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EFFECTS OF PRE-WEANING NUTRITION ON SUBSEQUENT GROWTH RATE, FEED CONVERSION EFFICIENCY AND CARCASS COMPOSITION OF IDENTICAL TWIN STEERS

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SUMMARY

Identical twin steers were reared on whole milk from birth so that one member of each set (H) grew at 0.68 kg liveweight gain per day and the other member (L) at 0.44 kg per day until weaning at 12 weeks of age. Steers then grazed together until the subsequent winter when twin sets were divided between three feeding treatments based on maize silage. After 13 weeks of controlled feeding the steers returned to pasture until slaughtered at a mean age of 91 weeks.

H steers weighed 20 kg more than L twins at 12 weeks of age and 29 kg more at slaughter. The carcass weight of H twins exceeded that of L twins by 17 kg, the difference being greatest in sets with low weaning weights. Carcass composition was only slightly affected by pre-weaning nutrition.

During controlled feeding at 1 year of age, liveweight gains of 0.60, 0.56 and 0.17 kg per day were recorded in groups of the twins fed maize meal + maize silage + urea *ad lib.*, maize silage + urea *ad lib.* and maize silage + urea at 75% of *ad libitum* intake, respectively. In the succeeding period at pasture (193 days) until slaughter mean liveweight gains recorded were 0.47, 0.56 and 0.60 kg per day. In the latter group, early rearing treatment did not affect ability to achieve compensatory growth after the winter nutritional restriction.

Differences in intake of digestible energy during the controlled feeding period reflected differences in liveweight. The efficiency of conversion of digestible energy to liveweight gain was not affected by rearing treatments when allowance was made for differences in liveweight.

Within rearing treatments, 1 kg of extra weaning weight was associated with 2.1 kg extra carcass weight in H animals, and 3.1 kg in L steers.

RESTRICTED feeding of calves from birth to 112 days of age limited the liveweight achieved at 400 days of age in the experiment of Everitt (1972). The poorly reared calves showed very little compensatory growth immediately after the nutritional restriction was lifted.

The present experiment was designed to examine whether steers nutritionally restricted as young calves up to the age of 12 weeks were capable of exhibiting compensatory growth in later life after a further period of restricted feeding. The effects of three levels of winter feeding on yearling steers which had been either well reared or poorly reared were therefore examined. Data on feed conversion efficiency and on the carcass composition of the cattle were also collected.

EXPERIMENTAL

ANIMALS

Twenty sets of spring-born, monozygous twin male Jersey and Friesian \times Jersey calves were collected. One calf died soon after arrival, reducing the number of sets to 19.

PRE-WEANING MANAGEMENT

Each twin pair was split so that one member (H) was fed on whole milk to grow at a rate of 0.68 kg liveweight gain per day up to weaning at 12 weeks of age. The other member of the set (L) was fed sufficient whole milk to provide an estimated liveweight gain of 0.34 kg per day up to 12 weeks of age. Calves were rotationally grazed on high quality pasture with hay offered *ad libitum*.

All calves were castrated at 4 weeks of age. They were drenched against internal parasites at monthly intervals and sprayed periodically against lice.

POST-WEANING MANAGEMENT

From weaning at 12 weeks of age the calves grazed together until their average age was 47 weeks. The four sets of twins in which within-set differences in liveweight were smallest were discarded from the trial at this stage although they were finally slaughtered at the same time and in the same way as the other steers. Five of the remaining 15 sets of twins were allocated at random to each of three winter feeding treatments:

Group 1: Maize silage plus maize meal (in a 6:1 ratio on a dry matter basis) fed *ad libitum*.

Group 2: Maize silage fed *ad libitum*.

Group 3: Maize silage at 75% of the intake of Group 2.

The maize silage (32.5% D.M.) was supplemented with urea at the rate of 7.7 g per kg D.M. to raise its nitrogen content to 1.74%.

The twins were individually fed indoors for 13 weeks after a preliminary period of 3 weeks. One animal in Group 1 died during this period so that results for this twin pair have been excluded from the analyses.

Digestibility of the maize silage + urea, and of the silage + urea + meal rations was determined using 3 Friesian \times Jersey steers fed at approximately 90% of *ad libitum* intake.

All twin steers returned to pasture in the spring (October 19) when they averaged 63 weeks of age. They grazed together until slaughter at an average age of 91 weeks (April 30).

SLAUGHTER AND PROCESSING

Export carcass weight (*i.e.*, kidney and channel fat removed; hot carcass weight - 5%) was recorded for each beast.

The yield of 90% visual meat by primal boneless, fat-trimmed cuts, and the bone and excess fat contents, were determined as described by Everitt (1961).

BIOMETRICAL PROCEDURES

Data were subjected to analysis of variance to assess the significance of within-set (pre-weaning treatment effects) and between-set (post-weaning treatment effects) differences and their interaction. Standard regression and covariance analyses were employed. Where appropriate data were available, analyses including the 4 discarded sets were also performed. These analyses are not reported here but in all cases gave similar results to those reported.

RESULTS

LIVEWEIGHTS AND GROWTH RATES

Calf Rearing Treatments

Mean liveweights and growth rates comparing H and L animals are recorded in Table 1 and Figs 1 and 2.

From arrival until weaning at 84 days of age, H calves grew at the planned rate but L calves grew at an average rate of 0.10 kg liveweight gain per day faster than required.

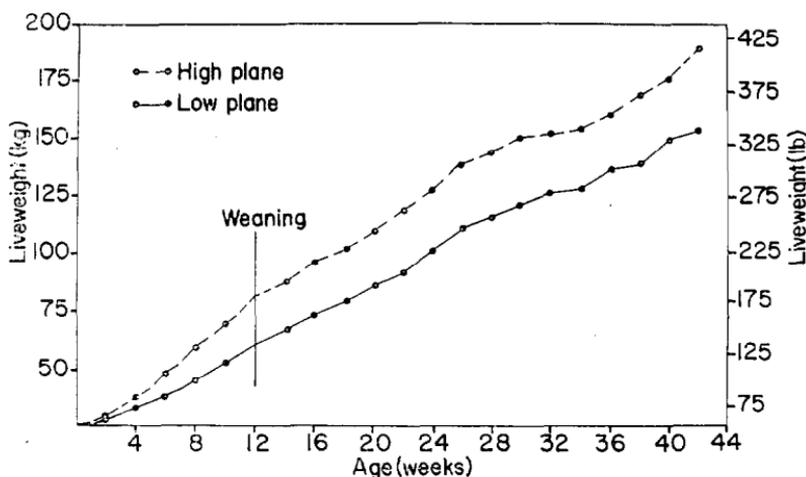


FIG. 1: Mean growth curves of identical twin H and L steers from arrival to 42 weeks of age.

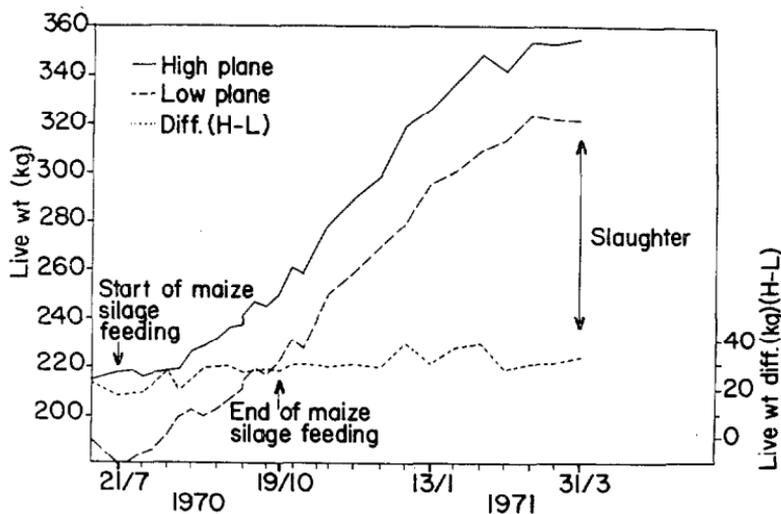


FIG. 2: Mean growth curves of identical twin H and L steers during controlled winter feeding and subsequently on pasture.

TABLE 1: MEAN LIVeweIGHTS, GROWTH RATES AND DIFFERENCES—COMPARISON OF H AND L ANIMALS

| Character | No. of Days | Mean | | Difference \pm S.E. (H — L) |
|-----------------------|-------------|-------|-------|----------------------------------|
| | | High | Low | |
| Liveweight (kg) | | | | |
| Arrival | — | 25.5 | | — |
| Weaning (84 days) | — | 82.3 | 62.3 | 20.0 \pm 1.0 *** |
| Jul. 21 | — | 208.2 | 182.5 | 25.7 \pm 2.1 *** |
| Oct. 19 | — | 248.6 | 220.7 | 27.9 \pm 4.6 *** |
| Jan. 13 | — | 325.4 | 294.6 | 30.8 \pm 4.9 *** |
| Apr. 30 (slaughter) | — | 354.7 | 326.1 | 28.6 \pm 6.0 *** |
| Growth rates (kg/day) | | | | |
| Arrival to weaning | 84 | 0.67 | 0.44 | 0.23 \pm 0.01 *** |
| Weaning to Jul. 21 | 243 | 0.52 | 0.49 | 0.02 \pm 0.03 NS |
| Jul. 21 to Oct. 19 | 91 | 0.44 | 0.42 | 0.02 \pm 0.03 NS |
| Oct. 19 to Jan. 13 | 86 | 0.89 | 0.89 | 0.04 \pm 0.03 NS |
| Jan. 13 to Apr. 30 | 107 | 0.27 | 0.29 | 0.02 \pm 0.05 NS |
| Oct. 19 to Apr. 30 | 193 | 0.55 | 0.55 | 0.00 \pm 0.03 NS |

Note: In this and subsequent tables the following abbreviations are used: * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$; NS = not significant; S.E. = standard error.

At weaning time, the mean liveweight of L animals represented 76% of the weight of their H twins.

In the immediate post-weaning period, when all animals grazed together, H calves continued to grow slightly but not significantly faster than L calves. When the winter feeding treatments commenced (July 21), the mean liveweight of L twins represented 88% of the weight of H animals. During the winter feeding period of 91 days, and afterwards on pasture up to the time of slaughter, H animals continued to grow slightly but not significantly faster than their L twins. The final liveweight at slaughter of L animals represented 92% of the weight of H twins.

Winter Feeding Treatments

Mean growth rates for animals in the three winter feeding treatments are compared in Table 2.

Growth rates of Groups 1 and 2 during the period of controlled feeding did not differ significantly. Group 3 steers, fed at a restricted level, grew appreciably slower than the other steers. When all animals returned to pasture in October, Group 3 steers grew slightly but not significantly faster than the other steers.

TABLE 2: MEAN GROWTH RATES AND DIFFERENCES—
COMPARISON OF WINTER FEEDING TREATMENTS

| Period | No. Days | Group | | | S.E. of Difference |
|--------------------|----------|-------|------|------|--------------------|
| | | 1 | 2 | 3 | |
| Jul. 21 to Oct. 19 | 91 | 0.60 | 0.56 | 0.17 | ±0.11 ** |
| Oct. 19 to Jan. 13 | 86 | 0.78 | 0.87 | 0.96 | ±0.11 NS |
| Jan. 13 to Apr. 30 | 107 | 0.22 | 0.31 | 0.31 | ±0.06 NS |
| Oct. 19 to Apr. 30 | 193 | 0.47 | 0.56 | 0.60 | ±0.07 NS |

There was no significant interaction on growth rate of early calf rearing treatment with wintering treatments either during the period of controlled feeding or during the subsequent period at pasture. That is, the ability to recover from a winter nutritional check at the yearling stage was not affected by the rearing treatments.

EFFICIENCY OF FOOD UTILIZATION

Feed intake during the controlled feeding period is recorded in Table 3. Dry matter digestibility of the Group 1 ration (silage and meal) was 64% and its digestible energy (D.E.) content 2.92 Mcal/kg D.M. The corresponding figures for Groups 2 and 3 were 63% and 2.86 Mcal/kg. In applying these figures to the identical twins it was assumed that rearing treatment had not affected digestive efficiency.

H steers consumed more D.E. per day than L animals. Corrected for differences in liveweight, however, intakes did not differ significantly. Total D.E. intake in Group 1 steers was only slightly higher than in Group 2 because the meal fed to the former depressed silage intake (Table 3).

TABLE 3: FEED INTAKE AND MEAN LIVELWEIGHT DURING
CONTROLLED FEEDING

| Pre-weaning Treatment (0-12 wk) | Winter Feeding Treatment (Group) | Mean Live wt (kg) | Dry Matter Intake* (kg/day) | Digestible Energy Intake (Mcal/day) | Digestible Energy Intake (Mcal/day) | |
|---------------------------------|----------------------------------|-------------------|-----------------------------|-------------------------------------|-------------------------------------|-----------|
| | | | | | Unadjusted | Adjusted† |
| High | 1 | 240.3 | 4.40 + 0.89 | 15.47 | 13.10 | 12.35 |
| | 2 | 235.3 | 4.93 | 14.09 | | |
| | 3 | 213.6 | 3.54 | 10.10 | | |
| Low | 1 | 207.9 | 4.02 + 0.81 | 14.10 | 11.97 | 12.71 |
| | 2 | 206.0 | 4.57 | 13.04 | | |
| | 3 | 192.7 | 3.22 | 9.19 | | |

*Shown as silage DM + meal DM where applicable.

†Adjusted by covariance for liveweight differences.

Efficiencies of food utilization during controlled feeding were compared by calculating for each rearing treatment the regression of D.E. intake on rate of liveweight gain (x_1) and mean liveweight^{0.73} (x_2). There was no significant difference between rearing treatments in regression equations (Table 4) and as neither intercept differed significantly from zero, regressions through the origin were calculated. The latter indicated requirements of 8.3 and 7.6 Mcal D.E. per kg liveweight gain for H and L reared animals, respectively.

TABLE 4: MULTIPLE REGRESSION COEFFICIENTS \pm S.E. RELATING D.E. INTAKE (MCAL/DAY) TO RATE OF LIVWEIGHT GAIN (x_1) (KG/DAY) AND LIVWEIGHT IN KG^{0.73} (x_2)

Residual standard deviations (RSD) and multiple correlation coefficients (R) are shown. Coefficients in parentheses refer to regressions fitted through the origin.

| Pre-weaning Treatment | Intercept | Multiple Regression Coefficient \pm S.E. of | | RSD | R |
|-----------------------|-----------------|---|------------------------------|------------|-------|
| | | x_1 | x_2 | | |
| High | 2.05 \pm 1.81 | 8.73 \pm 1.01 (8.27) | 0.154 \pm 0.038 (0.177) | \pm 0.72 | 0.972 |
| Low | 1.58 \pm 1.76 | 7.91 \pm 1.08 (7.56) | 0.147 \pm 0.041 (0.182) | \pm 0.87 | 0.962 |
| All | 1.48 \pm 1.13 | 8.20 \pm 0.70 (7.88) | 0.148 \pm 0.057 (0.180) | \pm 0.76 | 0.967 |

CARCASS WEIGHT AND COMPOSITION

The mean carcass weight and composition of H and L steers are compared in Table 5.

H animals were 17 kg heavier in carcass weight than L steers. The proportion of meat in the carcass was slightly higher in L than H steers and this was reflected in slightly more excess fat and bone proportions for H animals.

Carcass weights measured 28 weeks after the end of the winter feeding treatments (Table 6) were lighter in Group 3 than in the other two groups but the differences were not significant. Animals from Group 1, which had received the diet of maize silage plus maize meal during controlled feeding, had a lower percentage of meat in the carcass, and a higher proportion of excess fat and bone than the other two groups.

TABLE 5: CARCASS WEIGHT AND COMPOSITION—COMPARISON OF H AND L ANIMALS

| Character | Mean | | Difference \pm S.E. (H — L) |
|----------------------|-------|-------|----------------------------------|
| | High | Low | |
| Carcass wt (kg) | 179.3 | 162.3 | 17.0 \pm 5.3 *** |
| % Meat | 63.8 | 64.8 | -1.0 \pm 0.4 * |
| % Bone | 25.6 | 25.1 | 0.5 \pm 0.5 |
| % Excess fat | 10.6 | 10.1 | 0.5 \pm 0.5 |

TABLE 6: CARCASS WEIGHT AND COMPOSITION—COMPARISON OF WINTER FEEDING TREATMENTS

| Character | Group | | | S.E. of Difference |
|----------------------|-------|-------|-------|--------------------|
| | 1 | 2 | 3 | |
| Carcass wt (kg) | 171.8 | 176.1 | 164.8 | \pm 21.5 N.S. |
| % Meat | 62.3 | 65.8 | 64.3 | \pm 0.9 * |
| % Bone | 26.3 | 24.9 | 25.0 | \pm 1.3 N.S. |
| % Excess fat | 11.4 | 9.3 | 10.7 | \pm 1.1 N.S. |

Correction of the weights of carcass components for carcass weight confirmed that H animals, and Group 1 steers, yielded slightly, but significantly, less meat at a constant carcass weight.

RELATIONSHIPS BETWEEN WEANING WEIGHT AND SUBSEQUENT PERFORMANCE

As in the data of Everitt (1972), there was a positive and significant correlation between liveweight gain from weaning to 400 days of age (y) and the liveweight at weaning (x). Regressions for H and L groups were:

High

$$y = 1.73 (\pm 0.48)x + 6 \quad (r = 0.748, P < 0.01)$$

Low

$$y = 2.71 (\pm 0.39)x - 27 \quad (r = 0.912, P < 0.001)$$

On a between-animal within-treatment basis, a difference of 1 kg in 84-day weight was associated with a difference of 1.7 kg in gain over the period 84 to 400 days for the H group, and 2.7 kg for the L group.

The rearing treatments produced an average difference of 17 kg in carcass weight (Table 5). However, the magnitude of this effect was related to weaning weight (Fig. 3),

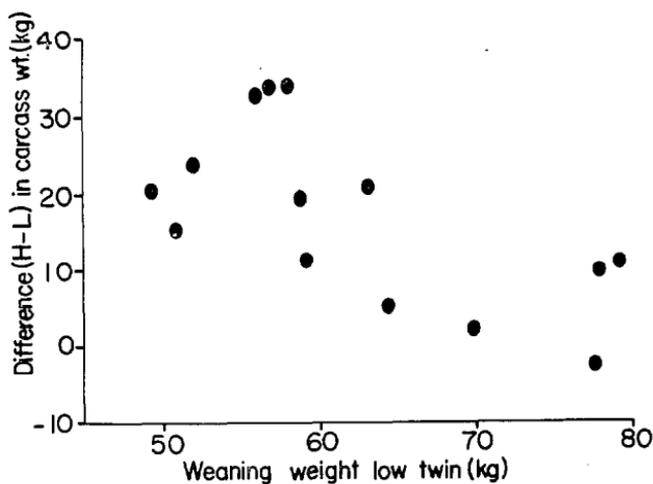


FIG. 3: Within-set difference in carcass weight (H-L) as a function of weaning weight of the L twin.

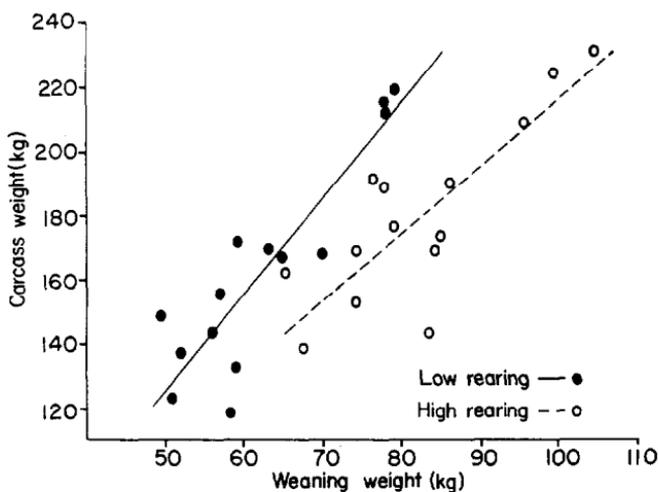


FIG. 4: Relationships of carcass weight to weaning weight.

with maximum effect on carcass weight occurring in those sets that were lightest at weaning.

Carcass weight is plotted against weaning weight for all animals in Fig. 4.

The between-animal within-treatment regressions of carcass weight (y , in kg) on weaning weight (x , in kg) were:

High:

$$y = 2.13 (\pm 0.42)x + 4 \quad (r = 0.850, P < 0.001)$$

Low:

$$y = 3.05 (\pm 0.39)x - 27 \quad (r = 0.927, P < 0.001)$$

An extra 1 kg weaning weight was associated with 2.1 kg of extra carcass weight in the case of H steers, and 3.1 kg in L animals.

DISCUSSION

The present data confirm those of Everitt (1972) in showing that weaning weight differences between identical animals produced by nutritional treatments can be long lasting. Results of the two experiments differ slightly in that some compensatory growth was observed by Everitt whereas in the present experiment animals well fed as calves (H) continued to grow slightly faster than L animals after weaning. Subsequent rates of growth were not affected by early rearing treatment so that the differences in weight were not recovered. The lack of clear compensatory growth in both of these experiments may be a result of the nutritional restriction having been applied soon after birth rather than 3 or more weeks later.

The duration and severity of feed restriction, but particularly the age of the animal at the time of restriction, appear to be major factors determining the permanency of stunting in mammals. The degree of compensatory growth achieved after a period of feed restriction depends upon the quantity, and possibly quality, of feed offered during recuperation as well as the time available for recovery. Marked differences between species exist in these relationships (reviewed by Allden, 1970). Cattle, like sheep, may be most susceptible to permanent stunting in the late prenatal to early postnatal stages of life (Wardrop, 1966; Everitt, 1967).

Many experiments have shown that a nutritional restriction of growth in cattle older than 4 months of age results in compensatory growth when feed conditions

improve. Prolonged undernutrition in the first year of life can cause stunting (reviewed by Crichton *et al.*, 1959). In New Zealand dairy cattle experiments, the period of feed restriction was not applied until the animals were at least three weeks old (Davey, 1962; Percival, 1951, 1953, 1956; Radford, 1954; Castle *et al.*, 1967), with no long-term effects on growth or other characters. Likewise, beef cattle compensatory growth studies in New Zealand have been undertaken with cattle older than 4 months at the time of imposition of feed restriction (Joblin, 1968; Morgan and Everitt, 1968; Scales and Lewis, 1971).

Compensatory growth during the recovery period in young calves appears possible on a highly digestible concentrate feed (Aitken *et al.*, 1963; Swart and Swart, 1965) but is less likely on bulky feeds such as pasture (Wardrop, 1966; Lonsdale and Tayler, 1969; Everitt *et al.*, 1969). The ultimate capacity of the gastro-intestinal tract of the nutritionally restricted young calf may be limited by inadequate development during the period of changing from non-ruminant to ruminant digestion. However, results from the period of controlled feeding in the present experiment indicated that voluntary feed intake was unaffected by rearing treatment provided allowance was made for liveweight differences. That is, there were significant differences in intake but these were consistent with the differences in liveweight. Similarly, the efficiency of conversion of D.E. to liveweight gain was the same for both rearing treatments when allowance was made for the differences in liveweight, and when it was assumed that rearing treatment had not affected digestive efficiency.

One of the objectives of the experiment was to determine whether the ability of a steer to make compensatory growth after a period of restriction as a yearling may be determined by its rearing treatment. Results from the animals in Group 3, though derived from only 5 sets of twins, do not show evidence of such an effect.

The carcass composition of the H and L animals did not differ significantly at a mean age of 91 weeks, after adjustment for differences in carcass weight. Allden (1970), in reviewing studies of nutritional handicaps during early life on body composition of beef cattle, concluded that animals that recovered from periods of growth restriction did not differ in composition from unrestricted cattle of similar weight. He went on to point out that fat responds more readily than any other tissue to high nutrient intakes in the period immediately after rehabilitation but this influence is transient and is not carried on into later life.

In practical terms, the producer is most likely to be interested in the relationship between final carcass weight and weaning weight. Everitt *et al.* (1969) found that every 1 kg of extra liveweight at 107 days was associated with an extra 1 kg of carcass weight at 620 days. The overall relationship in this experiment indicates an increase of about 2 kg of carcass weight per kg of extra weaning weight (Fig. 4). This relationship, however, is the end result of two separate but not necessarily additive relationships. There is, first, the nutritional effect imposed during rearing which has maximum influence at low weaning weights but little effect at higher weaning weights (Fig. 3). Secondly there is within groups of animals treated alike throughout the experiment an increase in carcass weight with increasing weaning weight which averages 2.1 kg of extra carcass weight per kg of extra weaning weight for the H twins, and 3.1 kg/kg for the L twins.

It would be misleading, however, to regard these two effects as representing purely nutritional and purely genetic effects, respectively. The estimate of 3.1 kg/kg for L twins results partly from the variation in nutritional effect with weaning weight — an apparent genotype \times environment interaction.

The results emphasize the need for caution in the interpretation of performance recording data based solely on liveweight at a standard age or weight gains in a test period in beef cattle selection programmes (Everitt, 1972), illustrating as they do long-lasting effects of pre-weaning nutrition in genetically identical animals.

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