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The relationships between beef ultimate pH, breed of cattle, muscle glycogen and enzyme levels and animal behaviour

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ABSTRACT

To determine the incidence of high ultimate pH (pH_u) across farms 967 cattle were involved in a survey which showed 3% of Angus, 21% of Simmental cross and 60% of the Friesians steers had an pH_u above the acceptable maximum of 5.8. In further work, muscle (*longissimus dorsi*) biopsies samples were taken from 60 two-year-old Angus, Simmental cross and Friesian steers (n = 20 per breed) in late November and assayed for glycogen concentration and enzyme concentrations that indicated muscle fibre type. Behaviour measurements were made on all animals before slaughter. Individual measurements of carcass characteristics were made 22-24 hours after slaughter, including carcass weight, pH_u, meat colour score, and fat depth (GR). Only one carcass had a pH_u above 5.8 and there was no pH_u difference between breeds (5.53, 5.55, and 5.58 for Angus, Simmental cross, and Friesian, respectively). There was no difference between breeds in the glycogen concentration in the muscle, although there were differences in enzyme concentrations that suggested differences between breeds in the proportion of the three muscle fibre types. Flight distance were small (4-7 m) but longer for Friesian than Simmental cross steers. There were no relationships between meat pH_u and flight distance, glycogen concentration or muscle enzyme concentrations. Breed did not appear to effect pH_u or muscle glycogen concentration.

Keywords: ultimate meat pH; Angus; Simmental; Friesian; *longissimus dorsi*; glycogen; enzymes; muscle fibre; flight distance.

INTRODUCTION

There is a growing interest amongst beef farmers in improving the overall level and consistency of beef quality. This may mean producing cattle in a defined time period to a given carcass weight range, and with a number of preferred characteristics such as; fat colour; meat colour; meat pH; fat depth and eye muscle area. (e.g. Richmond's Asian Beef programme; Smith *et al.*, 1996). Ultimate pH (pH_u) is of particular importance to the prime chilled beef trade as it directly influences shelf life, colour, and eating quality. Ideally beef should have a pH_u of about 5.5, while beef with pH_u of >5.8 has a darker colour and is not acceptable for chilled beef export (Lawrie, 1985; Smith *et al*., 1996).

Meat pH_u is primarily determined by pre-slaughter muscle glycogen concentration since it is the post-slaughter catabolism of the glycogen to lactic acid that produces the decrease in pH_u. At slaughter the glycogen concentration must be greater than 10.3 mg/g wet muscle tissue if enough lactic acid is to be produced to decrease pH_u to 5.5 (Tarrant 1989). Resting levels of glycogen can be influenced by the fibre type composition of muscle. Generally, slow twitch oxidative fibres (type I) contain lower levels of glycogen than fast twitch glycolytic fibres (type IIb) but, at least in sheep, fast twitch oxidative and glycolytic fibres (type IIa) are found to have the highest glycogen concentrations (Briand *et al*., 1981). Stress from behavioural reactivity to pre-slaughter handling and transport can causes depleted glycogen reserves (Tarrant 1989). The level of stress induced and therefore the extent of glycogen depletion is likely to vary with individual cattle and be related to the temperament of the animal. Cattle with poor excitable temperament would be expected to have lower glycogen concentrations and higher pH_u.

This paper reports on a survey, initiated by a group of farmers in the King Country (Sheath and Webby 1999), conducted to determine the incidence of high pH_u in the *longissimus dorsi* (LD) muscle in steers originating from their farms. Also, an experiment was conducted using animals on just one of the farms, to investigate further the effect of breed of steer on pH_u, differences in muscle glycogen concentration, muscle fibre type, and temperament.

MATERIALS AND METHODS

Survey

To measure the incidence of high pH_u (>5.8) in 2 to 3 year-old steers, seven farmers provided kill sheets with individual carcass information for 967 cattle. The kill sheets covered the 1995/96 season (August 1995 – August 1996) and included pH_u in the LD muscle measured 12 to 24 hours after slaughter on chilled carcass sides using a spear type electrode according to the accepted industry standard at the time. The breeds included Angus (n = 150), Friesian (n = 345), and ½ Simmental X ¼ Friesian X ¼ Hereford (n = 417). One farmer had a mixed mob (n = 55) of Hereford X Friesian and Angus X Friesian. Each farmer sent their steers to a different processing plant with only one farmer sending more than one breed to the same processing plant. There were four processing plants involved. This meant farm of origin, breed and processing plant were confounded.

Experiment

Twenty Friesian, 20 Angus, and 20 Simmental cross (½ Simmental with ¼ Friesian and ¼ Hereford) two-year-old steers that had been grazed from 1 year-of-age in varying mobs (some of one breed others mixed) on Phil Turner's farm at PioPio were brought together on 20 October 1997. For ease of management the steers were grazed as two groups, each group containing 10 steers of each breed. The heavier steers of each breed were in group 1 and the lighter steers in group 2.

Group 1 steers were slaughtered on the 12 February 1998 and Group 2 on the 18 February 1998. The animals were trucked for 4 hours to the Richmond Pacific plant near Hastings where they were slaughtered after an overnight lairage under Richmond's Asian Beef programme (Smith *et al.,* 1996). Individual carcass information linked back to the animal ear tag was provided in a detailed kill sheet, which included pH_u and meat colour score (1 light to 7 dark) based on the Japanese Grading Associations Beef grading standards, taken 23 hours after slaughter on the LD muscle on chilled carcass sides 30 minutes after a cut between the 9th and 10th rib. Fat depth (GR) and carcass weight were measured on hot carcasses after splitting into sides before chilling using New Zealand Meat Board grading standards.

On 26 November 1997 (78 and 84 days before slaughter) all cattle had a 300 mg biopsy sample removed from the LD muscle (Lambert *et al*., 1998). Samples were immediately frozen in liquid nitrogen and later assayed for glycogen and muscle fibre enzymes.

Muscle glycogen assay

Glycogen concentration was determined using the iodine binding method (Drieling *et al.,* 1987).

Muscle metabolic enzyme assay

The activity of the enzymes lactate dehydrogenase (LDH), isocitrate dehydrogenase (ICDH) and 3-OH-acyl CoA dehydrogenase (HAD) were measured as marker enzymes for the glycolytic, oxidative and lipid metabolism respectively. The muscle biopsies were pulverised under liquid nitrogen and homogenised and assayed according to the methods of Bass *et al*., (1969).

Behavioural reactivity measurements

Individual behavioural reactivity measurements were conducted on 27 January (16 days before slaughter, Group 1) and 13 February 1998 (5 days before slaughter, Group 2). Each animal was assessed once. These measurements were based on behavioural reactivity tests developed by Matthews *et al.*, (1997), and consisted of measures of paddock flight distance and animal sociability. The flight distance measurement recorded the distance to within which an observer could approach an animal at pasture before it moved away. This distance was then measured using laser range-finder binoculars or a tape measure if less than 4 m. Steers were evaluated in order of ear-tag number.

Animal sociability was measured in a 20 m x 6 m yard. Five animals were held at one end of the yard behind double strand electric tape. The test animal was introduced at the other end of the yard. Two observers standing unseen outside the yard on each side held a 10-cm-wide plastic ribbon. The ribbon presented a visual barrier to the test animal moving closer to its herd mates. The ribbon was then progressively lowered by 0.5 m at 30-second intervals until the animal crossed or ran through the tape. The sociability score of the animal was determined by the height level at which it crossed the ribbon (4 = 1.0 m; 3 = 0.5 m; 2 = 0 m; 1 = No ribbon; 0 = did not cross within 30 seconds of ribbon withdrawal).

RESULTS

Survey

Of the 967 carcasses measured, 311 (32.2 %) had a high pH_u (pH_u>5.8)in the LD muscle. More of the Friesian steers had high pH_u than Simmental crossbred steers (58% vs 21% P<0.001 (using a one-way analysis of variance)) which in turn had more (P<0.001) high pH_u steers than the Angus (3%) (refer Table 1). Even when comparing steers from the same farm and processed in the same plant more Friesian steers had a high pH_u than Simmental crossbred steers (61% vs 24%; P<0.001). There did not appear to be a difference between processing plants in the incidence of high pH_u.

Table 1: The incidence of high ultimate pH amongst group members by breed and farm.

Farm	A	A	B	C	D	E	F	G
Processing plant	A	A	B	B	C	A	C	C
Breed	Fr	Sim X	Sim X	Sim X	Mix[a]	Fr	Angus	Angus
No. of cattle in survey	138	68	247	102	55	207	70	80
Percentage of pH_u > 5.8	61	24	15	32	35	58	4	1

[a] Hereford X Friesian and Angus X Friesian

Experimental study

At the start of the experiment the Angus and Simmental crossbred steers were heavier (P<0.001) than the Friesian steers (596, 585, and 509 ± 5.4 kg respectively). Over the 37 days to the muscle biopsy the Friesian steers grew faster (P<0.05) than the Simmental crossbred steers (1.80 vs 1.33 ± 0.12 kg/day) with the Angus steers being intermediate (1.58 kg/day). The growth rates slowed over the subsequent 76 days but the difference in growth rate (P<0.05) between breeds continued up to the last weighing before the steers were slaughtered (Friesian 0.91 kg/day, Simmental crossbred 0.72 kg/day and Angus 0.86 kg/day). Before slaughter the Angus steers were heavier (P<0.05) than the Simmental cross steers (720 vs 695 ± 7.1 kg) with the Simmental cross steers in turn being heavier (P<0.001) than the Friesian steers (645 kg). These differences in liveweight were reflected in differences in carcass weights at slaughter, with the Angus steers being heavier and fatter than the Simmental crossbred steers, which in turn were heavier and fatter than the Friesian steers (Table 2).There were no differences between breeds in pH_u or meat colour score (Table 2). Only one steer (Simmental crossbred) had a pH_u greater than 5.8. There was also no difference between breeds in glycogen concentration in the LD. The gly-

cogen concentrations were high in all breeds and no steers had values below 10.3 mg/g, although 4 Simmental crossbred and 3 Friesian steers had values below 16 mg/g. The Simmental crossbred steer with the high pH_u had a muscle glycogen concentration of 27 mg/g when it was measured 78 days before slaughter. Simmental crossbred steers had a higher ($P<0.05$) concentration of LDH than Angus steers while Friesian steers had a higher ($P<0.05$) concentration of ICDH than Angus steers (Table 2). There were, however, no differences between breeds in the concentration of HAD or the ratio of LDH : ICDH.

The flight distance and sociability score for each breed type are presented in Table 2. Simmental cross steers had a lower ($P< 0.01$) paddock flight distance than Friesian steers, and there was a tendency for Friesian steers to have a greater flight distance than that of Angus steers ($P < 0.06$). Sociability scores did not differ between breed types.

Table 2: Mean (± SEM) for carcass, LD muscle and behavioural characteristics of the Friesian, Simmental cross and Angus steers grazed together from 20 October 1997 for 115 days before slaughter.

	Friesian	Simmental X	Angus	SEM
Carcass wt (kg)	313[a]	360[b]	383[c]	4.0
GR (mm)	3.7[a]	8.2[b]	12.5[c]	0.7
pH_u	5.59	5.55	5.53	0.02
Meat colour score	3.6	4.0	3.6	0.2
Glycogen conc. (mg/g fresh muscle)	25.8	23.6	25.7	1.5
LDH (U/g fresh muscle)	19.3[ab]	20.3[b]	18.4[a]	0.55
ICDH (U/g fresh muscle)	53.2[a]	48.2[ab]	44.8[b]	2.1
HAD (U/g fresh muscle)	50.3	45.0	47.5	1.9
Ratio LDH:ICDH	0.38	0.44	0.43	0.03
Flight distance (m)	6.9[a]	4.0[b]	5.2[ab]	0.61
Sociability score (0 – 4)	1.0	1.3	1.2	0.19

Means in the same row with superscripts that do not contain a common letter are significantly different ($P<0.05$)

The pH_u was correlated with the meat colour score ($r = 0.66$; $P<0.001$) and negatively correlated with carcass weight ($r = -0.28$; $P<0.05$) but there were no significant correlations with glycogen concentration, any fibre type measure, or any behaviour measure. Glycogen concentrations were positively correlated with ICDH ($r = 0.38$; $P<0.01$) and HAD ($r = 0.35$; $P<0.01$) and negatively correlated with the ratio of LDH : ICDH ($r = -0.32$; $P<0.05$).

DISCUSSION

The incidence of pH_u greater than 5.8 in the survey of carcasses from steers from the farmer group was 32%, which is greater than that of 9% recorded for 542 steer carcasses by Graafhuis and Devine (1994). A factor contributing to this incidence of high pH_u was the practice on some farms of forming new herds of selected steers close to slaughter. The farmers being unaware of the affect this had on the animals as changes in the behaviour of the steers was not marked compared to the behaviour of bulls in the same situation. The study of Purchas and Keohane's (1997) supports this, as they found mobs made up of animals combined for the first time on the day of trucking had a higher incidence of high pH_u. Barton and Pleasants (1993) reported on work where Friesian steers had darker meat than other breeds. Although the survey supported this finding with a greater incidence of high pH_u (darker meat) in Friesian steers, the experiment showed little differences in meat colour between breeds (refer Table 2).

The flight distance from humans of the cattle in this study was fairly small relative to other studies (Matthews *et al*., 1997). It is not certain why the Simmental crossbred cattle had lower paddock flight distances, but as the cattle were bought in, this may be related to handling experience at the farm of origin. Previous handling events and experiences can have a strong influence on subsequent behavioural reactivity (Matthews *et al*., 1997), although the three breed types had been run together for some months, and were generally very quiet and well-handled. They were trucked as a mob, but were kept separate from other mobs through to slaughter. Similarly, there were no differences in the concentrations of muscle glycogen between breeds. Breed had a small effect on the activity of metabolic enzyme in the LD, suggesting some differences in the fibre type composition. Also, muscle ICDH activity correlated significantly with muscle glycogen concentration. Although ICDH activity only identifies increased oxidative metabolism, the relationship between glycogen and ICDH probably reflects an increased proportion of type IIA fibre, since these fibres are associated with high glycogen concentration but type I fibres are not.

The failure to detect correlations between behavioural reactivity up to three weeks prior to slaughter and pH_u in this study is not surprising given that only one animal had muscle with pH_u greater than 5.8. It is unlikely however that the behavioural reactivity of the cattle would have changed greatly in that time. Although the determining factors for high pH_u among steer carcasses in New Zealand have not been fully identified (Graafhuis and Devine, 1994; Lambert *et al.*, 1998, Purchas and Keohane 1997 and Smith *et al*., 1996), it is possible that there would have been a greater incidence of high pH_u meat from the animals in this study if they had been more reactive and less quietly handled.

REFERENCES

Barton R.A.; Pleasants A.B. 1993. Fat colour and meat colour in different breeds of steers in five consecutive years raised on pasture and slaughtered at 30 months of age. *Proceedings of the New Zealand Society of Animal Production* **53:** 389-391.

Bass A.; Brdicza D.; Eyer P.; Hofer S.; Pette D. 1969. Metabolic differentiation of distinct muscle types at the level of enzymatic organization. *European Journal of Biochemistry* **10:** 198-206.

Briand M.; Talmant A.; Briand A.; Monin G.; Durand R. 1981. Metabolic types of muscle in the sheep: I. Myosin ATPase, glycolytic and mitochondrial enzyme activities. *European Journal of Applied Physiology* **46:** 347-358.

Dreiling C.E.; Brown D.E.; Casale L.; Kelly, L. 1987. Muscle glycogen: comparison of iodine binding and enzyme digestion assays and application to meat samples. *Meat Science* **20:** 167-177.

Graafhuis A.E.; Devine C.E. 1994. Incidence of high pH beef and lamb II: Results of an ultimate pH survey of beef and sheep plants in New Zealand. *Proceedings of the Twenty-eighth Meat Industry Research Conference. Auckland, July 1994.* pp.133-141.

Lambert M.G.; Knight, T.W.; Cosgrove G.P.; Anderson C.B.; Death, A.F. and Fisher, A.D. 1998. Exercise effects on muscle glycogen concentrations in beef cattle. *Proceedings of the New Zealand Society of Animal Production* 58: 243-244.

Lawrie, R.A. 1985. Chemical and biochemical constitution of muscle. *In:* Meat Science (author R. A. Lawrie). Pergamon Press, Oxford.

Matthews L.R.; Carragher J.F.; Slater J.L. 1997. Effects of flightiness, sociability and previous handling experience on the behaviour of cattle in yards. *Proceedings of the International Society of Applied Ethology.* Prague, August 1997. p 94.

Purchas R.W.; Keohane B.E 1997. Sources of variation in the ultimate pH of *M longissimus* from prime steers. *Proceedings of the New Zealand Society of Animal Production* 57:271-274.

Sheath G.W.;Webby R.W. 1999. The results and success factors of nine group farm monitoring programmes. *Proceedings of the New Zealand Society of Animal Production* **in press**

Smith D.R.; Wright D.R.; Muir P.D. 1996. Variation in meat pH in steers and association with other carcass attributes: analysis of a commercial database. *Proceedings of the New Zealand Society of Animal Production* 56:187-192.

Tarrant P. V. 1989: Animal behaviour and environment in the dark-cutting condition in beef – A review. *Irish Journal of Food Science and Technology.* 13*:* 1-21.