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Muscle glycogen and blood parameters in genetic strains of Angus cattle

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ABSTRACT

Angus selection and control herds in two long-term breeding studies were compared for muscle glycogen and blood parameters pre-slaughter. Trial 1 involved 3 years of bulls (n=85) from a yearling-weight (W) selection herd and a control (C1) herd, differing by 19% in yearling weight. Trial 2 involved one year of steers (n=45) from an experiment to increase age at puberty (A+ herd) or to reduce age at puberty (A- herd), relative to a control (C2) herd, with age at puberty differing from the C2 mean by 11% (A+) and -10% (A-). In Trial 1, muscle biopsies were taken for glycogen assay (Years 1 and 2), and blood samples were taken (Years 1-3) for creatine kinase, cortisol, lactate, non-esterified fatty acids (NEFA) and glucose; animals in Trial 2 (Year 2 only) were sampled at the same time as Trial 1. Samples were taken at 17 months of age (Year 1), 10 and 19 months (Year 2), and 19 and 20 months (Year 3, with an extra blood trait added). Muscle glycogen concentration was 19% higher in the W than C1 herd ($P<0.05$), and it was significantly lower in the A+ herd than in the other two herds ($P<0.001$). Cortisol ($P<0.05$) and glucose concentrations ($P<0.01$) were lower in the W than the C1 herd; NEFA was higher in the C2 herd than in the A- or A+ herds ($P<0.05$). No other blood parameters differed between herds. Repeatabilities for the 5 main blood traits in Trial 1 ranged from 0.14 to 0.38, being highest for creatine kinase (if excluding outliers), but repeatabilities were all low in Trial 2 (highest value only 0.13). The main conclusions came from Trial 1, in which most data had been collected, namely that across-year differences were found for 3 traits between herds (muscle glycogen, cortisol and glucose).

Keywords: muscle glycogen; metabolites; enzymes; cattle; genetics.

INTRODUCTION

Muscle glycogen concentration at time of slaughter influences ultimate pH of meat (Tarrant, 1989), which in turn influences meat quality and functional properties (Devine, 1994). Stress arising from reactions to pre-slaughter handling can deplete muscle glycogen, particularly in bulls, and lead to effects on meat pH (Tarrant, 1989). A New Zealand survey suggested that breed of beef animal affected meat pH, although a more detailed study found that neither muscle glycogen concentration nor pH was different in Angus, Simmental cross and Friesian steers (Webby *et al.*, 1999). Sanz *et al.* (1996) found that although breed of beef bull (Brown Swiss vs. Pirenaico) was known to affect temperament there was no difference in muscle glycogen concentration or meat pH of either unstressed or stressed bulls of these breeds. Subsequently Voisinet *et al.* (1997) reported that cattle with the most excitable temperament produced a higher incidence of "borderline dark cutters" (carcasses with elevated meat pH); temperament did not differ on average across breeds (Braford, Red Brangus and Simbrah), but it did vary within breeds.

In the present work we examined the influence of genetic lines within the Angus breed on muscle glycogen concentration. We also measured three blood metabolites that are implicated in glycolysis/glycogenesis and two indicators of reaction to handling stress (cortisol and creatine kinase). Animals were from two long-term breeding trials, one involving yearling-weight selection (Trial 1) and the other age-at-puberty selection (Trial 2).

MATERIALS AND METHODS

Trial 1 animals

Selection had been applied to industry-sourced Angus cattle (Baker *et al.*, 1986) to increase yearling weight in one herd (W), alongside an unselected control (C1) herd (Baker *et al.*, 1991). Bulls from the calf crops born in September/early October 1995, 1996 and 1997 were used in the present study (Table 1). Weaned calves were grazed on ryegrass-white clover pasture at AgResearch's Tokanui Station near Te Awamutu, with minimal hay or silage supplements in winter. All bulls were grazed together until slaughter at about 20 months of age in May 1997, 1998 or 1999 (Years 1 – 3). Bulls in each year were all slaughtered on one day. Average live weight of W animals pre-slaughter was 17±2% greater than that of C1 animals (479 vs. 408 kg, $P<0.001$).

Trial 2 animals

Genetic selection had been carried out since 1984 in Angus cattle to produce an "Age Minus" herd (A-) in which heifers were selected for reduced age at first behavioural oestrus (AFO) and an "Age Plus" herd (A+) in which heifers were selected for increased AFO, alongside a control herd (C2) in which no intentional selection was applied (Morris *et al.*, 1993; Morris and Wilson, 1997). The A+ and A- herds had diverged from the C2 herd by +11% and -10% AFO respectively by the mid-1990s (Morris and Wilson, 1997). Steers from the C2, A+ and A- selection herds at Tokanui Station, used in the present study, were slaughtered together in May 1998 (Year 2, relative to Trial 1), at an average of 20 months of age. Grazing management was as

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described for Trial 1. Pre-slaughter live weight overall averaged 452 kg, and there was no significant live weight difference (P>0.05) amongst herds.

TABLE 1: Summary of samples taken from the Weight-selected and Control herds in Trial 1 and the Age-at-Puberty-selected and Control herds in Trial 2.

Sample	Time of slaughter (May)		
	1997	1998	1999
Year of birth (average date, Sept)	1995	1996	1997
Number of Trial 1 bulls	30	25	30
Number of Trial 2 steers	-	45	-
Biopsy, year before slaughter	-	July	-
year of slaughter	Feb.	April	-
Plasma[1] (at same times as biopsies)			
5 metabolites/hormones	✓	✓	✓[3]
GGT	-	-	✓

[1] Except 1999 where serum was used; GGT = gamma glutamyltransferase.
[2] Creatine kinase, cortisol, lactate, non-esterified fatty acids, glucose.
[3] 5 weeks and also 3 days before slaughter in 1999.

Live-animal measurements

Sampling protocols for cattle in Trials 1 or 2 are summarised in Table 1. A 300 mg biopsy sample was extracted under local anaesthetic from the *M. longissimus dorsi* muscle, frozen, and subsequently analysed for glycogen concentration (Lambert *et al.*, 2000). Age at biopsy averaged 17 months (Year 1), and 10 and 19 months (Year 2, both Trials). Blood samples were taken at the same time as biopsies, and plasma non-esterified fatty acid (NEFA), glucose, lactate, creatine kinase (CK) and cortisol concentrations were subsequently determined (Lambert *et al.*, 2000). Blood samples were also taken at 19 and 20 months of age in Year 3 and the same 5 constituents in serum were determined. Serum gamma-glutamyltransferase (GGT) was also measured in Year 3 because of evidence of symptoms of facial eczema, in spite of prophylactic treatment with zinc salts.

Statistical methods

Selection-herd contrasts within trial were analysed using the SAS (1995) statistical package, fitting effects for herd, age of dam and year of birth. For Years 2 and 3, within-year repeatabilities (r) were estimated for muscle glycogen and the blood traits.

RESULTS

Trial 1

Muscle glycogen concentrations (Table 2) in the W herd averaged 19% higher than in the C1 herd (P<0.05), with glucose 7% lower (P<0.01) and cortisol 20% lower (P<0.05). The residual correlation between glycogen and glucose was -0.48, and the sign was consistent with the herd-mean differences for these two metabolites. There was no significant difference between herds in GGT concentration (Year 3), and only three animals were seriously affected with facial eczema. Overall, GGT (including the three affected) was correlated with glucose in April (-0.55) and May (-0.44), and with lactate in April (-0.35).

TABLE 2: Herd differences and repeatability (9-month interval, Year 2; 4-week interval, Year 3), for muscle glycogen and blood sample data from bulls in the Weight-selected (W) and Control (C1) herds.

Variable		Years of data	W herd	C1 herd	s.e.d.	Repeatability
Muscle glycogen	mg/g	2	18.6	15.6	1.2*	0.00
Blood Sample Data						
Creatine kinase	i.u./l	3[1]	317	230	84	-
		3[2]	147	153	10	0.38*
Cortisol	mg/l	3	15.6	19.4	1.9*	-
Lactate	mmol/l	3	2.70	2.94	0.21	0.14
Non-esterified fatty acids	mmol/l	3	0.31	0.31	0.03	0.25
Glucose	mmol/l	3	4.26	4.57	0.09**	0.30*
Gamma-glutamyl transferase[3]	i.u./l	1	15.5	16.4	1.8	-

[1] Includes 19 outliers >370 i.u./l (8(11%) in W herd, 11(15%) in C1 herd).
[2] Excludes 19 outliers.
[3] Excludes 3 outliers >30 i.u./l (2(13%) in W herd, 1(7%) in C1 herd).
*, P<0.05; **, P<0.01.

Repeatability (r, Table 2) ranged from 0.14 to 0.38 for the blood traits over Years 2 and 3 combined (significant if >0.27). For creatine kinase, r was 0.38 after removal of outliers (defined by Alpha Scientific Ltd (Hamilton) as those >370 i.u./litre). In spite of there being a consistent herd difference on each sampling occasion, muscle glycogen had a zero repeatability, based on a 9-month interval between biopsies.

Trial 2

Mean muscle glycogen concentration was lower in the A+ than the A- or C2 herds, and plasma NEFA concentration was lower in both the A+ and A- herds compared with the C2 animals (Table 3). Repeatabilities over a 9-month interval were all very low (0.00 to 0.13) and not significant.

TABLE 3: Herd differences and repeatability (9-month interval), for muscle glycogen and blood sample data from steers in the herds selected for reduced (A-) or increased (A+) age at puberty or in the Control (C2) herd.

Variable		A- herd	C2	A+ herd	Average s.e.d.	Repeatability
Muscle glycogen	mg/g	21.4	22.2	18.7	0.9***	0.00
Blood Sample Data						
Creatine kinase	i.u./l[1]	217	209	254	102	-
	i.u./l[2]	106	138	121	16	0.07
Cortisol	mg/l	15.3	12.4	10.9	3.2	-
Lactate	mmol/l	1.47	1.40	1.12	0.22	0.13
Non-esterified fatty acids	mmol/l	0.28	0.35	0.28	0.03*	0.13
Glucose	mmol/l	4.59	4.35	4.52	0.12	0.00

[1] Includes 10 (11%) outliers > 370 i.u./l.
[2] Excludes outliers
*, P<0.05; ***, P<0.001.

DISCUSSION

The higher muscle glycogen in the W than the C1 herd could have been directly linked to the genetic constitutions of the 2 groups, as a result of genetic selection, or the effect could have been indirect through live weight. Other recent work (Lambert *et al.*, unpublished data) also suggests that, for animals of similar age, there is a positive relationship between live weight at slaughter and muscle glycogen concentration. However the difference in glycogen concentration between A+ animals and A- and C2 animals, which was of similar magnitude to that between W and C1 animals, could not be explained on that basis because those herds were of similar live weight at slaughter. The higher muscle glycogen in the W herd was accompanied by a lower plasma glucose concentration, but in Trial 2 this did not happen. The lack of repeatability of individual animal glycogen concentrations over 9 months suggests that other dominant factors also influence concentrations at any specific time.

In addition to the higher muscle glycogen concentration found in the W herd in this study, we have also reported reduced shear force (increased tenderness) of meat from this herd (Morris *et al.*,1998). In the 1998 study, the shear force of *M. longissimus dorsi* samples stored at -1˚C after rigor mortis averaged 8.2% less in the W than C1 herds at 1 day after slaughter ($P<0.05$), and corresponding values for the W herd, relative to the C1 herd, were 15.9% less ($P<0.05$) and 9.5% less ($P<0.10$) at days 3 and 7 respectively. The underlying reasons for this between-herd relationship of muscle glycogen with shear force, however, are not clear.

The higher cortisol levels in the C1 herd could result from a tendency for C1 animals to be stressed more by the yarding/sampling procedures used than W animals. However, the differences were also consistent with the negative phenotypic relationship between cortisol and live weight reported for cattle and sheep by Purchas *et al.* (1980), and this may have been the underlying reason for them. The only other notable effect on blood traits in the selection lines was the elevated NEFA levels in the C2 herd, for which we presently have no explanation.

CONCLUSIONS

There was a consistent difference (Trial 1) in muscle glycogen, blood cortisol and glucose concentrations across years. This suggests that they were all directly or indirectly associated with live weight, the selection criterion used to generate the herd difference.

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