Effect of Cattle Diet on Some Aspects of Meat Quality

O. A. Young, C. C. Daly, A. E. Graafhuis & S. M. Moorhead
MIRINZ, P.O. Box 617, Hamilton, N. Z.

Introduction

New Zealand's pasture-based system is cost efficient, but the meat produced has certain quality attributes that restrict marketing opportunities. Ultimate pH is often high in N.Z. beef compared to beef produced in other countries (Graafhuis & Devine, 1994), which is from cattle often finished in feedlots. In contrast to feedlot finishing, N.Z. cattle are handled much less frequently during production, leading to more stress than for feedlot-finished cattle and so reduce muscle glycogen. Alternatively, diet *per se* might be important in maintaining adequate glycogen reserves, an important issue because N.Z. cattle are raised and finished on pasture. Another difference between N.Z. and overseas experience is that the rate of rigor attainment is reportedly faster in other countries. N.Z. beef is often described as being dark in colour compared to overseas product, perhaps attributable to pH kinetics. While high pH is an obvious cause, anecdotal evidence suggests that meat from grain-finished cattle is lighter and redder even when pH is the same. Diet might be cause. Fat from pasture-finished cattle is yellower due to carotene accumulation, clearly a diet effect. Due to the high concentration of tocopherol in green leaf tissue (Aitken & Hankin, 1970) its concentration in pasture-finished meat is not a major concern, but neither has a direct comparison been made between two fundamentally different diet regimes.

Thus we compared the effects of two dietary regimes on glycogen reserves, indicators of stress, pH and temperature decline post-mortem, ultimate pH, lean meat and fat colour, and tocopherol concentration in lean meat to see which differences were caused by diet, and which by other factors.

Materials and Methods

Two groups of six Angus-cross steers were finished for nine weeks on ryegrass/clover (in spring) or a maize-based diet. All animals experienced substantial contact with humans in that period. Carcass weights were recorded at slaughter (non-penetrative stunning, throat cut, no electrical stimulation). Subcutaneous fat thickness was measured at the 13th rib. Blood was collected directly from the cut carotid artery. Plasma was analysed for creatine kinase activity (Szasz *et al.*, 1976) and lactate dehydrogenase activity. The carcasses were held at 5.5°C. Temperature and pH were monitored in the *longissimus dorsi et lumborum*, until the meat reached its ultimate pH. Subcutaneous fat was excised from the brisket region, and the colour measured through polyethylene film, in CIE colour space. The complete *longissimus dorsi* was excised at 22 hrs. The fat content of lean tissue was measured as was tocopherol concentration (Pfalzgraf & Stenhart, 1995). Lean meat colour was measured 48 hours after slaughter, and after one hour blooming. After measuring residual glycogen, free glucose and lactate, glycolytic potential was calculated, an estimate of the glycogen present at slaughter (Fabiansson & Reutersward, 1985). A *t*-test for significance was applied to the data for the two treatment groups of six.

Results

The most striking compositional difference in the two diets was for carbohydrate, over five-fold higher in the maize diet ($P < 0.001$). The liveweights of the two groups were the same at the start of the trial, but the cattle on ryegrass/clover performed better because of diet adjustment problems with maize; mean carcass weights were 309 and 275 kg, respectively ($P < 0.01$), differences reflected in intramuscular fatness (Table 1), and in subcutaneous fat thickness (11.3 *vs* 1.5 mm). In the carcass chiller, the temperature decline in *lumborum* was faster for the maize treatment ($P < 0.001$), while pH fall was numerically slower there, but not statistically significant.

Table 1. Selected meat quality data for *longissimus dorsi et lumborum* of steers finished on two diets.

Variable		Finishing diet: Ryegrass/clover	Finishing diet: Maize-based	Statistical significance
Lipid concn. in lean meat (% of fresh wt.)		4.13 ± 0.62¶	1.99 ± 0.63	***
Tocopherol concn. in lean meat (ppb of fresh wt)		3.66 ± 0.27	2.53 ± 0.59	**
Lean colour	L*	40.6 ± 0.69	41.5 ± 1.1	NS
	a*	10.6 ± 1.0	10.3 ± 1.3	NS
	b*	8.48 ± 0.6	8.33 ± 0.58	NS
Fat colour	L*	69.4 ± 1.3	73.4 ± 2.2	**
	a*	2.17 ± 1.6	0.14 ± 0.9	*
	b*	26.1 ± 2.7	23.1 ± 2.6	$P = 0.08$

¶ Values are means of six cattle ± standard deviations.

The tocopherol concentration in lean meat was higher for pasture-finished cattle. Fat from the pasture treatment was darker (L*), redder (a*) and marginally yellower (b*) than fat from the grain treatment. Thus, as short a time as nine weeks on a maize diet is sufficient to affect tocopherol concentration and fat colour. By contrast, meat colour was unaffected by diet treatment.

The plasma activities of creatine kinase and lactate dehydrogenase were higher in the pasture than the maize treatment, but the concentration of lactate was similar (Table 2). The correlation coefficient between the plasma enzyme activities was 0.78 ($P < 0.01$).

Table 2. Muscle enzyme activities and lactate concentration in plasma

Variable	Finishing diet: Ryegrass/clover	Finishing diet: Maize-based	Statistical significance
Creatine kinase activity (units/l)	439 ± 127¶	172 ± 39	**
Lactate dehydrogenase activity (units/l)	3030 ± 450	2160 ± 220	**
Lactate concentration (mmole/l)	8.99 ± 2.3	10.1 ± 2.4	NS

¶ Values are means ± standard deviations.

As expected from ultimate pH data, lactate concentration in meat was unaffected by diet treatment (Table 3). In contrast, free glucose and residual glycogen were higher in the maize treatment as was glycolytic potential ($P < 0.05$ for each).

Table 3. Meat ultimate pH and glycolytic potential in *longissimus dorsi et thoracicus*

Variable	Finishing diet		Statistical significance
	Ryegrass/clover	Maize-based	
Meat ultimate pH	5.66 ± 0.28¶	5.60 ± 0.07	NS
Lactate concn. (μmole/g fresh wt.)	69.0 ± 7.8	71.0 ± 2.5	NS
Free glucose concn. (μmole/g fresh wt.)	3.64 ± 1.3	5.88 ± 1.8	*
Residual glycogen (μmole lactate equiv./g fresh wt.)	2.37 ± 2.4	11.9 ± 8.4	*
Glycolytic potential (μmole lactate equiv./g fresh wt.)	81.1 ± 13	106 ± 22	*

¶ Values are means and standard deviations.

Discussion

Rigor attainment, as judged by the rate of pH fall, was statistically the same in both treatments, but numerically it occurred slightly more rapidly in the ryegrass/clover treatment, consistent with the significantly slower cooling in the larger, fatter animals that comprised that treatment. Therefore, the faster rate of pH fall reported in overseas studies cannot be attributed to dietary factors.

The ultimate pH in the *longissimus dorsi et thoracicus* muscle was unaffected by diet. Ultimate pH has marked effects on meat colour (Hood & Tarrant, 1981) but because the mean ultimate pH was unaffected by treatment, no colour effects due to pH were expected. Clearly then, diet as an independent variable had no effect on meat colour (Table 1), and reports of brighter red meat from grain-finished cattle must be due to other factors, perhaps breed and processing, or differences in storage and blooming time. Fat colour was, by contrast, strongly affected by diet, as cattle tend to accumulate carotene from green leaf tissue (Yang *et al.*, 1992). Since carotene is distinctly yellow, it was expected that the b^* value (yellowness) would be the most significantly affected colour parameter. This was not case, suggesting that other plant pigments, perhaps the xanthophylls, are also important in the characteristic colour of pasture-finished beef. Another factor affecting fat colour might be vascularisation (blood would increase a* values), but this was not measured in our study.

Although ultimate pH was the same in both treatments, there was a greater range of values in the ryegrass/clover treatment with one particularly high value (6.12), suggesting a lower and more variable concentration of muscle glycogen in pasture-finished animals at the time of slaughter. The glycolytic potential confirmed this. Values were significantly lower in the pasture-finished animals, which were, unexpectedly, better nourished than their grain-finished equivalents. Thus the difference in the glycolytic potential occurred in spite of reduced overall energy intake in the grain-finished animals. The difference is perhaps due to selective repartitioning of dietary energy towards increased muscle glycogen. Grain diets, which are rich in carbohydrate, have been shown to increase direct absorption of glucose (Nocek & Tamminga, 1991; Huntington *et al.*, 1996), as well as a shift in the proportions of the volatile fatty acids produced in the rumen, from less acetate to more propionate (Gross *et al.*, 1988). Such changes can modify the endocrine response to blood-borne nutrients (Harmon, 1992), particularly insulin, so altering the utilisation of dietary energy.

An alternative explanation is that muscle glycogen concentrations on-farm were equivalent between the two treatment groups, but that the physiological response of the pasture-finished animals to the pre-slaughter handling procedures resulted in greater glycogen depletion. Glycogen is depleted from muscle in response to physical exertions, particularly when the exertions are severe and in response to increased sympathetic activity consequent to excitation and stress (Apple *et al.*, 1994; McVeigh *et al.*, 1982). The conditions under which these experimental animals were slaughtered were not considered stressful, and all animals were accustomed to being handled during the trial. Nevertheless, there were significant differences in plasma creatine kinase and lactate dehydrogenase activities at slaughter. Their elevation identifies increased permeability of the muscle cell membrane, an effect caused primarily by muscular activity (Armstrong *et al.*, 1983). As such the activities have been used extensively as an index of stress (Warriss *et al.*, 1984). The half-life of the activities in plasma is typically hours (Volfinger *et al.*, 1994), so they are a marker of muscle damage accumulated over much of the pre-slaughter handling period. In contrast, blood lactate concentration represents a more direct measure of glycogen depletion in muscle, but the time course of the response is acute because of the rapid uptake of lactate, primarily in the liver. Therefore, the absence of a treatment effect for lactate in blood taken during post-slaughter bleeding does not represent a contradiction with conclusions drawn from the enzyme activities.

Why pasture-finished animals, accustomed as they were to frequent handling on-farm, should respond to preslaughter handling with a significantly higher level of muscle membrane permeability to intracellular enzymes can only be a matter of speculation.

Because the severity and duration of potential pre-slaughter stressors in this experiment were seemingly low, the most probable explanation for the difference in the glycolytic potential between treatments is the greater accumulation of muscle glycogen in the maize-finished animals. The implication for pasture-finishing systems is that while the initial level of glycogen is nominally sufficient to yield a normal ultimate pH, the amount available to buffer against stress-induced losses is marginal. The possibility that pasture-finished animals may be intrinsically disposed to an exaggerated glycogen-depletion response to pre-slaughter handling would act to compound the risk of elevated ultimate pH.

References

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