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Farm of origin and finishing environment effects on beef quality attributes

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ABSTRACT

An experiment was conducted to test the hypothesis that finishing environment can affect beef quality attributes, including fat and meat colour, meat pH, subcutaneous fat depth (FD) and intramuscular fat (IMF) content of pasture-fed beef. 181 rising 2-year old Angus steers were obtained from 4 source farms and finished at 4 North Island locations. On 3 properties, home-bred cattle were compared to a common control line. On a fourth property, cattle from the 3 sources were compared to each other and to the control. FD, meat pH and meat colour were affected by location ($P<0.01$), but not source. Only source effects were significant ($P<0.05$) for IMF. Both source and location affected fat colour ($P<0.01$). Steers that were killed later had significantly ($P<0.01$) higher meat pH ($r=0.33$), darker meat ($r=-0.24$), greater IMF ($r=0.26$), higher plasma carotene levels at slaughter ($r=0.38$) and yellower fat b* ($r=0.39$). The results indicate that both farm of origin and finishing environment can affect meat quality. Both sources of variation appeared to be mediated, in part, by cattle growth rate.

Keywords: cattle**;** beef quality; growth.

INTRODUCTION

The New Zealand beef industry is dependent upon the supply of commodity product to a very narrow market base, with 71% of the total beef and veal exports going to the North American market in the year ended September 1998 (Anon, 1999). Most of this product was manufacturing beef. Concern about reliance on a single market led to interest in alternative high value markets (eg Japan) during the early 1990's (Wright *et al*., 1997). These markets discriminate on the basis of fat colour, meat colour, meat pH and marbling.

It is possible to produce pasture-finished beef meeting these quality specifications (Muir *et al.*, 1998a, 1998b, 1998c). The main problem is variability of quality. Repeatability of supplier effects on meat quality attributes is low (Smith *et al.*, 1997) making it difficult to ensure consistent supply of product meeting quality specifications.

The importance of environmental effects on the quantity of meat produced is well documented (eg Everitt *et al.*, 1969). Environmental effects on meat quality may be equally large. One possible source of variability in beef in New Zealand may be the large amount of trading of cattle that occurs and finishing over a wide range of environmental conditions. Mobs of cattle drafted for slaughter by a producer may be fairly uniform with respect to liveweight, but diverse with respect to farm of origin, genetic background, early growth and development, and time required to finish. This variability in cattle history may contribute to variability in quality.

This paper reports the results of an experiment conducted to examine the relative contribution of farm of origin and finishing environment to variation in meat pH, meat and fat colour, intramuscular fat content and subcutaneous fat depth of Angus steers.

METHODS

The experiment was conducted over the period August 1995 to June 1996. Farms selected for the experiment were in a range of environments with widely different topography and climate. The three breeding properties involved in the experiment were near Taihape, Wairoa and Hastings. Each property provided 50 rising 2 year old Angus steers, weighing between 404 and 520 kg (average 456 kg). Of the 50 steers from each property, 10 were slaughtered initially to provide base data on meat quality and 20 were transported to a central finishing property in Hawkes Bay (control farm). The remaining 20 steers were kept on the farm of origin. An additional 70 Angus steers (control cattle group) were purchased from a single source by Richmond Ltd and an initial representative group of 10 steers were slaughtered. The remaining 60 were divided into 4 groups of 15 and distributed to the 3 breeding properties and to the central finishing property. On each property, all experimental cattle were farmed on pasture in a single mob.

Animals were weighed at approximately monthly intervals. The initial liveweight (LW_I) was estimated from the first weighing in September, 4 to 6 weeks after transportation of cattle to new properties. This weighing was selected to minimise any relocation effects (Holroyd and Haster, 1994). Initial rate of liveweight gain (LWG_I) at the start of the experiment was estimated from linear regression of liveweight on date over the period September to December 1995 (4 measurements). This period was selected because it allowed comparison of all cattle over a common period, prior to the first draft for slaughter. Cattle were drafted for slaughter to achieve target hot carcass weights (HCW) of 300 kg or more. With the exception of the final kills from each treatment, slaughter groups comprised 7 to 10 cattle. Days to slaughter (DAYS) was calculated as days from 1 September 1995.

Blood samples were collected from trial animals in

August 1995 and November 1995 and at the final weighing before slaughter. These were analysed for plasma carotene (PC) concentration by methods described in Knight *et al.*, 1994.

Carcass measurements were made in the Richmond Ltd Pacific plant near Hastings. Cattle were slaughtered by electrical stunning using 530 volts DC for 15 seconds and electrically stimulated for 9 seconds using 90 volts AC. Fat depth (FD) was measured at the 12th rib, over the 4th quarter of the *M. longissimus dorsi* (Kneebone *et al.*. 1950). Chroma measurements were made on chilled sides, 12 hours or more after slaughter, using a Minolta CR-300 Chromameter (8-mm diameter measuring area) and recorded as CIE L*a*b* tristimulus values (Rigg, 1987). Meat chroma was measured on ribeye muscle (*M. longissimus thoracis*) cut between rib 12 and 13, 30 minutes or more after cutting. Subcutaneous fat chroma was measured over the loin area. Three replicate scans of the chromameter were made for each tissue, with the measuring head moved to a new position for each scan. Samples of ribeye steaks from the 12th rib (approximately 100g) were freeze dried, ground to 2 mm, and chemical intramuscular fat (IMF) determined on duplicate samples by the Soxhlet method on a Decator Soxtec analyser.

Analysis of variance of treatment effects included main effects (source and location) but not their interaction. The interaction was excluded because imbalance in the experimental design precluded accurate estimation of main effects in models containing the interaction term. Preliminary analysis including the interaction term indicated significance of the Source x Location interaction for only one variable (fat L*). Associations between variables were estimated from the simple correlations and from partial correlations after adjusting for source and location differences. The latter were derived from the error sum of squares and cross-products matrix of multivariate analyses of variance of source and location effects on the dependent variables.

RESULTS

Means and standard deviations of the meat attributes that were measured in the trial are presented in Table 1. The most pronounced differences between the pre-trial sample and the trial groups (apart from HCW) were on fat attributes, with an increase in FD and IMF and a decline in fat L* values.

Pre-trial source effects

Analyses of variance of source effects on meat attributes indicate significant differences between sources in plasma carotene levels, fat depth, meat pH and colour of meat and fat. (Table 2). Adjustment for variation in HCW had little effect on the significance level of differences between sources. Variation in FD was correlated with variation in HCW. However, IMF showed no consistent association with HCW.

TABLE 1: Means and standard deviations of carcass and meat attributes measured in the experiment.

	Pre-trial Sample			Trial groups		
Variable	N	Mean	Std	N	Mean	Std
LW_I (kg)	40	456	±26	181	456	±26
LWG_I (kg/day)				181	1.08	±0.24
Average LWG to slaughter(kg/day)				181	0.63	±0.17
DAYS				181	225	±59
Final LW (kg)				181	614	±28
HCW (kg)	40	239	±16	181	324	±17
FD (mm)	40	3.4	±1.7	178	10.4	±3.0
IMF (%)	40	2.0	±0.9	176	5.0	±1.6
Meat pH	40	5.51	±0.09	180	5.52	±0.12
Meat chroma						
L*	40	35.9	±1.9	178	34.4	±2.1
a*	40	21.7	±1.4	178	21.3	±1.6
b*	40	11.0	±1.0	178	11.4	±1.2
Fat chroma						
L*	40	71.3	±4.0	178	63.9	±3.5
a*	40	5.6	±1.7	178	3.8	±1.4
b*	40	19.4	±2.5	178	19.6	±3.0
Plasma carotene at slaughter	39	9.4	±2.7	176	8.4	±2.6

TABLE 2: Analysis of variance of source effects on carcass and meat attributes at pre-trial slaughter (August 1995).

	Model 1: No covariate adjustment		Model 2: Adjusted for HCW		
Variable	Significance of Source effects	R^2	Significance of Source effects	Regression on HCW	R^2
PC Aug 95	**	0.29	**	ns	0.35
FD (mm)	***	0.44	***	0.028*	0.51
IMF (%)	ns	0.11	ns	ns	0.17
Meat pH	***	0.72	***	ns	0.72
Meat chroma					
L*	***	0.51	***	ns	0.51
a*	***	0.35	***	0.027*	0.44
b*	*	0.24	*	ns	0.31
Fat chroma					
L*	***	0.35	**	ns	0.40
a*	ns	0.14	*	-0.038*	0.25
b*	ns	0.17	ns	ns	0.20

ns=not significant at P<0.05; * =P<0.05, **P<0.01, ***=P<0.001.

Attributes of finished steers.

Analysis of variance of measurements made on finished steers indicate highly significant (P<0.001) source and location effects on rate of liveweight gain during the first four months of the trial and on the days required to reach target slaughter weights (Table 3). Cattle that were below average in LW at the start of the trial had slightly lower rates of LWG during the first four months (r = 0.15, P<0.05), lower average LWG from the start of the trial to slaughter (r=0.47, P<0.001) and hence took significantly longer to reach slaughter weight (r = -0.55, P<0.001). Source and location effects on LWG_I and DAYS remained highly significant after covariate adjustment for LW_I.

Source and location also had significant effects on carcass quality attributes. However, many of the source effects appeared to be mediated by HCW or DAYS or both. With the exception of PC at slaughter and fat L* value,

TABLE 3: Analysis of variance of source and location effects on carcass attributes of finished steers.

	Model 1: No covariate adjustments			Model 2: Adjusted for HCW and DAYS				
	Significance of:			Significance of:		Regression coefficients		
Variable	Source	Location	R^2	Source	Location	DAYS	HCW	R^2
LWG_I	***	***	0.62					
DAYS	***	***	0.50					
Plasma carotene								
Aug 95	***	ns	0.24					
Nov 95	**	***	0.29					
Slaughter	**	**	0.10	*	**	0.02***	ns	0.23
FD(mm)	ns	***	0.21	ns	*	ns	0.027*	0.23
IMF (%)	*	ns	0.09	ns	*	0.011***	ns	0.16
Meat pH	*	***	0.11	ns	ns	0.0004*	-0.0012**	0.18
Meat chroma								
L*	***	ns	0.12	ns	*	-0.008*	ns	0.17
a*	ns	**	0.08	ns	**	ns	0.015*	0.11
b*	*	**	0.11	ns	ns	ns	0.013*	0.13
Fat chroma								
L*	*	***	0.30	*	***	ns	ns	0.32
a*	ns	*	0.07	ns	*	ns	ns	0.09
b*	**	**	0.14	ns	***	0.023***	ns	0.26

ns=not significant at P<0.05; * =P<0.05, **P<0.01, ***=P<0.001.

source of cattle was not statistically significant after adjusting for HCW and DAYS. After these covariate adjustments, location had significant effects on plasma carotene levels at slaughter, FD, IMF and meat and fat chroma values. No direct effects of source or location on meat pH could be detected after adjustment for HCW and DAYS.

Cattle that took longer to reach target weight had higher levels of IMF (simple r=0.26, P<0.01). After adjusting for source and location effects, the partial correlation between IMF and DAYS was 0.28 (Table 4). As in the analysis of data from the pre-trial sample of steers (Table 2), IMF was not associated with HCW. In contrast to IMF, FD was weakly associated with HCW but was not related to DAYS (Table 4). No association between FD and IMF was evident.

TABLE 4: Partial correlations between carcass attributes, calculated after adjusting for source and location main effects (Correlations coefficients with P<0.05 are not shown.)

		Correlation with:					
Variable	DF	LW_I	LWG_I	DAYS	HCW	FD	IMF
FD (mm)	168				0.16*		
IMF (%)	168	-0.15*	-0.17*	0.28***			
Meat pH	167	-0.21*		0.20**	-0.22**		
Meat chroma							
L*	167	0.15*	0.17*	-0.20**	0.16*		0.16*
a*	167				0.16*		
b*	167				0.19*		
PC at slaughter	164	-0.29***	-0.23**	0.37***			0.23**
Fat chroma							
L*	167		0.22**			-0.31***	-0.16*
a*	167						-0.31***
b*	167	-0.20**	-0.26***	0.35***		-0.20**	0.20**

* =P<0.05, **P<0.01, ***=P<0.001.

Meat pH increased with increasing time to reach slaughter weight (simple r=0.33. P <0.001). A slightly weaker correlation was observed for the relationship between low LW_I and high pH (simple r= -0.28, P<0.001). . Meat pH decreased with increasing HCW (simple r=-0.22, P<0.01). These correlations remained significant after adjusting for treatment main effects (Table 4). A parallel trend was observed for meat L* values, with meat becoming darker with increasing DAYS (r=-0.24, P<0.01) but lighter with increasing HCW (r=0.16, P<0.05). Meat a* and b* values were positively associated with HCW (r=0.23 and 0.24, respectively, P<0.01).

Increased time to slaughter resulted in higher plasma carotene levels (simple r=0.38, P<0.001) and higher fat b* (r=0.39, P<0.001). These correlations remained significant after adjusting for treatment effects (Table 4). Within-treatment variation in PC levels was positively associated with variation in fat b* (Table 5). In addition, high PC levels were associated with low fat L*.

TABLE 5: Partial correlations of PC levels with subsequent measurements of PC and with fat chroma variables, calculated after adjusting for source and location main effects.

	Correlation with				
Variable	PC (df=160)		Fat chroma (df=158)		
	Nov	Slaughter	L*	a*	b*
PC Aug	0.52 ***	0.28 ****	-0.05 ns	-0.02 ns	0.32 ***
PC Nov		0.58 ***	-0.21 **	-0.01 ns	0.43 ***
PC Slaughter			-0.30 ***	0.14 ns	0.44 ***

ns=not significant at P<0.05; * =P<0.05, **P<0.01, ***=P<0.001.

FD and IMF were also associated with fat chroma (Table 4). Increasing FD was associated with lower fat L* and b* values, while increasing IMF was associated with a higher fat b* and lower fat a*. Some of the correlation between IMF and fat b* may be due to a joint dependency of both fat b* values and IMF on DAYS. After adjusting for DAYS, the partial correlation between fat b* and IMF was insignificant (r=0.11, P=0.15). However, after this covariate adjustment, the partial correlation between IMF and fat a* was still highly significant (r=-0.30, P<0.001).

DISCUSSION

Both farm of origin and finishing environment had highly significant effects on rate of liveweight gain. Differences between finishing environments probably relate mainly to differences in nutrition. Differences between farm of origin could stem from differences in genetic potential or in prior nutritional status (Everitt and Jury, 1977).

Although source and location effects on carcass attributes were statistically significant, they were small, and treatment effects could account for only a minor proportion of the total variation between cattle, with coefficients of determination in the range of 10 to 30%. Most of the variation was between animals in the same treatment. A similar conclusion was drawn from an earlier survey which estimated the repeatability of supplier effects on fat depth and meat and fat chroma as between 4 and 22% (Smith *et al.*, 1997).

Differences between cattle in carcass and meat attributes could be related, in part, to growth rate. In general, cattle that were below average weight at the start of the trial also had lower rates of weight gain. The combination of

lower start weights and lower growth rates resulted in some cattle not reaching target weights until about 6 months after the fastest growing cattle were slaughtered. Slow growing 'tailenders' had higher pH, darker meat and yellower fat colour at slaughter. However, cattle that took longer to finish did have slightly higher IMF and thus would be expected to have greater visual marbling.

Although fat depth was significantly associated with carcass weight, IMF was not, contrary to earlier reports (May *et al.*, 1992; Muir *et al.*, 1998c). Part of the reason for lack of association of HCW and IMF is probably the relatively narrow range of carcass weights (278 to 366 kg) in the present study. However, the nil association with HCW and the significant positive association with DAYS suggest that maturity effects were more important than weight effects.

Increase in meat pH with increasing cattle age has been reported previously (Smith *et al.* 1996). In the current study, an increase in pH was observed over a relatively narrow timeframe (190 days), with an estimated slope of 0.0004 pH units per day or about 0.01 pH units for each month delay in slaughter. Longer time to slaughter was due, in part, to lower LW_I. The significant negative association between LW_I and meat pH suggests that some of the effect of time on meat pH was related to factors affecting liveweight gain before the start of the trial. Increasing HCW was also associated with a small but significant decrease in meat pH, a result consistent with earlier studies (eg, Jones and Tong, 1989; Murray, 1989; Smith *et al.*, 1996). A parallel trend was observed for meat chroma values, with meat becoming brighter and more intensely coloured with increased HCW and brighter with decreased time to slaughter.

In the present study, the associations of DAYS and HCW with meat pH were of little practical significance and only 4 of the 181 cattle had pH in excess of the normal limit of 5.8. However, the results presented here suggests that, when other factors contribute to pre-slaughter stress, faster growing cattle will be less at risk of high pH dark cutting meat. Three possibilities could account for an association between growth rate and meat pH: (1) slow growing animals have lower muscle glycogen stores (2) slow growing animals utilise muscle glycogen stores differently to faster growing animals or (3) animals that are especially sensitive to stress grow more slowly. This last explanation is supported by work of Voisinet *et al*. (1997) showing that cattle that became agitated during routine handling had lower average weight gains than cattle with calm temperaments

Older cattle tend to have yellower fat (eg. Morgan and Everitt, 1969; Walker *et al.*, 1990). As with meat pH, fat b* was negatively associated with liveweight at the start of the trial, suggesting again that part of the effect of time to slaughter was related to prior growth and development. After adjusting for DAYS, cattle source effects on fat chroma values were insignificant, suggesting that farm of origin effects on fat colour were mediated by the potential of cattle to grow quickly.

Differences in fat colour due to finishing environments were partially related to differences in carotene levels in blood plasma samples collected in spring, with high levels of plasma carotene in spring leading to yellower fat at slaughter 3 to 7 months later. Although the correlations between plasma carotene concentration and fat b* values were only moderate (r=0.32 to 0.47), blood testing may be a useful tool for the early identification of cattle or lines of cattle that are likely to have unacceptably yellow fat.

Another factor that related to subcutaneous fat colour was fat depth, with thicker fat having less intense yellow pigmentation. These results are similar to an earlier analysis of a much larger (n=1701) dataset (Smith *et al.*, 1997). This association may be due simply to a dilution effect, with carotenoid pigments being less concentrated because of a faster rate of fat deposition. Because of the negative association of fat b* with time to slaughter, greater fat cover would have a beneficial effect on fat colour only when it is achieved quickly. Greater fat depth also reduced luminosity (L*) of subcutaneous fat. As in earlier results (Smith *et al.*, 1997) this association appeared to be stronger than the association between FD and fat b*. Although Seiner *et al.* (1992) indicated that L* has no relationship with fat colour, calibration of chromometer data against visual fat colour scores (D R Smith, unpublished data) has indicated that fat with lower L* values have higher (poorer) fat colour scores ($r=-0.45$, $n=1485$, $P<0.001$). Thus, the overall effect of increased fat depth could be poorer fat colour.

The results of this study indicate that both farm of origin and finishing environment affect meat quality attributes. The main source of variation, however, was within-treatment, ie, between cattle in the same mob. Within- and between-treatment variation in meat quality was associated with rate of liveweight gain, with "tail-end' cattle having the poorest quality. The significant correlations between quality attributes and liveweight at the start of the experiment suggest that some of the variation in meat quality was conditioned by within-line variation in growth and development prior to the finishing period. Improvement in the consistency of quality of pasture finished beef for specific markets may require greater attention to the factors affecting variability in growth during early development as well as during the finishing period.

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