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Marbling produced in yearling heifers of Angus origin finished over a medium-term period on a high energy pasture

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ABSTRACT

This study provides baseline information on the level of marbling that can be produced from yearling heifers of Angus origin when finished over a medium-term, 169 day, period on a high energy pasture. Two groups of heifers were tested, which included 30 Angus x Jersey heifers and 26 straight-bred and cross-bred (mainly Hereford x and Friesian x) Angus heifers. The daily live weight gain of the heifers during finishing averaged 788 g/d and did not differ between the two groups of heifers studied ($P > 0.05$). At slaughter, the carcass weights of the Angus x Jersey heifers were lighter than the group of straight-bred and cross-bred Angus heifers ($P < 0.05$). Nevertheless, both groups produced average striploin marbling scores of 2 on the Japanese Meat Grading Association 12 point scale ($P > 0.05$), with 39% of the cattle achieving scores ≥2. The high level of variability in marbling across both groups of heifers indicated that the average level of marbling achieved could be further improved by using some predictor of marbling performance to select animals to be finished in the pasture-based system. All of the heifers produced very tender beef with average shear force values <5 kg F.

Key words: heifers; pasture-based; high growth rate; marbling, tenderness.

INTRODUCTION

Marbling, visible intramuscular fat depots, is considered to be the only visual meat trait that gives any repeatable guide to eating quality (Price, 2004). Consequently, in many New Zealand beef export markets such as Japan, Korea, and United States premiums are paid for marbled beef and this trait forms an important part of their beef grading schemes (Hocquette *et al*., 2009). As New Zealand pasture-based systems are not traditionally associated with producing marbled meat, most New Zealand beef exported into these markets targets lower value segments where marbling is not required. However, many affluent overseas consumers now also want more "natural" beef, originating from farm systems similar to New Zealand's, with low chemical inputs such as from antibiotics, and high animal welfare, health, and environmental standards (MAF, 2009). From a human health perspective, pasture-based beef has an added advantage in its more favourable fatty acid profile and greater antioxidant concentration compared to grain-based beef from feedlot systems; the latter being the primary source for marbled beef (Dunne *et al*., 2009).

Marbling is affected by the slaughter age, breed, sex, and growth rate of the animal (Dubeski *et al*., 1997a). Intramuscular fat increases with age, with earlier maturing cattle breeds such as Angus, Wagyu, and Jersey depositing intramuscular fat earlier than later maturing breeds (Koch *et al*., 1976; Malau-Aduli *et al*., 2000; Bindon, 2001). For a given weight and time on feed, females have a higher marbling potential than males (Harper & Pethick, 2004). Grain finishing has also been shown to have consistent beneficial effects on marbling compared with pasture finishing (Bindon, 2001), presumably because of the difficulties in achieving similar levels of growth and finish in pasture-fed cattle (Muir *et al*., 1998b). However, when pasture- and grain-finished beef is compared at similar carcass weights or the same degree of fatness, the type of feeding system has no effect *per se* on marbling (Muir *et al*., 1998a; Steen *et al*., 2003).

This study investigated whether lightly marbled beef could be produced from a typical New Zealand pasture-based system as a potential niche product, combing the desirable characteristics of both pasture- and grain-based finishing systems into one. It was hypothesised that lightly marbled beef, with a marbling score of 2 to 3 on the Japanese Meat Grading Association 12 point scale of 1 = None to 12 = Extreme, could be achieved if cattle with high marbling potential were finished on a high energy pasture, which in turn would ensure sufficient growth rates for the animals to deposit intramuscular fat. Animal growth performance, carcass composition, Japanese grading and meat quality were measured in this study.

MATERIALS AND METHODS

Animals

Fifty-six yearling heifers were used in the study. The heifers were sourced from two commercial farms and consisted of a group of 30 Angus x Jersey heifers and a group of 26 straight-bred and cross-bred, mainly Angus x Hereford and Angus x Friesian (Angus/Angus-cross) heifers. The Angus x Jersey heifers were included in the study because they are a small framed genotype that should reach a mature size earlier than larger breeds, thereby creating greater opportunity for them to lay down extra adipose tissue before slaughter. In contrast, the Angus/Angus-cross heifers were included in the study as more typical cattle genotypes used in New Zealand heifer finishing systems. The heifers were approximately 15-months-old at the start of finishing and their initial live weights were 298 ± 3 kg (mean ± standard error) and 351 ± 4 kg, respectively.

Finishing

The heifers were finished for 169 days over summer and autumn between December 2008 and June 2009, on a commercial sheep and beef farm in Kaiwera, Gore (Southland) to emulate a typical New Zealand heifer finishing system aiming to slaughter the cattle prior to their second winter. Throughout this period the heifers grazed a newly sown mixed-species pasture selected for its high nutritional value and metabolisable energy (ME) content (>11 MJ ME/kg dry matter (DM)) that had been sown in October 2008. The pasture contained Italian ryegrass (*Lolium multiflorum,* 'Grasslands Moata'), white clover (*Trifolium repens,* 'Grasslands Kopu II'), red clover (*Trifolium pratense,* 'Grasslands Hamua') and chicory (*Cichorium intybus,* 'Grasslands Choice') sown at a rate of 25, 2, 3, and 1.5 kg/ha, respectively. The heifers were rotationally grazed together as a single mob with paddock shifts occurring at approximately weekly intervals. Post-grazing residual pasture heights were ≥8 cm and no supplements were fed to the heifers over the entire finishing period. Additional cattle were brought onto the finishing block to help maintain pasture quality when required.

On farm measurements

Pre- and post-grazing pasture heights were measured with a sward stick each time the heifers were moved into a new paddock. A bulked pre-grazing herbage sample was also hand-plucked to grazing height along a paddock transect to determine the nutritive value of the herbage offered to the heifers. The samples were dried at 65°C to a constant weight, ground using a 1 mm sieve size, and analysed for their nutritive value by near infrared reflectance spectroscopy (Corson *et al*., 1999). Heifer live weight was measured at the start of the trial and then every three weeks during finishing.

Slaughter process, carcass grading and meat sampling

The heifers were slaughtered at Canterbury Meat Packers Ltd., Ashburton, using their standard slaughter, electrical stimulation and chilling procedures. Hot carcass weight and fat depth was measured by Canterbury Meat Packers Ltd. staff. The day after slaughter, the carcasses were split between the 12th and 13th rib and a Japanese grader visually scored each carcass for marbling in the *M. longissimus dorsi et lumborum* (striploin), fat colour, meat colour and firmness/texture (Japan Meat Grading Association, 1988). Marbling and loin area were also assessed using a camera system specifically developed for Five Star Beef Ltd. that has been calibrated against the Japanese grading system. The pH was measured in the striploin using a Mettler Toledo pH meter with a combination electrode (Mettler Toledo Inlab 427; Mettler Toledo Inc, Columbus, Ohio, USA). A 25 cm striploin sample was removed from the carcass, vacuum-packed and stored at 2 to 4°C until 9 days *post mortem* when two, five-cm-long, and one, one-cm-long, samples were taken for shear force analysis at 9 and 28 days *post mortem*, and chemical analysis of the intramuscular fat content, respectively. The samples were vacuum-packaged and either frozen immediately for the "9 days" shear force and intramuscular fat samples, or stored at -1.5°C until 28 days *post mortem*, when the "28 days" shear force sample was frozen.

Meat quality

The striploin samples for shear force analysis were cooked from frozen in a 100°C water bath until an internal temperature of 75°C, measured with a thermocouple, was reached. The cooked sample was immediately placed in an ice-water slurry and when cool, ten 10 mm x 10 mm cross-section subsamples were sheared using a MIRINZ tenderometer (Macfarlane & Marer, 1966). Intramuscular fat was measured by Soxhlet solvent extraction and gravimetric measurement of extracted fat weight (AOAC, 2006).

Statistical analysis

Initial heifer live weight, final slaughter weight, average daily liveweight gain, and beef carcass and meat quality characteristics were compared between the two groups of heifers using single factor analysis of variance in GenStat (Payne *et al*., 2008). Initial heifer live weight, final slaughter weight, carcass weight and ultimate pH were tested as covariates where appropriate, but were only retained in the models if significant ($P < 0.05$). Based on a test for discordancy of a single outlier in a normal sample, one Angus x Jersey heifer was removed from the analyses of variance because it had an excessively high ultimate pH of 5.98 ($P < 0.05$). The pattern of live weight change of the two groups of heifers over

TABLE 1: Nutritive value of pasture available to heifers during finishing period. DM = Dry matter.

Component	Mean ± Standard error of mean
Crude protein (g/100g DM)	27.1 ± 1.4
Neutral detergent fibre (g/100g DM)	41.1 ± 0.9
Lipid (g/100g DM)	2.5 ± 0.1
Soluble sugars and structural carbohydrates (g/100g DM)	13.1 ± 0.7
Organic matter digestibility (g/100g DM)	84.0 ± 0.1
Metabolisable energy (MJ/kg DM)	12.5 ± 0.1

time was analysed using a residual maximum likelihood (REML) approach with splines and time contrasts within ANOVA. The underlying assumptions of the models were checked through inspection of scatter, residual and normal probability plots, along with the use of the Shapiro-Wilk test for normality. Homogeneity of variance in marbling between the two groups of heifers was tested using the Bartlett's Test.

TABLE 2: Heifer carcass and loin characteristics (mean ± standard error). Dressing out % based on hot carcass weight.

Measurement	Breed type		P value
	Angus x Jersey	Angus/Angus-cross	
Number of animals	30	26	
Carcass weight (kg)	208 ± 3	255 ± 4	<0.001
Dressing-out %	51.4 ± 0.5	56.7 ± 0.7	<0.001
Canterbury Meat Packer's fat score (Unadjusted)	5.4 ± 0.1	6.3 ± 0.4	0.055
Canterbury Meat Packer's fat score (Adjusted for carcass weight)	5.8 ± 0.3	5.8 ± 0.4	0.966
Five Star Beef camera			
Marbling	1.9 ± 0.1	1.9 ± 0.1	0.813
Loin area (cm^2) (Unadjusted)	45.7 ± 1.2	50.2 ± 1.2	0.007
Loin area (cm^2) (Adjusted for carcass weight)	46.9 ± 1.3	48.7 ± 1.5	0.451
Japanese meat quality grading score[a]			
Marbling	2.2 ± 0.1	2.1 ± 0.1	0.406
Fat colour	4.8 ± 0.1	4.2 ± 0.1	<0.001
Meat colour	3.2 ± 0.1	3.2 ± 0.1	0.729
Firmness and texture	2.6 ± 0.1	2.4 ± 0.1	0.275
Intramuscular fat (%)	4.9 ± 0.4	4.8 ± 0.4	0.808
$pH_{24\,h}$	5.62 ± 0.02	5.56 ± 0.02	0.028
Shear force (kg F)			
Day 9	4.2 ± 0.1	4.9 ± 0.3	0.049
Day 28	4.0 ± 0.1	4.2 ± 0.2	0.397

[a]Japan Meat Grading Association standards (Dubeski *et al*., 1997b):
Marbling: 1 (None) to 12 (Extreme). Optimum between 8 and 12.
Fat colour: 1 (Brilliant white) to 7 (Beige). Optimum between 1 and 4.
Meat colour: 1 (Pale) to 7 (Dark red). Optimum between 3 and 5.
Firmness/Texture: 1 (Inferior / Coarse) to 5 (Very good / Very fine). Optimum is 5.

RESULTS AND DISCUSSION

Characteristics of pasture offered to heifers

Pre- and post-grazing pasture heights were 17 ± 1.1 cm and 11 ± 1.5 cm, respectively. Based on previous rotational grazing studies, primarily using perennial ryegrass/white clover swards, the post-grazing pasture height was within the critical 9 to 12 cm range needed to maintain herbage intake and live weight gain of the heifers close to their maximum (Hodgson & Brookes, 1999). The pasture offered to the heifers was also of a high quality with a ME content similar to some grain-based feedlot rations (Table 1) (Muir *et al*., 1998b). The herbage was highly digestible with an organic matter digestibility >80% and contained a high crude protein content (Table 1). The neutral detergent fibre content was within the range generally found in good quality pasture (Waghorn & Clark, 2004). Post-grazing pasture heights and herbage nutritional values remained relatively constant over the entire finishing period with coefficients of variation <20% (J.A. Archer, Unpublished data).

Finishing

The average daily liveweight gain of the Angus x Jersey and Angus/Angus-cross heifers was 792 ± 19 g/day and 783 ± 28 g/day, respectively, and did not differ significantly between the two groups of cattle (P >0.05). These average daily liveweight gains were similar to previously reported high heifer growth rates achieved on ryegrass-based pastures (Steen *et al*., 2003; Hickson *et al*., 2009), but were generally lower than average daily liveweight gains reported for grain-based finishing systems (Lunt & Orme, 1987; Dubeski *et al*., 1997a). The average daily liveweight gain of both groups of cattle did not change over time (P >0.05), indicating that the heifers were consistently being fed a high plane of nutrition throughout the 169 day finishing period. The slaughter weight of the Angus x Jersey heifers was lower than for the Angus/Angus-cross heifers (433 ± 4 kg versus 487 ± 6 kg, P <0.001), mirroring initial differences in live weight between the two groups of cattle at the start of the finishing period.

Carcass grading

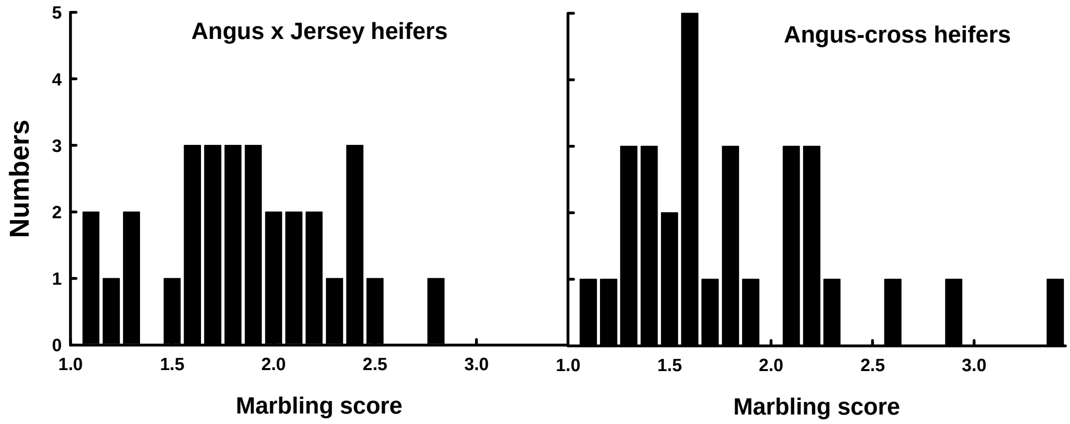
The Angus/Angus-cross heifers had a greater carcass weight, loin area, and Canterbury Meat Packers Ltd. fat score compared to the Angus x Jersey heifers (Table 2). The difference in carcass weight reflected the latter group's lower live weight at slaughter and lower dressing out percentage (Table 2). The difference in loin area and Canterbury Meat Packers Ltd. Fat score between the two groups of heifers was not significant when adjusted to a common carcass weight ($P > 0.05$). Carcass weights of the Angus x Jersey heifers ranged from 187 kg to 236 kg, which would be considered too light for Japanese export market specifications (Bindon, 2004). In contrast, the carcass weights of the Angus/Angus-cross heifers ranged from 221 kg to 285 kg with over 70% of these carcasses being heavier than the 240 kg threshold required for the Japanese grain-fed yearling market.

The amount of marbling in the striploin was similar in the two groups of heifers when scored using the Japanese grading scheme and measured with the Five Star Beef Camera (Table 2). The average Japan Meat Grading Association marbling score was 2.2 ± 0.1, which is comparable to marbling scores achieved in Australian grain-based feedlot systems when cattle are finished over similar medium-term periods of time of around 150 days, to Japanese B2 market specifications (Bindon, 2004). However, there was considerable variability in the marbling score achieved in the pasture-based system that was used, with only 22 out of 56 heifers (39%) having marbling scores ≥2 (Figure 1). The variation in marbling scores did not differ between the two groups of heifers ($P > 0.05$). In the future using some predictor of marbling performance such as gene markers, ultrasound scanning, or information on the herd's previous performance, it may be possible to select cattle for finishing to increase their marbling scores with less within group variation.

Intramuscular fat was also similar in the two heifer groups (Table 2) and was above the minimum level (3%) required to achieve acceptable consumer satisfaction with beef shown in an American study (Savell & Cross, 1988). Muir *et al.* (1998b) measured equivalent levels of about 5% intramuscular fat in 36 to 40 month-old Angus steers that had carcass weights of 340 kg after being intensively finished on spring ryegrass-based pastures for six weeks. The relationship between carcass weight and intramuscular fat content of the striploin is sigmoidal in nature, with intramuscular fat only increasing significantly once a carcass is greater than about 200 kg (Muir *et al.*, 1998c; Pethick *et al.*, 2004). Therefore, it is likely that greater levels of marbling and intramuscular fat would have been achieved if the heifers grew to a higher level of finish. The lighter carcass weights of the Angus x Jersey heifers may also have inhibited the higher marbling potential of this smaller framed genotype to be fully realised in comparison to the heavier and larger framed Angus/Angus-cross heifers. Potential options for increasing carcass weight and thus intramuscular fat and marbling from the pasture-based finishing system used would be to graze the heifers for a further period on high quality winter pastures and/or crops or, if the heifers were not to be carried over winter, to either start the heifers on the high quality pastures earlier as weaners or to source heavier yearlings.

The Japan Meat Grading Association fat colour scores where 1 = White to 7 = Beige, were significantly higher in the Angus x Jersey heifers compared to the Angus/Angus-cross heifers, indicating that the former group of cattle had more yellow fat (Table 2). Yellow fat is caused by the ingestion of high levels of carotenoids in pasture. This trait reduces the acceptability of pasture-based beef in high value markets such as Japan (Boom &

FIGURE 1: Variation in striploin marbling score measured with Five Star beef camera calibrated against the Japan Meat Grading Association 12-point scale, where 1 = None and 12 = Extreme marbling.



Sheath, 1997). It was expected that the Angus x Jersey heifers would be downgraded to cull cows due to their low carcass weights or the yellow fat that is associated with the Jersey breed (Barton & Pleasants, 1993). Nevertheless, only one Angus x Jersey heifer was downgraded and this was for alternative reasons related to it having an ultimate pH above 5.8. Potentially the high rate of liveweight gain and fat deposition of the heifers could have diluted the concentration of carotenoids accumulated in their fat, resulting in an acceptable fat colour (Knight *et al*., 2001).

According to the Japan Meat Grading Association (2008) grading system, there were no differences in average meat colour or firmness and texture scores between the two groups of heifers (Table 2). The overall meat quality grade given in the Japanese system is based on the lowest score out of the four meat quality attributes measured (Strong, 2004). Thus, while the firmness and texture grades of 2.5 where 1 = Inferior/coarse to 5 = Very good/Very fine, would be acceptable for B2 market specifications, it, along with the amount of marbling, would need further improvement if even more valuable markets such as the Japanese B3 market were to be targeted.

Meat quality

The ultimate pH value of the striploin was marginally higher in the Angus x Jersey heifers compared to the Angus/Angus-cross heifers (Table 2). Ultimate pH is known to affect meat tenderness between a pH range of 5.8 to 6.2 (Pulford *et al*., 2008). Although the ultimate pH was significantly higher in the Angus x Jersey heifers ($P < 0.05$), it was still well below the threshold value for intermediate pH meat and unlikely to have affected tenderness measured as shear force. At Day 9 *post mortem* the Angus/Angus-cross heifers had significantly higher shear force values than the Angus x Jersey heifers. However, the difference between the two groups of heifers was again small at 0.7 kgF and had disappeared by Day 28 (Table 2). Both groups of heifers would qualify for the New Zealand Quality Mark (Frazer, 1997). This requires beef to have an ultimate pH of ≤ 5.8 and a mean shear force of ≤ 8 kgF, while 95% of the samples should also have a shear force <11 kgF at the point of retail sale. With shear force levels below 5 kgF on both measurement days, the striploin would be considered to be very tender (Bickerstaffe *et al*., 2001).

CONCLUSION

This study provides baseline information on carcass and meat quality characteristics that can be achieved when yearling heifers of Angus origin are finished over a medium-term period on a high energy pasture. Light marbling as assessed by a Japanese marbling score of ≥ 2 was produced in 22 out of 56 heifers (39%), demonstrating that lightly-marbled beef can be produced from such a pasture-based system. Japanese meat grading scores for meat colour, fat colour, and firmness and texture also indicated that the meat quality of the lightly-marbled heifers would meet Japanese B2 market specifications. However, the carcass weights of the Angus x Jersey cross heifers were too light for this export market. The lighter carcass weights of the Angus x Jersey heifers may have inhibited the higher marbling potential of this smaller framed genotype to be fully realised in comparison to the heavier and larger framed Angus/Angus-cross heifers. The high level of variability in marbling across both groups of heifers indicated that the average level of marbling achieved could be further improved through using some preditor of marbling performace to selected animals finished in the pasture-based system.

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