Correlated responses in a weight-selection experiment with beef cattle

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ABSTRACT

A selection experiment at Waikite (Rotorua) began in 1971 with closed Angus herds selected for adjusted 13-month weight (AS1), adjusted 18-month weight (AS2) or with random replacement (ACO). A closed Hereford herd, selected for adjusted 13-month weight (HS1), was also established. At both 13 and 18 months of age, annual responses in live weight in the AS1, HS1 and AS2 herds averaged 0.96, 0.62 and 0.48% of the ACO herd means (calvings 1972-85). Five correlated responses were estimated.

1. Cow weight: From all ages of cows recorded over 4 seasons (on average 11 years of selection completed), AS1 and AS2 cows were 7.5 and 8.2% heavier respectively than ACO cows; HS1 cows were 2.5% heavier than AS1 cows, the same margin as in 1971.
2. Maternal weaning weight: (AS1 and AS2 herds only, relative to ACO): responses was estimated in a tester herd from calvings in 1982-86. The maternal grandsires were selected AS1 and AS2 bulls born after almost 2 generations (6 years) of selection. The AS1 herd was superior by 8.6 kg (5.7%) and the AS2 herd by 2.2 kg (1.5%).
3. Scrotal circumference: From the 1982-85 crops, the AS1 and AS2 bulls had respectively 0.9 ($P < 0.01$) and 0.3 cm larger circumferences at 13 months of age and 0.7 ($P < 0.01$) and 0.1 cm larger values at 18 months of age than those of ACO bulls; means for HS1 bulls were 1.4 ($P < 0.01$) and 0.4 cm below corresponding AS1 values.
4. Height at withers: AS1 and AS2 bulls from the 1981 calf crop were respectively 3.5 and 2.5 cm taller ($P < 0.05$) than the ACO bulls; the HS1 bulls were 2.3 cm taller ($P < 0.05$) than the AS1 bulls.
5. Food intake: Average intake of silage by Angus bulls from the 1980 and 1981 crops were 10.4% and 11.7% greater ($P < 0.01$) for AS1 and AS2 than ACO cattle respectively. Expressed relative to body weight, there was no significant difference due to herd. The pooled regression of daily intake of dry matter on 18-month weight was 0.0091 kg/kg ($P < 0.05$), with a correlation of 0.32. The correlations of pre-fasting plasma tryptophan and the fall in plasma tryptophan concentration with average previous intake were 0.50 and 0.41, for bulls fasted over a 48 h period.

Keywords Selection; yearling weight; Angus; Hereford; cow weight; maternal effect; scrotal circumference; height; food intake.

INTRODUCTION

A weight selection experiment with beef cattle was established in New Zealand in 1971 (Baker *et al.*, 1980), on hill country at Waikite near Rotorua. Annual selection responses achieved in 3 herds have been up to 2.12 kg (0.94% of the mean) in yearling weight, over the 14-year period of calvings 1972-85 (Baker *et al.*, 1988). Preliminary estimates of correlated responses have been examined for live weights at some other ages (Baker *et al.*, (1980), Morris and Baker (1982)), for reproductive performance (Morris *et al.*, 1983) and for the relationship between birth weight and calf survival (Morris *et al.*, 1986).

The objective of this paper is to summarise associated responses in: (1) cow weight, (2) maternal weaning weight, (3) scrotal circumference of young bulls, (4) height at withers, and (5) food intake by 18-month bulls.

MATERIALS AND METHODS

Design of Selection Experiment

The experiment was set up in 1971 on the Land Corporation property, Waikite Station, about 25 km South East of Rotorua. The cattle consisted of widely-sampled Angus and Hereford herds (Baker *et al.*, 1980). The Angus cattle were allocated to three herds, one selected for adjusted weight at 13 months of age (AS1 herd), one for adjusted 18-month weight (AS2 herd) and a control with no intentional selection (ACO herd). The Hereford herd (HS1) was selected in the same way as the AS1 herd.

All herds were managed for early-spring calving. They were run together for as much of the year as possible, the main exception being for single-sire joining during an 8-week period. Selected bulls were used for one year only, as yearlings (AS1 and HS1 herds) or as 2-year-olds (AS2 herd); the ACO bulls were used as 2-year-olds. Yearling mating was applied to heifers in the AS1 and HS1 herds, with 2-year-old first matings in the AS2 and ACO herds. From mating 1984 onwards, a random half of the ACO heifers was also mated as yearlings. Mean generation intervals (Baker *et al.*, 1988) were 3.3 yr (AS1 and HS1 herds) and 4.2 yr (AS2 herd). Numbers of pregnant cows wintered per year were about 150 each in the AS1 and HS1 herds, and 130 each in the AS2 and ACO herds.

Cow Weight

Body weights were taken at the start of mating (November), near the time when calves were weaned at 5 months of age (February), during pregnancy diagnosis (March/April) and in winter (July) before calving. Weights from five age groups of heifers and cows (1, 2, 3, 4 and 5+ yr) were analysed for each of four production years, 1984/85 to 1987/88. Because unjoined heifers were managed separately, their weights were excluded from the above data set (i.e. AS2 and half the ACO heifers, from 1.25 to 2 yr of age). There were 2376 records (i.e. cows x years), representing about 1130 cows and 11 years of selection, on average.

A least squares analysis was applied to cow weight at each of the four weighings, fitting herd (4), year (4), age of cow (5) and the interaction between herd and age.

Maternal Weaning Weight

An Angus progeny testing herd was also maintained at Waikite. One year after they were used in their own herds, selected AS1 and AS2 bulls and further ACO bulls were mated to balanced samples of test herd cows. A new sample of bulls was used each year. The tester cow herd was self-replacing, so that a diallel was created; AS1-sired, AS2-sired and ACO-sired females were mated to each source of bull.

Weaning weights from the calf crops born in 1982-86 were available for analysis (597 calves). The least squares model included source herd of sire (3), source of maternal grandsire (3), their interaction, calf year of birth (5), calf sex, age of dam (2 to 5+ yr) and date of birth (covariate). Sources of maternal grandsire represented the genetic effects on maternal weaning weight (MWW). The grandsires were bulls born at an average of 6 yr (1.5 to 2 generations) after selection began. The MWW effect due to herd of origin was calculated as twice the maternal grandsire effect minus the sire effect (Koch *et al.*, 1983).

Scrotal Circumference

Bulls in all herds born in 1982-85 were measured for scrotal circumference (SC). All bulls of a given calf crop were recorded on one day in October (at 13 months of age) and again in March (18 months).

A least squares analysis was fitted (823 bulls), with herd (4), year of birth (4), age of dam (2 to 5+ yr), the three 2-way interactions and date of birth (covariate). Results were not adjusted for live weight.

Height at Withers

Measurements of height at withers (HW) were obtained from all bulls of the 1981 calf crop on one day in March 1983 (18 months of age). The least squares models for SC and HW (194 bulls) were similar except that interactions were not included for HW. Results were not adjusted for live weight.

Food Intake

Angus bulls from the 1980 (n=32) and 1981 (n=31) calf crops were transferred to Ruakura at about 18 months of age in order to record *ad libitum* food intake (FI). The AS1, AS2 and ACO bulls were sampled in order to represent their respective herd means, but excluding the heaviest and lightest extremes of each herd. All AS1 and AS2 sire groups and most ACO sire groups were sampled.

Bulls were habituated to individual pens and then recorded for 5 weeks (1980 crop) or 9 weeks

(1981 crop). Silage in excess of that required by each bull was weighed in daily, and bulked refusals were weighed three times a week. Average daily dry matter intake (DMI) was calculated from each week's data for each bull. Correlations (pooled within herd), calculated amongst DMI records for all pairs of weeks, averaged 0.83 (range 0.62 to 0.97) for the 1980 bulls and 0.76 (range 0.52 to 0.92) for the 1981 bulls. Data from all weeks were averaged to provide one FI value for each bull.

The use of plasma tryptophan (PT) as an indicator of FI (following work with dairy cows by Davis *et al.* (1982)) was tested in both years in a 2-week trial after the intake recording already described. In week 1, a random half of the bulls was offered half of their *ad libitum* intake for 48 h, whilst the other half was fasted over the same period. One blood sample from the tail of each bull was collected for PT before, and one after, the 48 h period. In week 2, the two treatment groups of bulls were reversed and the measurements repeated.

Results were analysed from the two years of data combined, including fitting interactions between year and herd, and between year and treatment group (50 or 0% intake). Correlations were obtained between FI and initial PT or the fall in PT, and also between FI in the last of the 5 or 9 weeks and the two PT variates.

RESULTS

Herd Responses in Live Weight

Expressed as percentages of the mean of the ACO herd, the annual responses in live weights (calvings 1972-85) were 0.96% and 0.48% respectively for the AS1 and AS2 herds (Baker *et al.*, 1988); the corresponding value for the HS1 herd was 0.62%. Surprisingly, percentage responses were the same at 13 and 18 months of age. The cumulative responses in Angus herds in 1984 ranged from 6 to 12% at both 13 and 18 months of age. The difference in 18-month weight between Hereford and Angus cattle before the experiment began was 10.3% (Johnson *et al.*, 1986). Relative to the AS1 herd, this narrowed for example to about 6% by the 1981 crop (which was the year of birth for bulls compared below for HW).

Cow Weight

Figure 1 shows the mean live weights of AS1, AS2 and ACO cows, at ages from 1.25 to 6.0 yr. Averaged over all ages, AS1 and AS2 cows were 7.5 and 8.2% heavier respectively than their ACO counterparts. The interaction between herd and age was significant ($P<0.01$); this could be partly due to different management in the AS1 and AS2 herds as a result of the experimental design, and to different genetic responses in each herd. The cows recorded here were the result of 11 years of selection, on average. The correlated responses were thus equivalent to annual increases in cow weight of about 0.7 and 0.75% of the ACO herd mean for the AS1 and AS2 herds, respectively.

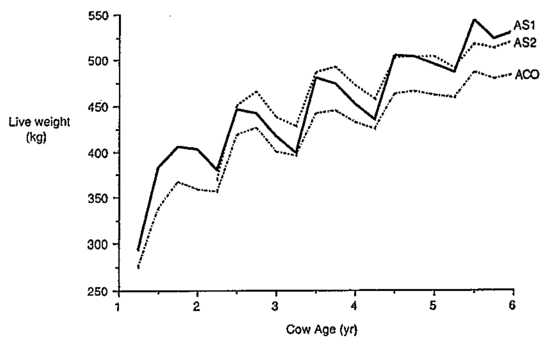

FIG. 1 Weights of selection and control cows from 1.25 to 6 years of age (for descriptions of herds, see text).

TABLE 1 Effects of herd on scrotal circumference (SC) of bulls at 13 and 18 months of age, and on height at withers (HW) of bulls at 18 months of age

Herd[1]	SC (cm) 13 months	SC (cm) 18 months	HW (cm)
HS1	30.5	35.9	113.5
AS1	31.9	36.3	111.2
AS2	31.3	35.7	110.2
ACO	31.0	35.6	107.7
sed	0.24	0.29	0.90

[1] HS1 and AS1 = Hereford and Angus herds selected for 13-month weight; AS2 = Angus herd selected for 18-month weight; ACO = Angus control herd.

Cows in the HS1 herd had mean live weights 2.5% greater than corresponding age group of AS1 cows.

Maternal Weaning Weight

The maternal genetic effects on calf weaning weight were 8.6 kg (5.7%) for the AS1 herd and 2.2 kg (1.5%) for the AS2 herd, relative to the mean of the ACO herd (s.e.d. = 3.6 kg). Only the AS1 maternal effects were significant. Interactions between direct and maternal effects were not significant.

Scrotal Circumference

Mean scrotal circumference (SC) of AS1 was greater (by 0.7 to 0.9 cm) than that in the control herd (average sed = 0.24 cm at 13 mo; 0.29 cm at 18 mo) (Table 1). The interaction between herd and year was significant ($P<0.01$) for SC at 18 months of age, but of minimal biological importance. The HS1 bulls had significantly smaller SC values (by 1.4 cm) than did the AS1 herd at 13 months of age. From an additional analysis, the linear regressions of SC on live weight were 0.047 and 0.025 cm/kg respectively at 13 and 18 months of age (both $P<0.01$).

Height at Withers

Bulls from both the AS1 and AS2 herds were taller than those from the ACO herd (sed = 0.9 cm) (Table 1). Relative to ACO bulls, the differences in height in the AS1 and AS2 herds were on average 3.3% and 2.3% of the mean. The HS1 bulls were 2.3 cm (2.1%) taller than the corresponding AS1 bulls, for a difference in live weight of 5.9% at 18 months. The residual standard deviation of height at withers (HW) was 4.2 cm. From an additional analysis, the regression of HW on 18-month weight was 0.056 cm/kg ($P<0.01$).

Food Intake

The sample of AS1 and AS2 bulls used in the food intake study was respectively 28 kg (8.0%) and 24 kg (6.8%) heavier than the ACO bulls ($P<0.01$).

Average FI values for the 1980 and 1981 bulls were 6.01 and 7.62 kg dry matter per day ($P<0.01$). There was no interaction between year and herd for FI. Combining the data from the 2 years, the average FI values were 7.01, 7.09 and 6.35 kg dry matter per day, for the AS1, AS2 and ACO herds respectively ($P<0.01$; average sed = 0.25 kg). The residual standard deviation was 0.80 kg/d, 11.7% of the mean.

Bulls in the selection herds ate 10.4% and 11.7% more respectively than those in the ACO herd. Average intakes in each herd were roughly proportional to body weight: daily intakes as a percentage of body weight were 1.87, 1.91 and 1.83% for the AS1, AS2 and ACO herds respectively, non-significant differences. The residual standard deviation of percentage intake was 0.22%. From an additional analysis, the pooled linear regression of food intake on 18-month weight was 0.0091 kg/kg ($P<0.01$), with a correlation of 0.32.

There was no difference between herds in initial plasma tryptoplan (PT) concentration (week 1) although there were 10 to 12% differences between herds in measured food intake. PT was lower ($P<0.01$) in 1980 (7.73 mg/litre) than in 1981 (12.90 mg/litre). There was also no difference between herds in the fall in PT concentration resulting from fasting; means averaged 2.36 and 6.25 mg/litre for the 50 and 0% treatment groups respectively. There were no significant interactions between herd and year for initial PT or for PT fall (fasted). The linear regressions of initial PT (week 1) and PT fall on FI were 0.80 and 0.58 mg/litre/kg dry matter/d. The reciprocal regressions were 0.11 and 0.09 kg dry matter/d/mg/litre PT (or fall in PT), and the correlations were 0.30 and 0.23. The corresponding regressions of average dry matter intake/d in the last week of intake recording (i.e. immediately before the tryptophan experiment), on initial PT and on PT fall were 0.25 and 0.20 units respectively and the correlations 0.50 and 0.41.

DISCUSSION

Direct Response

The rate of response in live weight in the HS1 herd was about two-thirds of that in the AS1 herd, because lower reproduction in the Hereford males and females (Morris *et al.*, 1983) affected selection intensity and female generation interval. The AS1 herd showed a greater response than the AS2 herd at both ages. This was partly due to the different generation intervals and to a 13% lower realised heritability in the AS2 herd (Baker *et al.*, 1988).

Cow Weight

Before the selection experiment began, the breed difference at Waikite in 1968-1971 was 2.5% (Morris *et al.*, 1987), which was the same difference as reported here.

Relative to direct selection responses in 13-month weight (AS1 herd) and 18-month weight (AS2 herd), it appears that the live weights of cows are rising faster in the AS2 herd. In a previous analysis of Waikite pre-calving cow weights, where cows had experienced an average of only 8 years of selection (Morris and Baker, 1982), the AS2 herd was also heavier than the AS1 herd (within age group), and both herds were heavier than the ACO herd. The increases in cow weight of 6 kg in the AS1 herd and 9 kg in the AS2 herd were relatively smaller than in this analysis, presumably because fewer years had passed. The AS2 cows were heavier than AS1 cows (in spite of the faster yearling response in the AS1 herd), probably a reflection of the management practice of not joining AS2 cattle until 2 years of age. However, weights of AS1 and AS2 cows were very similar by 4 years of age and appeared to cross over at 5 years of age.

Koch's experiment in Nebraska (reviewed by Baker and Morris (1984)) has shown a smaller increase above control in cow weight (19 kg or 3.5%) in the herd selected for 15-month weight. Relative to the Waikite ACO herd, the AS1 cows lost most weight in spring, when they were under greatest nutritional stress. This finding was analogous to that of Bryant (1983) with high and low breeding index dairy cows.

Maternal Weaning Weight

Although the changes in MWW due to selection were small, they were positive in both Angus herds. This was in spite of the small negative genetic correlation known to exist between maternal and direct weaning weight (as in a previous experiment at Waikite (Morris *et al.*, 1987) and in a review by Baker (1980) of other experiments).

Scrotal Circumference

Angus bulls were also found to have larger SCs than Herefords, in a large United States beef cattle experiment reported by Lunstra *et al.* (1988); their estimate was 1.8 cm at 12 months of age. In addition, their experiment showed a positive genetic correlation (0.10) between SC and body weight, confirming our correlated responses, because (at least in the AS1 herd) the SC values were greater than in ACO bulls.

Height at Withers

Based on the power relationship between height (a linear measurement) and body weight, an extra 2.3% in height in the Angus selection herds might be equivalent to an extra 7.1% in weight. This was of the same order of magnitude as the average superiorities in weight (9.8% and 4.9%) of AS1 and AS2 bulls respectively over ACO bulls in the 1981 calf crop.

For the breed comparison, the hip heights found by Lunstra *et al.* (1988) were 115 and 116 cm for Hereford and Angus at 354 days of age. This indicated that the breeds were of similar height; the difference in our experiment was only 2%, in favour of taller Herefords.

Food Intake

Intake in this experiment was closely related to body weight. Results from the Nebraska study with selected and control Herefords (intake over a *fixed weight* range), were that bulls from the weight-selected FWL herd had a 4.0% greater intake than the control herd (Koch *et al.*, 1982).

It would still be of interest to measure the intakes of Waikite cows from the selection and control herds at different physiological stages, because (as shown in Figure 1) there were different weight gains or losses during the year in each herd.

The measurements of initial PT and PT fall during fasting were shown here to be related to FI in growing beef bulls, as it was in dairy cows, but the correlations were only of medium size. Repeated blood samplings on each animal may have to be assessed as a means of increasing the accuracy. Differences among herds in intake were the same in the last week of recording as in all weeks combined, but the residual standard deviation was 22% larger for the last week of data alone, indicating the greater variability found with a single week of data. The blood samples for PT were obtained immediately after this last week, thus illustrating the difficulty of validating results for any technique with food intake.

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