 5.5, and for beef to be exported in the chilled form it is common practice to exclude carcasses where the LT pH_{ult} is above a cut-off such as 5.8 or 6.0 (Purchas 1989). In order to achieve satisfactory pH_{ult} values it is necessary for muscle glycogen levels at slaughter to be above about 50 µmole/g so that sufficient lactic acid accumulates during the *post mortem* period to bring about the fall in pH. Therefore the problem of minimising high muscle pH_{ult} values is mainly one of preventing muscle glycogen depletion during the pre-slaughter period by eliminating the two main stimuli for this process, which are, first, via the action of adrenaline produced as a result of stressful events and, secondly, through excessive muscular activity (Tarrant 1989).

The incidence of elevated levels of LT pH_{ult} for prime steers in New Zealand has been reported by Graafhuis and Devine (1994), where mean LT pH_{ult} of 542 steers in four processing plants was 5.59 with 9% of the carcasses having values above 5.8, and by Smith *et al.* (1996), where the mean LT pH_{ult} of 16,905 carcasses within the Richmond Asian Beef Programme was 5.61 with 8% exceeding 5.8. Results from these surveys revealed some significant trends in the incidence of high pH_{ult}, but generally the effects where quite small which is consistent with results from other countries (Purchas 1989). The objective of the work reported here was to monitor a smaller number of mobs of prime steers in more detail than in previous studies with the aim of identifying causes of variation in the incidence of high LT pH_{ult} between mobs.

MATERIAL AND METHODS

Trial 1

Twelve mobs of rising 2- and 3-year-old steers made up of a range of breeds and crosses were assessed on farms and at Manawatu Beef Packers Ltd, Feilding. All assessments were made by the same person (BK) on the farm, during transportation, and at the plant, using a combination of descriptive scales for items such as type of country (flat, rolling, hill), breed or cross, use of growth promotants, weather conditions, and method of rearing; and numerical scoring systems for a range of other characteristics (Table 1).

The scales in Table 1 for "handling aids", "tempo of activities", "level of control", and "animal temperament" were used in assessing 11 separate stages from mustering on the farm through to the stage when the cattle were moving up the race to the knocking box. The "Conditions" scale at the bottom of Table 1 was used to assess the ease of flow when mustering the cattle on the farm, the ease of flow through the yards, the absence of protrusions in the yards and at gateways, and loading facilities.

TABLE 1: A summary of the scoring systems used for a range of characteristics.

Characteristic	First and last item on the scale
Handling frequency	1 = > once/month; 5 = < once/ 6 months
Mob splitting/mixing	1 = No change in size; 5 = Mobs combined within the last week
Handling aids (other than dogs)	1 = No use of aids; 7 = Heavy use of an electric probe
Tempo of activities	1 = Slow and restrained; 5 = Fast and frantic
Level of control over stock	1 = Fully under control; 5 = Out of control
Animal temperament	1 = Docile and placid; 5 = Excited and upset
Extent of dog use	1 = No dogs used; 5 = Heavy use of dogs
Dog behaviour	1 = Shy and stand-offish; 5 = Aggressive (biting and barking)
Tightness of packing during transport	1 = Very loose; 5 = Very tight
Smoothness of the trip	1 = Very smooth; 5 = Very rough
Conditions during/of...[a]	1 = Excellent; 5 = Significant problems

[a] The situations where this scale was applied are explained in the text.

Mobs were trucked for from 11-63km to Manawatu Beef Packers (MBP) in Feilding and on arrival were randomly divided into two groups of approximately equal size that were held in covered yards with access to fresh water for 3 and 27 hours, respectively, prior to slaughter. All cattle were washed at the plant using a high-pressure hose and a walk-through bath. They were stunned before exsanguination and were dressed following normal commercial procedures.

While on the slaughter floor the number of permanent incisor teeth erupted was recorded, and bruises were assessed on a 5-point scale where: 1 = very slight; 2 = definite but not enough to trim; 3 = serious enough to trim; 4 = broken and bleeding; 5 = extreme (A.E. Graafhuis, MIRINZ, personal communication). A composite bruising score was taken as the sum of the scores for the two most severe bruises.

After at least 24 hours in the chiller each side was quartered between ribs 12 and 13 and, following at least 20 minutes exposure to air, the following measurements were made by a MBP employee: muscle pH (using a combination electrode directly in the muscle); muscle and fat colour (using the 7-point Japanese BMS and BFS standards); and intramuscular fat (using the 12-point Japanese marbling standards).

Trial 2

Trial 2 was similar to Trial 1 with 34 mobs of prime steers, but all cattle in each mob were slaughtered following a similar holding time, and 10-15mm slices of the LT muscle were taken at the time of quartering for subsequent measurement of pH_{ult} at 48-72h *post mortem*.

RESULTS AND DISCUSSION

Mean carcass weights for steers in the two trials (Table 2) were higher than the national average for prime steers (c. 300kg), and in Trial 1 those slaughtered after a 27-hour hold were lighter than those held only 3 hours. The dressing-out percentage was slightly higher for the 27h group (Table 2) which was expected as they were based on live weights at slaughter and the weight of gut-fill would tend to be lower following the longer holding time. Live weights at the time when the mobs were split into the two holding-time groups were not measured, so it is not clear whether the longer holding time contributed to the lower carcass weight or not, but based on results of other studies (eg. Purchas 1992), the effects of an extra 24 hours holding for steers is likely to be small. Dressing-out percent values are not given for Trial 2 because no holding-time treatment was involved.

TABLE 2: Means (±SD) for characteristics of the 3- and 27-hour hold groups for the 12 mobs in Trial 1 and for all the cattle of the 34 mobs in Trial 2.

	Trial 1				Trial 2	
	3h-Grp	27h-Grp	RSD[a]	Pb	Mean	SD
Number of steers	205	200			779	
Carcass weight (kg)	345.3	336.9	27.9	0.003	336.2	36.4
Dressing-out %	56.4	56.7	1.67	0.07		
Ultimate LT pH	5.57	5.62	0.31	0.10	5.85	0.38
Meat colour score[c]	4.94	5.03	0.36	0.015	5.36	0.56
Marbling score[d]	1.18	1.19	0.47	0.76	1.19	0.52
Bruising score[e]	2.53	2.67	2.16	0.53	2.20	2.00
Number of teeth	4.59	4.46	2.21	0.54	3.64	2.04
Fat depth (mm)	9.34	9.25	3.61	0.79	6.63	3.40
Percentage with pH_{ult}:	> 5.8	11.2	19.0			39.7
	> 6.0	4.9	11.5			23.3

[a] RSD = residual standard deviation

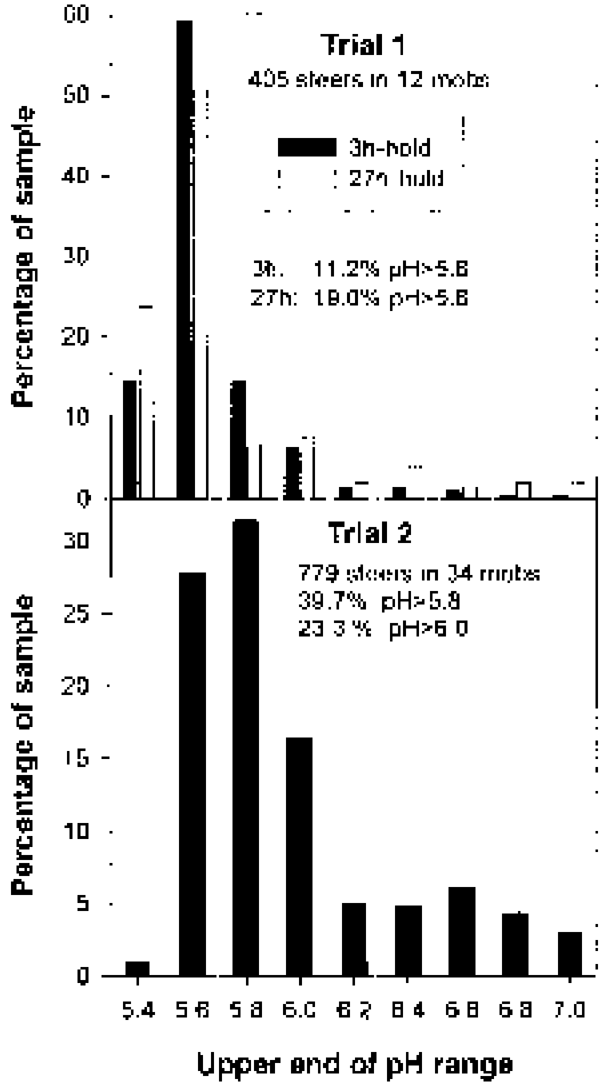
[b] P = Statistical significance of the difference between the 3h- and 27h-hold groups.

[c] On a range of 1 (light red) to 7 (dark red)

[d] On a scale of 1 (light marbling) to 12 (heavy marbling)

[e] On a scale of 0 (least bruising) to 10 (see text)

FIGURE 1: Frequency distributions for LT ph_{ult} values for prime steers for Trials 1 (upper histogram) and 2 (lower histogram). For Trial 1 separate bars are shown for the groups held for 3 and 27 hours at the plant.



Mean pH_{ult} was slightly higher for the 27h-hold group in Trial 1, which was consistent with the significantly darker meat colour for that group (P = 0.015), and with the higher percentage of pH_{ult} values above 5.8 and 6.0 (Table 2 and Figure 1). The mean pH_{ult} for Trial 2 carcases was higher than for Trial 1, as was the meat colour darkness score and the percentages of pH_{ult} values above 5.8 and 6.0. The frequency distributions for pH_{ult} were similar for the two groups of Trial 1 (Figure 1), but for Trial 2 the distribution was flatter and the peak was at 5.8 rather than 5.6. For both trials the distributions showed a longer tail to the right, as has been reported elsewhere, but the presence of a secondary peak at about 6.6 was more apparent for Trial 2 than Trial 1 (Figure 1). For both trials 1 and 2 the percentage of pH_{ult} values above 5.8 were higher than those reported by Graafhuis and Devine (1994) or Smith *et al.* (1996) for similar cattle, but the reason for this is unknown.

Mean values for marbling score, bruising score, number of teeth, fat depth, and muscle depth did not differ between the two groups of Trial 1, and values for Trial 2

TABLE 3: Levels of probability (P) from one-way analyses of variance (AOV) evaluating the differences in the percentage of pH_{ult} values above 5.8 for groups of mobs with regard to various characteristics.

Mobs grouped according to:	P level from AOV for: Trial 1 (n = 24)	Trial 2 (n = 34)
Type of country (4 classes from flat to hill)	0.24	0.95
Use of growth promotants (see text)	0.01*	0.34
Extent to which mobs were mixed	0.01*	0.76
Use of electric prodders during unloading	0.73	0.15
Use of electric prodders in race to knocking box	0.33	0.88
Tempo (Table 1) during unloading	0.46	0.03*
Tempo during holding at the plant	0.38	0.35
Tempo during washing	0.40	0.29
Tempo when in the race leading to the knocking box	0.16	0.17
Animal temperament (Table 1) during unloading	0.38	0.51
Animal temperament during holding at the plant	0.16	0.49
Animal temperament during washing	0.84	0.68
Animal temperament in race to knocking box	0.71	0.59

* = significant at $P < 0.05$

were similar (Table 2). Correlation coefficients showed that with increasing pH_{ult} there was the expected darkening of meat colour within each Trial (r = 0.47 & 0.50; P<0.01), but no suggestion of relationships between pH_{ult} and bruising score, number of permanent incisor teeth erupted, or carcass weight.

The influence of selected treatments and conditions during the pre-slaughter period on the incidence of high-pH beef for the mobs of both trials is shown in Table 3 in terms of the probability levels from analyses of variance for the percentage of pH_{ult} values that were greater than 5.8. High probability levels indicate that the item the mobs were grouped on had little influence on ultimate pH. Similar results were obtained when the proportion of pH_{ult} values above 6.00 were analysed.

The significant effect of growth promotant use for Trial 1 (Table 3) was due to the 4 mobs receiving Revalor® having a higher percentage of pH_{ult} values above 5.8 (13.6%) than the 8 mobs receiving no growth promotant (11.9%) or the 12 mobs receiving Compudose®. Trial 2 included 6 mobs that had received Revalor®, but no effect on pH_{ult} was detected. Samber *et al.* (1996) reported that the use of Revalor® as three successive implants had no effect on the incidence of "dark-cutting" for feedlot steers, but pH_{ult} values were not reported.

The 8 mobs in Trial 1 comprising cattle from different initial mobs had a higher percentage of pH values above 5.8 (27.7%) than the 16 mobs that were not mixed (9.5%), but no such effect was shown in Trial 2 where 18 of the 34 mobs were mixed. Reports of significant increases in the incidence of high-pH beef following mixing of mobs have mainly involved bulls rather than steers (Price and Tennesson 1981; Kenny and Tarrant 1987). Mohan Raj *et al.* (1992), however, found no significant interaction between bulls versus steers and mixed versus unmixed mobs with regard to average pH_{ult} values.

The incidence of pH_{ult} above 5.8 tended to be higher for groups that were scored higher for tempo (Table 3), although this effect was significant only at the time of unloading for Trial 2. When tempo scores at unloading, holding, washing, and in the race to the knocking box were summed and plotted against the percentage of pH_{ult} values above 6.0, a significant positive relationship was shown ($P < 0.01$; Figure 2), but there was a wide scatter of points around the line. Relationships between scores for average temperament within a mob and the percentage of pH_{ult} values above 5.8 or 6.0 were not significant, but there was a positive correlation between the sum of the four tempo scores and the corresponding sum of four temperament scores ($r = 0.56$; $P < 0.01$).

The relationships and effects described above are in the expected directions in light of what is known about factors that can lead to glycogen depletion (primarily muscular activity and stresses that lead to adrenaline release (Tarrant 1989)), but they are not close enough to be of practical value in identifying "at-risk" mobs as far as the incidence of high-pH beef is concerned. Reasons for the relationships not being closer may include the following. First, measures of pH_{ult} are not necessarily a good indication of muscle glycogen concentration at slaughter because increases in glycogen concentrations above a certain level are not reflected in any changes in pH_{ult}. Furthermore, glycogen concentrations at slaughter may not reflect the extent to which animals have been subjected to glycogen-depleting events either, if the initial glycogen level prior to those events is variable. Secondly, the extent of glycogen depletion during the pre-slaughter period for an individual animal or a mob is likely to be due to the additive effects of a series of glycogen-depleting events rather than to any one such event (Devine and Chrystall 1989), whereas the scoring systems used in this study assessed only one aspect at a time. With a larger number of mobs it would be possible to use multiple regression or multivariate techniques to assess the combined effects of several factors. Finally the subjective scoring systems used here for many of the characteristics would have led to relationships that may not have been as close as they would have been for an objective measurement of the same characteristic.

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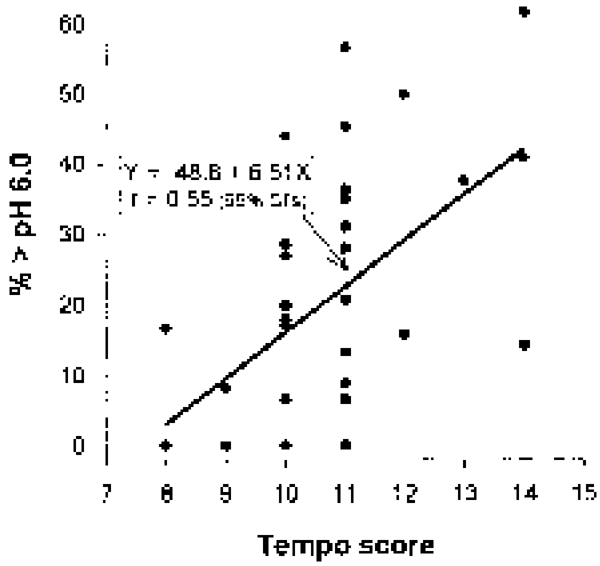
FIGURE 2: The relationship between tempo score and incidence of LT pH_{ult} values of greater than 6.0 for 34 mobs of prime steers in Trial 2. The tempo score used was the sum of the four tempo scores for each mob of cattle during unloading, holding at the plant, washing, and during movement to the knocking box.



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