THE ROLE OF NUTRITION IN THE GENOTYPE X ENVIRONMENT INTERACTIONS OF BOS TAURUS AND BOS INDICUS CATTLE IN NEW SOUTH WALES

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SUMMARY

Four experiments are described in which cattle of three breed types (Hereford, Brahman × Hereford and Brahman) were offered low N subtropical grass hays in pens. The response of feed intake, rumen ammonia concentration and liveweight change of steers to additions of nitrogen (as urea), protein (as casein) and protein meals was recorded.

Liveweight change of all steers was increased significantly (P<0.01) by urea, formaldehyde-treated casein and protein meals. Brahman steers were able to maintain rumen ammonia concentrations (c. 40 mg N/L) at a level higher than Hereford or Brahman × Hereford steers when on basal hay diets of low N content (5.8 g N/kg DM). Brahman steers in general had lower feed intakes (g/kg liveweight) than other steers but also had smaller (P<0.01) increases in liveweight to inputs of nitrogen and protein in the diet.

Both Hereford and Brahman × Hereford steers increased feed intake and liveweight with inputs of nitrogen and protein in the diet; Brahman × Hereford particularly being responsive to protected proteins.

I INTRODUCTION

The presence of a genotype x environment interaction has considerable bearing on the matching of the most suitable genotypes to particular locations or production systems. Whilst there have been reports of genotype x nutrition interactions with respect to feeding level and ME content (e.g. Anderson 1978), there have been studies in which no significant interaction was observed (e.g. Kress et al. 1971; Ferrell et al. 1978). One of the problems of estimating the interaction is in choosing the appropriate criteria between genotypes. Overall, the scope for detecting the genotype x environment (GxE) interaction is directly related to the magnitude of differences between genotypes and between environments (Wilson 1974). When these differences are large the interaction has been significant as with the changes in rank between divergent genotypes of Bos taurus and Bos indicus breeds in the presence or absence of environmental stresses (Frisch and Vercoe 1984).

Hearnshaw and Barlow (1982) reported a significant interaction between breed types on different pastures within the one location (Grafton, N.S.W.). Brahman x Hereford (BxH, Fl) steers grew faster than other crosses and purebred Herefords on low N native pastures but on improved pastures, the B. taurus crosses grew faster from weaning to 18 months than BxH or Hereford steers. However, in diverse locations throughout New South Wales, Fl steers were 16% heavier than purebred steers in the subtropics and on average 10% heavier in other areas of the state (Darnell et al. 1987). In other words, there was no change in ranking between breed types across environments in New South Wales. In the dry tropics, the greater the Bos indicus content during low rainfall years, the greater was the resistance of cattle to weight loss (Frisch 1972). These advantages were attributed to the greater resistance to tropical stresses (heat, ectoparasites) by B. indicus cattle (Frisch 1976).

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Kennedy (1982) attributed the ability of *B. indicus* crosses to maintain a higher liveweight than Hereford steers on low N forages to a more extensive rumen digestion and more efficient protein synthesis. In contrast to Queensland and New South Wales results, BxH heifers grew slower than Hereford heifers on improved high N pastures at Hamilton in Victoria (Morgan 1981). Production of Hereford cattle on low N forages in the subtropics was increased substantially by protein meal supplements (Hennessy 1983; Hennessy et al. 1981).

Therefore, part of the reason for a GxE interaction involving *B. indicus* and *B. taurus* cattle, and their cross, might be related to the quality of the diet, in particular the nitrogen content. It is the purpose of this paper to report on four experiments undertaken at Grafton, New South Wales, which examined the production of cattle on a low N – low digestible forage and the effect on production of additional nitrogen and protein in the diet.

II MATERIALS AND METHODS

There were four experiments.

Experiment 1. Thirty steers, consisting of 10 of each of Hereford (Bos taurus) Brahman (*Bos indicus*) and Brahman x Hereford breed types of a mean liveweight of 302 ± 12 kg were allocated randomly to single pens in a covered area. They were-offered a chaffed hay made from carpet grass (*Axonopus affinis*) dominant pastures collected in the New South Wales sub-tropics. The pasture was 50.5 ± 2% digestible (OM) and contained 5.8 gN/kg dry matter. Batches of hay were sprayed with a urea solution (120 g/L) resulting in 27 ± 0.9 g urea/kg air dried hay. This sprayed hay was fed twice a day in amounts aimed at providing steers with either 0, 6, 12, 18 or 30 g urea intake/day over 42 days. Cattle were weighed between 7.30 and 8.00 am before feeding on day 1 and between the same times on day 42. Samples of rumen fluid, parotid saliva and blood were taken before urea feeding and on days 37, 38 of the experiment.

Experiment 2. The thirty steers from Experiment 1 were re-randomized and allocated to five treatment groups in this experiment. Two steers per breed were allocated to treatments in which formaldehyde-treated casein was offered at either 0, 75, 150, 225 or 300 g/d.

Casein was sprayed with formaldehyde as a 20 g/L solution at a rate of 6.3 g formaldehyde/kg crude protein. For the treated casein, 98 ± 0.7% remained in terylene bags (25 um pore size) after 48 h suspension in the rumen of a fistulated steer.

The treated casein was offered in two meals a day in containers separate from those in which hay was offered.

Experiment 3. Twenty-seven steers from Experiment 2 were selected, re-randomized and allocated to three treatments in this experiment. Three steers per breed group were allocated to each of three treatments, a basal hay diet (similar to those in experiments 1 and 2), one in which 300 g/d of casein was added in two meals a day and one in which 300 g/d formaldehyde-treated casein, and hay containing 30 g urea were included.

Experiment 4. A new batch of eighteen steers of a mean liveweight of 302 ± 15 kg was used to compare the effects of two protein meals on production.
The hay offered was taken from pastures of similar composition to the hay used in Experiments 1-3 but had a higher N content (7.8 g/kg DM), although similar in digestibility (52%). Three steers per breed type were allocated to three treatments of either basal hay diet only, or 1 kg/d of cottonseed meal (67.4 gN/kg DM) or 1 kg/d of formaldehyde-treated sunflower meal (56.5 gN/kg DM), given as two meals/day.

Statistical Analysis

Final liveweights, and liveweight gains, were adjusted for the effect of initial liveweight in a least squares analysis of variance on these parameters in each experiment. Hay intake was also adjusted for differences between steers in intake when each was offered the basal diet of hay. Similarly, nitrogen concentrations in samples of rumen fluid, plasma and saliva, taken at the end of each experiment, were adjusted for differences in concentrations between animals taken prior to treatments being imposed.

III RESULTS

Experiment 1.

Hay intake increased (P<0.001) linearly (r=0.99) with sequential additions of urea to the diet. However, intake differences between urea treatments were not significant (P<0.01) until d 28. There was a strong breed difference (P<0.001), with Brahman steers on the highest urea intake eating 6.4% less hay (at 17.6 g DM/kg liveweight) than Hereford or Brahman x Hereford steers which had similar intakes (18.8, 18.4 g DM/kg liveweight) (Table 1).

TABLE 1. Hay intake and final liveweight of steers of Hereford, Brahman x Hereford and Brahman breeds according to urea intake.

<table>
<thead>
<tr>
<th></th>
<th>Hereford</th>
<th>Brahma x Hereford</th>
<th>Brahman</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Final Liveweight (kg)</td>
<td>DM Intake (kg/d)</td>
<td>Final Liveweight (kg)</td>
</tr>
<tr>
<td>Urea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(g/d)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>309</td>
<td>4.9</td>
<td>295</td>
</tr>
<tr>
<td>5</td>
<td>310</td>
<td>5.8</td>
<td>303</td>
</tr>
<tr>
<td>9</td>
<td>314</td>
<td>5.4</td>
<td>307</td>
</tr>
<tr>
<td>18</td>
<td>318</td>
<td>5.7</td>
<td>309</td>
</tr>
<tr>
<td>30</td>
<td>325</td>
<td>6.1</td>
<td>316</td>
</tr>
<tr>
<td>mean ± SE</td>
<td>315 ± 3</td>
<td>5.6 ± 0.2</td>
<td>306 ± 3</td>
</tr>
</tbody>
</table>

There was a significant (P<0.01) difference between breeds in final liveweight adjusted for initial liveweight and a significant (P<0.01) linear effect of urea on adjusted final liveweights. Hereford steers had higher (P<0.01) growth rates overall treatments than steers of B. indicus origin, viz 63: -163; -233 + 87 g/d for Hereford, Brahman x Hereford and Brahman breeds respectively.

Liveweight change in Hereford steers was linearly (r²=0.92) related to urea intake; each g/d intake of urea resulting in 12.9 g/d growth. This ratio was 9.6 g/d for Brahman x Hereford steers and 10.8 g/d for Brahman
Maintenance of liveweight by steers of each breed type was estimated, by using these ratios as requiring forage N contents (g/kg DM) of 6.6, 8.1 and 8.5 for Hereford, Brahman x Hereford and Brahman steers respectively.

There were significant between breed differences \( (P<0.01) \) in rumen ammonia content, with the highest concentration recorded in Brahman steers viz 41 compared with 17 and 14 ± 3 mg N\&-N/L in Brahman \& Hereford and Hereford respectively. Increasing urea intakes had no effect on rumen ammonia concentration in Brahman steers although there was a significant linear effect in Hereford \( (r^2=0.98) \) and Brahman \& Hereford \( (r^2=0.69) \) steers respectively. There was a significant linear effect \( (P<0.01) \) of urea intake on plasma urea nitrogen concentrations with the concentration being significantly higher \( (P<0.01) \) in Brahman steers (49 mg N/L) than in Hereford (24 mg N/L) or Brahman \& Hereford (32 mg N/L) steers.

Experiment 2.

Hay intake was increased \( (P<0.01) \) by additions of formaldehyde-treated casein (FTC) to the basal diet with 89% of the variance accounted for by linear components. Brahman steers consumed significantly \( (P<0.01) \) less (6.5%) hay than Brahman \& Hereford steers. Although there was no significant breed \& treatment interaction, the table listing responses follows (Table 2).

**TABLE 2.** Hay intake and final liveweight of Hereford, Brahman \& Hereford and Brahman steers supplemented with FTC.

<table>
<thead>
<tr>
<th>FTC (g/d)</th>
<th>Hereford Final Liveweight (kg)</th>
<th>DM Intake (kg/d)</th>
<th>Brahman &amp; Hereford Final Liveweight (kg)</th>
<th>DM Intake (kg/d)</th>
<th>Brahman Final Liveweight (kg)</th>
<th>DM Intake (kg/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>332</td>
<td>4.8</td>
<td>338</td>
<td>5.1</td>
<td>322</td>
<td>5.0</td>
</tr>
<tr>
<td>75</td>
<td>335</td>
<td>4.8</td>
<td>344</td>
<td>6.0</td>
<td>325</td>
<td>5.9</td>
</tr>
<tr>
<td>150</td>
<td>341</td>
<td>6.3</td>
<td>355</td>
<td>6.3</td>
<td>326</td>
<td>5.3</td>
</tr>
<tr>
<td>225</td>
<td>339</td>
<td>6.6</td>
<td>348</td>
<td>6.1</td>
<td>347</td>
<td>6.1</td>
</tr>
<tr>
<td>300</td>
<td>351</td>
<td>6.5</td>
<td>356</td>
<td>6.5</td>
<td>344</td>
<td>5.8</td>
</tr>
</tbody>
</table>

\[ \text{mean} \pm \text{SE} = 338 \pm 7 \quad 5.7 \pm 0.2 \quad 348 \pm 7 \quad 6.0 \pm 0.2 \quad 333 \pm 7 \quad 5.6 \pm 0.2 \]

Within breeds, Hereford steers' hay intake (14.9 g/kg liveweight) increased by 18% with 300 g/d FTC (17.8 g/kg LW) whereas the increases were 21% for Brahman \& Hereford and 9% for Brahman steers with the supplement.

There was no significant difference between breeds in final steer liveweight or daily liveweight change. However, liveweight change was increased significantly \( (P<0.01) \) by FTC (equation 1).

\[ \text{LWC} = 49 \left( \pm 3 \right) + 1.65 \left( \pm 0.5 \right) \text{FTC} \quad r^2 = 0.94 \quad (1) \]

so that a liveweight change of 500 g/d was associated with a daily supplement of 273 g FTC.

Steers of different breed types differed \( (P<0.01) \) in rumen ammonia concentration; being (mg N/L) 37, 28 and 49 ± 4.7 for Hereford, Brahman \& Hereford and Brahman steers respectively. The relationship between rumen
ammonia concentration and supplementary FTC was linear ($r^2 = 0.78$) for all breed types. To raise concentrations to 50 mg N/L in this experiment required (g/d) FTC of 224, (315) and 156 for Hereford, Brahman x Hereford and Brahman steers respectively. Plasma urea N concentrations were increased ($P<0.01$) by FTC in the diet, with concentrations in steers supplemented with 300 g FTC/d being higher than in steers on the basal diet (103 v 56 ± 17.3 mg

Experiment 3.

Hay intake was increased ($P<0.01$) by casein and by urea plus FTC, with intake maximising between days 21-28. Differences were significant ($P<0.01$) between breeds as was the interaction, breed x treatment. Overall, Brahman x Hereford steers ate 4% less hay (16.3 g/kg liveweight) than Hereford steers and Brahman steers ate 11.8% less hay (15.0 g/kg liveweight). Brahman steers were significantly lighter ($P<0.01$) than others, with liveweight of those on the casein supplement being significantly ($P<0.01$) less (Table 3).

TABLE 3. Hay intake and final liveweight of Hereford, Brahman x Hereford and Brahman steers on a low N hay diet supplemented with casein or FTC.

<table>
<thead>
<tr>
<th>Supplement</th>
<th>Hereford Final Liveweight (kg)</th>
<th>DM Intake (kg/d)</th>
<th>Brahman x Hereford Final Liveweight (kg)</th>
<th>DM Intake (kg/d)</th>
<th>Brahman Final Liveweight (kg)</th>
<th>DM Intake (kg/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nil</td>
<td>335</td>
<td>4.8</td>
<td>331</td>
<td>5.0</td>
<td>329</td>
<td>4.9</td>
</tr>
<tr>
<td>Casein</td>
<td>349</td>
<td>6.3</td>
<td>342</td>
<td>5.7</td>
<td>321</td>
<td>4.8</td>
</tr>
<tr>
<td>Urea + FTC</td>
<td>364</td>
<td>6.6</td>
<td>378</td>
<td>6.4</td>
<td>363</td>
<td>5.4</td>
</tr>
</tbody>
</table>

Mean ± SR 349 ± 7 5.9 ± 0.13 350 ± 7 5.7 ± 0.13 338 ± 7 5.1 ± 0.13

Brahman steers had the greatest ($P<0.01$) weight loss (-360 g/d) of steers in any treatment when supplemented with casein. On the basal diet, or when supplemented with urea and FTC, they performed equally as well as Hereford steers. Brahman x Hereford steers responded best ($P<0.01$) of the breed types to urea plus casein (740 g/d) with Hereford and Brahman steers responding similarly (548, 542 g/d).

Experiment 4.

Hay intake by supplemented cattle increased with time of supplementation but differences between treatments reached significance ($P<0.01$) only from day 28. During the final seven days, Brahman x Hereford steers ate 13% more hay (23.4 g DM/kg liveweight) than Hereford steers and Brahman steers ate 18% less (Table 4). However, Brahman steers had smaller ($P<0.01$) liveweight changes than other steers viz (g/d) 790, 725, 340 + 118 for Hereford, Brahman x Hereford and Brahman respectively. There was no difference between supplements as to their effect on liveweight nor a breed x treatment interaction. Protein meal supplements significantly ($P<0.01$) increased liveweight change steers over 42 days (g/d) 290, 770 and 760 + 80 for basal diet, cottonseed meal and formaldehyde-treated sunflower meal.
TABLE 4. Final liveweight and hay intake (days 35-42) of steers of three breed types when given alternative protein meal supplements.

<table>
<thead>
<tr>
<th>Supplement</th>
<th>Hereford Final Liveweight (kg)</th>
<th>Brahman x Hereford Final Liveweight (kg)</th>
<th>Brahman Final Liveweight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DM Intake (kg/d)</td>
<td>DM Intake (kg/d)</td>
<td>DM Intake (kg/d)</td>
</tr>
<tr>
<td>Nil</td>
<td>238</td>
<td>250</td>
<td>294</td>
</tr>
<tr>
<td>F-SFM</td>
<td>262</td>
<td>285</td>
<td>310</td>
</tr>
<tr>
<td>CSM</td>
<td>270</td>
<td>289</td>
<td>307</td>
</tr>
<tr>
<td>mean ± S</td>
<td>257 ± 10</td>
<td>274 ± 9</td>
<td>303 ± 10</td>
</tr>
</tbody>
</table>

There was no significant difference between breeds in rumen ammonia concentration which was increased by supplementation (P<0.05) from 31 to 59 ± 8.7 mg N/L.

IV DISCUSSION

The experiments reported in this paper confirm the importance of nitrogen in the diet to maximise intake of low N pasture hay in Hereford and first-cross steers, and the role of protected protein to improve production efficiency. A feature of the Brahman cattle in these experiments was their relatively high rumen ammonia levels when on the basal low N diets. In only one experiment (4) was this not so. On spear grass hay (5.8 gN/kg DM), Hunter and Siebert (1985) also reported lower ammonia levels in Hereford than in Brahman cattle (14 v 29 mg N/L). Conversely, in the present study rumen ammonia concentrations were not increased above 40 mg N/L in Brahman steers by the addition of rumen degradable N or by protected protein. This ability to maintain ammonia levels, at or near the optimum for microbial protein production (50-80 mg N/L; Satter and Slyter 1974, 32-90 Alvarez et al. 1983), has to be an important aspect in the tropical adaptation of Brahman cattle (Turner, 1975; Hunter and Siebert 1985). But in spite of this advantage, Brahman steers were little more successful than Hereford steers in preventing losses in liveweight when on the unsupplemented basal diets of the four experiments. In pen studies in the tropics, Brahman steers have not had higher intakes of low N forages than Hereford steers, nor greater liveweights (Hunter and Siebert 1985, 1986) in spite of higher rumen ammonia concentrations in Brahman steers. Under tropical conditions, grazing Brahman steers apparently had better growth than B. taurus crosses (Frisch 1972) and similarly when grazing in subtropical conditions in Florida (Peacock et al. 1982). But these advantages under grazing do not appear to be expressed when the cattle are confined to pens and offered a low N hay.

In contrast to the Brahman steers, the response of Hereford steers to additional dietary nitrogen and protein in this study has indicated the importance of these components in the production of these cattle. The low rumen ammonia concentration, reduced feed intakes and consequently low production of the Hereford steers on the low N hay indicates the vulnerability of this breed to low N intakes. The addition of rumen degradable protein (either as urea or casein) to the basal diet maximised hay intake in Hereford steers, as reported previously (Redmond et al. 1980; Hunter and Siebert 1987), however, in the present study protection of protein against N loss in the rumen increased the efficiency of using feed for liveweight gain. At the same hay intake (g DM/kg liveweight), Hereford steers gained an extra 240 g/d when feed 300 g/d of protected rather than
soluble casein. Therefore, an insufficiency of dietary protein is the major nutritional reason for the poor performance of Hereford cattle on low N forages and an important reason why Hereford cattle have lower weight gains than cattle in coastal areas of New South Wales as reported by Thompson et al. (1981) and Darnell et al. (1987).

The Brahman x Hereford steers tended to maintain rumen ammonia levels above that of Hereford steers on low N roughages and to slowly gain weight whereas both Hereford and Brahman steers lost weight when unsupplemented. Brahman x Hereford steers also exhibited strong responses to the addition of protein to low N diets. Their hay intake increased by 21% with the addition of FTC in experiment 2 and ate 6% more hay than Hereford steers. Their growth increased by 740 g/d with the addition of urea (30 g/d) and FTC (300 g/d) to the basal diet compared with a response of 548 g/d by Hereford steers, which ate 4% more hay than the Brahman x Hereford steers. On the other hand, Brahman x Hereford steers only matched the Hereford steers in growth in experiment 4 by apparently eating 13% more hay than Hereford steers.

In general, the capacity of Brahman x Hereford steers to maintain their liveweight on low N diets and to respond more to inputs than did purebred Hereford and Brahman steers represents a special case. Production from the F1 genotype is not merely represented by the expression of additive genetic effects, and the interaction between them and the environment, but also to the contribution of non-additive genetic effects (i.e. heterosis) and their interaction with environmental effects. In a subtropical environment, the weaning weight of calves from F1 cows was 45 kg more than those weaned from Shorthorn cows, and 22 kg more than those from Brahman cows (Peacock et al. 1976). Heterosis is reduced with interse mating or by back crossing to either breed. Peacock et al. (1976) found that weaning weight of calves decreased significantly when either parent breed (Shorthorn or Brahman) exceeded 0.75 with the genotype. Consequently, when the genotype moves from the F1 the nutritional responsiveness to dietary protein, or other nutrients, is likely to be less, especially when the move is to a greater proportion of B. indicus in the genotype.

The present study confirmed the responsiveness of Brahman x Hereford steers to inputs of dietary protein. In the grazing study of Darnell et al. (1987), Brahman x Hereford steers also responded more to increases in pasture quality than did Hereford steers, being 41 kg or 10% heavier on improved pastures throughout various sites in New South Wales. However, some of the advantages of the Brahman x Hereford genotype can be attributed to its different grazing behaviour to Hereford steers and their greater resistance to endo- and ecto-parasites as well as to having a small nutritional advantage.

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