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EVALUATION OF THE EFFECT OF NUTRICHARGE ON WEIGHT LOSS DURING LONG-DISTANCE TRANSPORT

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Abstract

Three groups of steers and heifers were transported from a property in central Queensland to two properties near Armidale in northern NSW. For two days prior to transfer, one half of the animals was offered molasses + 10% by weight of cotton seed meal (M+CSM - control group) at the rate of 2kg / head / day whilst the other half (treated group) was offered 2kg / head / day of M+CSM plus 10% by weight of a product (Nutricharge) containing electrolytes, sugars and amino acids. Prior to transport, liveweights and temperament scores were recorded. A range of haematological values was derived from blood samples derived before and after transport. Weight changes between weight prior to transport and weekly weights for the first month after arrival were recorded. Nutricharge treatment had no effect on weight changes during, or recovery after, long-distance transport. There was a significant relationship between temperament scores and weight loss during transit and for the initial recovery period, but no relationship with subsequent weight gains, with docile animals losing less weight during transit and recovering that lost weight more rapidly than their more temperamental contemporaries. Nutricharge treatment did not modify the effect of transport stress on haematological values. Substantial variations in associations between haematological values and weight gain occurred between breeds and between breed of sire (for crossbred animals). No general trends occurred for the relationship between haematological values and weight gain. Phenotypic and genetic relationships were estimated between temperament scores and haematological values. In general, genetic relationships between temperament scores and pre- and post-transport values for most haematological measures were moderate, indicating that, genetically, most traits were related. However, phenotypically, relationships were close to zero for most traits, indicating the expression of the traits was considerably affected by environmental factors. It is possible that haematological values reflect acute stress of animals being bled, rather than chronic stress associated with transport. This may explain differences between the relationships between temperament scores and haematological values and weight loss during long distance transport.

Introduction

In northern Australia, cattle are currently transported long distances either to port prior to live export to South East Asia or to feedlots established closer to the grain growing regions than many breeding properties. As well, the meat processing industry in northern Australia is becoming concentrated into fewer, larger abattoirs that operate at higher line speeds to enable them to process more animals. This means the distance animals are transported to slaughter may in some cases have risen substantially. Greater transit distances, higher speeds of operation and inadequate handling facilities may result in greater stress on the animal, resulting in greater weight losses during transport and poorer quality meat (Warriss, 1994). On delivery to abattoirs, an increased incidence of stress-induced dark cutters and a general lowering of meat quality are often recorded (Grandin, 1980; Burrow, 1997). Where animals are delivered to a feedlot, this often results in a slow adaptation to rations and an increased susceptibility to disease (Fell *et al.*, 1997).

Previous work from Canada has indicated that the electrolyte balance of cattle may be particularly important in overcoming preslaughter stress (Schaefer *et al.*, 1988; 1990). It is possible that maintaining the electrolyte balance could also reduce weight loss during long-distance transport. Unpublished trial reports from northern Australia have shown no benefits from electrolyte supplementation (Thompson *et al.*, 1990; Pinch, 1993; as cited by Phillips, 1997). Jubb *et al.* (1993) found no reduction in liveweight loss in cattle transported short or long distances in Western Australia after being injected with vitamins A, D, and E. In two of three experiments reported by Phillips (1997) there were no effects of electrolyte and sugar supplements on liveweight loss during long distance transport and on carcass and meat quality attributes. However in a third experiment, where animals received supplementation both before transport and during lairage at the abattoir, Phillips found no significant reductions in liveweight loss during transport but improved carcass hydration that resulted in an improvement in dressing percentage of 0.6% in treated animals compared with control animals. There was also a strong trend to improved meat colour score in carcasses from treated animals (Phillips, 1997).

These Australian reports are generally contrary to the reports from Canada, where treated animals were offered watered supplemented with Nutricharge, a product containing sugars, electrolytes and amino acids. Studies by Jones *et al.* (1992) and Schaefer *et al.* (1992) reported that the solution offered during lairage at the abattoir reduced carcass weight losses by 6 kg (1.2% of final liveweight) but had few effects on meat quality. It is possible these effects may have been achieved by offering water alone, as the comparison in these studies was between treated water and no water. However an earlier study by Schaefer *et al.* (1990) demonstrated a significant improvement in dressing percentage (based on both hot and cold carcass weights) and also on abattoir weight as a percentage of farm weight in animals that had been offered either an electrolyte supplement or a glucose supplement when compared with animals that had been offered either water alone or had not been watered.

This experiment evaluates the effect of the supplement developed from the Canadian studies (Nutricharge) on weight loss during long distance transport, and subsequent recovery of this weight loss following the stress of the long distance transport.

It is also possible that animals with poor temperament (see for example the reviews of Grandin, 1980 and Burrow, 1997) or that are particularly susceptible to stress (I.G. Colditz, personal communication) may suffer greater weight losses during long distance transport and have higher rates of morbidity in the post-transport period than animals with better temperaments or greater resilience to stress. In conjunction with the evaluation of Nutricharge, the relationships between temperament scores and stress and liveweight loss during long distance transport and post-transport morbidity were examined.

Materials and methods

Animals and management

Three groups of steers and heifers were transported from Duckponds in Central Queensland to two different properties near Armidale in northern NSW. Similar experimental protocols were established for all groups. Summary attributes of each of the experimental groups are shown in Table 1.

Except for one group of crossbred calves that were born at Duckponds, all calves had been born and reared on collaborator properties in Central Queensland, and delivered to Duckponds after weaning at about 6 months of age. Within the crossbred and two straightbred groups, animals were allocated to treatment group (Control or Nutricharge) on the basis of age, sex, sire, property of origin and weight on arrival at Duckponds. Animals transferred from Duckponds to NSW need to be cleared of ticks at two points during their journey. This necessitated dipping all animals (with Bayticol® Pour-On, Bayer Australia) twice at Duckponds prior to their departure. Animals were dipped on the first occasion approximately four weeks prior to transfer, when they were also weighed and different measures of temperament were recorded. The measures of temperament included a subjective crush score (on a 1-5 scale from calm to struggling wildly), a flight speed score (an electronic measure of the rate at which animals vacated a weighing crush into an open yard, with low scores indicating animals with poor temperaments; Burrow *et al.*, 1988) and a visual flight speed score (5 point scale from very fast to very slow). Animals were returned to the paddock after dipping and data recording. Three weeks after the first dip treatment, animals were returned to the yards and the procedures were repeated (weights and temperament scores recorded). Due to a delay in delivery of some of the Brahman calves to Duckponds, the only temperament measurement recorded on the entire group of Brahmans was a single flight speed score recorded at the time of the second weighing. The following day, a blood sample was collected by venipuncture from all animals to determine base levels for haematological values. Experimental animals were retained in the yards for 7 days from day of second dipping prior to transport to ensure all animals were free of ticks, as well as for experimental purposes.

For the first 5 days in the yards, animals were managed as a single group and were offered above-maintenance rations of grassy lucerne or forage hay (~ 4 kgs per head per day) plus > 2 kgs per head per day of molasses premixed with 10% cottonseed meal (M+CSM). All animals had been trained to eat the M+CSM mix on arrival at Duckponds, and they consumed the targeted intake during the first 5 days. After 5 days in the yards, animals were drafted into treated and control groups and maintained in separate yards. Control groups received hay and M+CSM as per days 1 to 5. Treated groups were offered hay as per days 1 to 5, but in addition to M+CSM, 10% Nutricharge (for product details, see Schaefer *et al.*, 1992) by weight was added to the M+CSM mix and offered at a rate of > 2 kg per head per day.

Even though the animals had not been trained to eat Nutricharge prior to the start of this experiment, intake of the product by both groups of straightbred calves was good, with the total amount of mix offered being consumed over the two days of treatment. However, during the two days of treatment in the crossbred group, weather conditions were considerably cooler than normal for Central Queensland and the molasses mixes became partially solidified. Approximately 50% of the control mix and 40% of the Nutricharge mix that was offered was consumed during the two days of treatment in the crossbred group.

One week after the second dipping, all animals were trucked from Duckponds. Early on the morning of departure, access to remaining molasses mixes was restricted and the gate between the treated and control groups was opened to allow free mixing of all animals for about two hours before loading. It is assumed that this ensured random allocation within treatments to different trucks and to upper and lower and forward and rear decks of these trucks during transit. All trucks departed Duckponds by 8 a.m. on all occasions. Animals were initially transported to Taroom, about 500 km from Duckponds, where all were offloaded, watered, inspected for presence of ticks, dipped in a plunge dip and allowed to dry in a yard with access to water, prior to being re-loaded and transported a further 365 km to Goondiwindi. At Goondiwindi, animals were managed in a single yard for the next 3 days with full access to water and were fed poor quality sorghum stubble hay at a rate > 5 kg / head / day. On the third day, all animals were dipped in a plunge dip before being reloaded and trucked to either Tullimba (crossbreds and Brahmans) or Longford (straightbred Belmont Red and Santa Gertrudis) properties near Armidale, NSW, a distance of about 500 km. Animals arrived at their destinations late in the evening of the third day, having travelled a total distance of approximately 1365 km.

About 36 hours after arrival at Tullimba or Longford, all animals were weighed and rebled to determine post-transit levels for haematological values. Thereafter, they were weighed on a weekly basis for the first month after arrival. At time of fourth weight in the crossbred group and the second and third weight in the straightbred Belmont Red and Santa Gertrudis group, flight speed scores were also recorded. Flight speed scores were not recorded in the Brahman group at Tullimba. Throughout the first month after their transfer, records were kept of any illness, injury or ill-thrift in any of the experimental animals. In the crossbred group, a treated steer was recorded as being lame (suspected hip injury in the paddock) at time of third weighing after arrival at Tullimba. However no illness or ill-thrift that could be attributed to transfer from Duckponds was recorded in either crossbred or straightbred groups.

Haematology and immunology tests

A comprehensive battery of red and white blood cell values were derived from blood samples collected before and after transport as indicators of immune competence of individual animals. Definitions of values are given in Table 2. Blood samples (10 ml / animal) were collected from the median caudal vein in EDTA vacutainers. Blood was chilled and transported overnight from Duckponds to Armidale for analysis. Total white cell counts and red cell values were determined on a Coulter S880 haematology analyser. 100 μl aliquots of blood were stained for flow cytometry as reported by Colditz *et al.* (1996). A double staining procedure was performed on each aliquot to identify CD45+ cells (leucocytes) and a second marker of interest, either CD8, T19, CD14 or L-selectin. Data from 10,000 cells per sample were recorded on a FACS Vantage flow cytometer (Becton Dickinson). CD14 staining was used as the basis for differential white cell counts. CD8+ lymphocytes are suppressor/cytotoxic lymphocytes involved in regulation of immune responses and clearance of viral infections, T19+ (WC1+) lymphocytes are present in high numbers in mucosal surfaces, and L-selectin is an adhesion molecule on neutrophils involved in the migration of these cells to sites of infection. Its expression is reported to be suppressed by stress (Burton *et al.*, 1995).

Statistical analyses

Effects of treatment, breed and temperament scores

Data from each experimental group were analysed separately using least-squares procedures (Proc GLM; SAS/STAT, 1989). For all data sets, initial liveweight was assumed to be the average of the two weights recorded at time of dipping treatments at Duckponds. Liveweights at Duckponds were recorded as fasted weights, whereas liveweights at Tullimba and Longford were unfasted. Variables analysed in all data sets were initial weight and weight change from initial weight to first, second, third and fourth weights after transfer from Duckponds.

Effects included in analysis of crossbred data were :

- Sire breed (Angus, Belmont Red, Brahman, Charbray, Charolais, Hereford, Limousin, Santa Gertrudis, Shorthorn)
- Herd of origin of calf (Brigalow Research Station, Duckponds)
- Sex of calf (steer or heifer)
- Treatment (Control or Nutricharge)
- Dam's property of origin (within herd of origin)
- Age of calf in days at start of experimental protocol (fitted as a linear covariate)
- An average of the two crush scores and the two visual flight speed scores recorded at Duckponds was also fitted as a covariate in separate models, using the above fixed effects and age as a regression. Flight speed scores recorded at Duckponds were atypical of flight speed scores in other experimental data sets, in that both the mean and range of measurements was substantially higher than expected. There was also a poor correlation between flight speed scores at Duckponds and the single flight speed score at Tullimba (r_p<0.40). This was believed to reflect the intensive handling that these calves had received through the yards at Duckponds since birth and the weaning period, and was therefore considered to be a poor measurement of the animal's temperament. Hence only the flight speed score recorded at Tullimba was fitted as a linear covariate in a third model to determine the relationships between flight speed and liveweight change during transit.
- All first order interactions, including the interaction between treatment and the regression of flight speed score, were non-significant (*P*>0.10) and were not included in the final analysis.

Effects included in analysis of straightbred Belmont Red and Santa Gertrudis data were :

- Breed (Belmont Red, Santa Gertrudis)
- Herd of origin within breed (3 Belmont Red and 4 Santa Gertrudis herds)
- Sex (steers and heifers)
- Treatment (Control or Nutricharge)
- Age of calf in days at start of experimental protocol (fitted as a linear covariate)
- An average of two crush scores, four flight speed scores and two visual flight speed scores was also fitted as a linear covariate in three separate models, using the above fixed effects and age as a regression.
- All first order interactions, including the interaction between treatment and the regression of different temperament scores, were non-significant (*P*>0.10) and were not included in the final analysis.

Effects included in analysis of straightbred Brahman data were :

- Herd of origin (4 herds)
- Sex (steers and heifers)
- Treatment (Control or Nutricharge)
- Age of calf in days at start of the experimental protocol (fitted as a linear covariate)
- The single flight speed score recorded at Duckponds was also fitted as a linear covariate
- First order interactions were not significant (P>0.10) and hence were removed from the final analysis

Effects of haematological values

Haematology data were analysed separately within transport group (crossbreds, straightbred Belmont Red and Santa Gertrudis and straightbred Brahman). Except for CD45 (see Table 2 for definition), all blood cell values were fitted as linear covariates to models that included fixed effects outlined above for the different groups of calves. Measurements of temperament were not included in these models. Initially, the interactions between sex and breed and the various blood cell values were fitted to the model, but as sex x blood cell value interactions were never significant, they were removed from the models. However the interaction between breed and blood cell values was included in all models based on crossbred and straightbred Belmont Red and Santa Gertrudis groups. In addition, sire within breed was fitted as a random effect to all models. Data were analysed using Proc MIXED (SAS/STAT, 1989), initially using either transformed or non-transformed data (the type of transformation varied and was dependent on the parameter being analysed, with the aim of each of the transformations to normalise the data) but levels of significance did not change with the transformation. Hence only results from non-transformed data are presented. Haematalogical values were available from pre-transport blood samples (except for red blood cell parameters in the crossbred calves, where equipment failure precluded their measurement) and post-transport blood samples and were fitted to the models as either pre- or post-transport values or as the difference between pre- and post-transport values to indicate changes in the values due to transport of the animals.

CD45 was fitted as a fixed effect (either presence or absence of CD45 antibody) in separate models for each group of calves, with none of the other blood cell values included in these models.

Relationships between temperament and haematological values

Phenotypic (r_g) and genetic (r_g) relationships between flight speed scores and haematological values were estimated from bivariate analyses using the MTDFREML programs (Boldman *et al.*, 1993) that use a derivative free algorithm (Meyer, 1989) and incorporate SPARSPAK routines from George *et al.* (1980). An animal model including an additive genetic effect of the animal was used to apportion variances and covariances for flight speed scores and haematological values. Fixed effects in the models included breed, herd within breed, sex and nutricharge treatment. Partial confounding existed between breed and transport group (crossbreds and the 2 straightbred groups). However common sires were represented in the crossbred group and both of the straightbred groups (through common Belmont Red and Santa Gertrudis sires in the crossbred and first straightbred group; and common Brahman sires in the crossbred and second straightbred group).

Results

Effects of treatment and breed

Nutricharge treatment had no effect on liveweight change during the experimental period in any crossbred or straightbred group (Table 3). Within the crossbred group, breed of sire had no effect (P>0.05) on liveweight change from initial weight at Duckponds to first weight at Tullimba, but had a significant effect on initial liveweight and remaining liveweight gains (P<0.001; Table 4). These changes probably reflect a better initial adaptation to the cooler Tullimba environment by British and Continental crossbreds when compared to their tropically adapted contemporaries. Within the first straightbred group, there was no difference between Belmont Red and Santa Gertrudis weaners in initial weights and liveweight gain to first weight after arrival at Longford. Thereafter though, Santa Gertrudis gained significantly more weight than Belmont Red, possibly also reflecting their higher British-breed content and hence a better immediate adaptation to the cooler climate (Table 5).

Relationships between temperament and weight loss

Within the crossbred group, neither crush score nor visual flight speed score at Duckponds was related to weight change over the experimental period. This may reflect the intensive handling these calves had received through the yards at Duckponds since birth and therefore the crush and visual flight speed scores may also have been poor measurements of temperament of these animals. The single flight speed measurement recorded at Tullimba was significantly related to weight change from initial weight to first and second weights after arrival at Tullimba (P<0.01), but was not related to initial weight or weight gains after second weight was recorded. The regressions are shown in Figure 1. These equations indicate that animals with the lowest flight speed scores (those with the least desirable temperaments) lost on average about 4.5% more weight over the immediate transit period than animals with the highest flight speed scores and then gained weight more slowly during the recovery period.

Within straightbred Belmont Red and Santa Gertrudis calves, both crush speed and visual flight speed scores were significantly (P<0.05) related to weight gain to first weight at Longford, but were not related to initial weight or subsequent weight gains. As with the crossbred group, animals with the least desirable temperament scores had the lowest weight gains from initial weight to first weight at Longford, with the differences in weight gains between the least and most docile animals (as assessed by the subjective temperament scores) being about 5 kgs (3% of initial liveweight). The average of four flight speed scores at Duckponds and Longford tended (P<0.10) to be significantly related to weight gain to first weight but was not related to subsequent weight gains. The regression showing the relationship between average flight speed score and weight gain to first weight at Longford is shown in Figure 2.

Within Brahman calves, the single flight speed score at Duckponds was significantly related to weight change between initial weight and second and third weights (P<0.05) at Tullimba, but was not related to weight change to first or fourth weights (P>0.10). Animals with the least desirable temperament scores had the lowest weight gains after transfer to Tullimba. The regressions showing the relationship between flight speed score and liveweight change between initial weight and first, second and third weights at Tullimba are shown in Figure 3.

From previous studies (Burrow, 1991; Burrow and Dillon, 1997), only 10% (10/93) of Brahmans in this study could be considered docile (flight speed score ≥ 1.0s). It is therefore possible that because the majority of animals in this group were measured as nervous, the minority of docile animals behaved in a similar nervous manner to the majority of the group during transit and hence, there was no relationship between flight speed score and weight loss during transit in this group (Figure 3a). However once animals reached their destination and were no longer being intensively handled as a group, the Brahmans with highest flight speed scores were able to regain lost weight more rapidly than their contemporaries that had lower flight speed scores (Figures 3b and 3c).

As shown in Table 3, crossbred and straightbred Brahman calves lost weight during transit to Tullimba, whilst straightbred Belmont Red and Santa Gertrudis calves gained weight. Flight speed scores had the least relationship with weight change during transit in this latter group. Mean flight speed scores for crossbreds, straightbred Belmont Red and Santa Gertrudis calves and straightbred Brahman calves was 0.75 ± 0.22s, 1.45 ± 0.48s and 0.67 ± 0.17s respectively. Whilst there was confounding between groups of animals and numbers of measurements that contributed to the average flight speed score and also sites of measurement, the differences in flight speed scores between the groups were sufficiently large to indicate that Belmont Red and Santa Gertrudis had higher flight speed scores than crossbreds and Brahmans. Hence flight speed scores may be useful predictors not only of individual animals that will lose weight during long-distance transport, but may also be useful predictors of how well groups of animals will fare during such transit.

Relationships between haematology values and weight loss

Nutricharge treatment had no effect on changes in blood values associated with transport from Duckponds to northern NSW. There was no effect of sex on the blood values under study. However there were significant differences between genotypes for these values.

Haematological values derived from pre-transport blood samples were analysed to determine their relationship with pre-transport (initial) weight. In the absence of intercurrent infections, pre-transport haematological values should be influenced predominantly by their physiological associations with body weight, with an additional minor effect of the stress of handling influencing the values. It is noteworthy that the crossbred group which had been intensively handled at Duckponds prior to the experiment had the lowest total white cell counts and lowest neutrophil percentages in pre-transport blood samples (Table 2). These values increase rapidly with stress and the elevated levels in straightbred groups suggest they were experiencing appreciable stress during handling prior to transport. Table 6 shows all relationships that are significant or tending to significance ($P<0.10$) between blood values and initial weight and weight gains from first to fourth weights post-transport for the three groups of cattle. Relationships not shown in this table were not statistically significant. The relationship between pre-transport blood values and initial body weight differed between genotypes (Table 6). In the crossbred group there were no significant relationships between pre-transport blood values and initial weight. Amongst Brahmans, heavier animals had higher white cell counts, a lower expression of L-selectin receptors on neutrophils, and a tendency to have lower mean corpuscular volume ($p<0.07$). Amongst Santa Gertrudis and Belmont Reds, heavier animals had higher haemoglobins, higher lymphocyte count and lower platelet count, and a tendency to have lower eosinophil counts ($p<0.08$).

Haematological values derived from pre-transport blood samples were also analysed to determine their relationship with weight gain from initial weight to first to fourth weight after transport. These analyses test the ability of pre-transport values to predict the severity of transport stress on the individual. The relationship between pre-transport values and post-transport weight gain differed between genotypes (Table 6). For crossbreds, weight gain after transport was greater for individuals with lower initial T19+ lymphocyte counts. For Brahmans, higher weight gains were associated with higher white cell counts, higher number of L-selectin receptors on neutrophils, a tendency to higher mean corpuscular volume, and lower platelet count. For Santa Gertrudis and Belmont Red animals, higher weight gains were associated with lower initial white cell counts, higher mean corpuscular volume, and higher platelet count. There was a tendency for higher weight gains to be associated with lower initial lymphocyte counts, lower monocyte counts and lower neutrophil counts.

Haematological values derived from post-transport blood samples were analysed to determine their relationship with weight gain from initial weight to the first weight after transport. This association measures the effect of transport stress (as reflected in weight change) on concomitantly measured haematological values. Again, the pattern of relationships varied amongst genotypes (Table 6). For crossbreds, weight gain after transport was associated with a smaller increase in neutrophil count, and a smaller decrease in numbers of T19+ lymphocytes ($p<0.08$), and lower platelet counts ($p<0.06$). For Brahmans, weight gain after transport tended to be associated with a larger decrease in haemoglobin concentration ($p<0.06$), a larger decrease in number of CD8+ lymphocytes, a larger increase in number of L-selectin+ neutrophils and a higher number of platelets. For Santa Gertrudis and Belmont Red animals, there were no significant associations between weight gain and blood parameters after transport. However several parameters approached significance, with higher weight gains tending to be associated with higher haemoglobin and larger decrease in numbers of T19+ lymphocytes.

Haematological values derived from post-transport blood samples were also analysed to determine their ability to predict weight gain from initial weight to second to fourth weights after transport. Differences were again observed across genotypes (Table 6). For crossbreds, higher weight gains were associated with a smaller decrease in haemoglobin concentration during transport, lower number of CD8+ lymphocytes after transport, and a smaller decrease in numbers of T19+ lymphocytes. For Brahmans, higher weight gains were associated with higher lymphocyte counts, higher monocyte counts, higher neutrophil counts, higher eosinophil counts, higher numbers of L-selectin+ neutrophils, lower number of L-selectin receptors per neutrophil, lower red cell counts, larger increase in haematocrit, larger decrease in mean corpuscular volumes, and higher platelet counts. Higher weight gains also tended to be associated with larger decreases in haemoglobin concentrations following transport. For Santa Gertrudis and Belmont Red animals, higher weight gains were associated with a higher mean corpuscular volume, with a larger drop in T19 counts after transport, a larger drop in haematocrit, and a lower drop in red cell counts, and tended to be associated with several other parameters, specifically higher haemoglobins, higher lymphocyte counts, higher monocyte counts, higher neutrophil counts, and higher eosinophil counts.

Relationships between temperament and haematological values

Genetic (r_g) and phenotypic (r_p) correlations between flight speed scores and various haematological values are shown in Table 7. In general, genetic relationships between flight speed scores and all blood values were moderate to high, indicating that at the genetic level, the traits were related. The exceptions were pre-transport eosinophil %, pre-transport CD8 positive lymphocyte %, post-transport haematocrit % and all values of L-selectin positive neutrophils, L-selectin mean fluorescent intensities and T19 positive lymphocytes. However phenotypic relationships between flight speed scores and blood values were all low and close to zero, indicating that at the phenotypic level, the traits were unrelated. Due to relatively small numbers of observations in the study and the confounding between transport group and breed, the standard errors associated with these correlations are expected to be high. Nevertheless, differences in magnitude between r_g and r_p for the same traits were sufficiently great to indicate that the expression of the traits was considerably affected by environmental factors.

Other effects

In crossbreds, herd of origin had a significant ($P<0.05$) effect on initial weight but no effect on liveweight change during the experimental period. Dam origin had no effect on weight or liveweight change. Steers were heavier than heifers at start of the experimental period but lost slightly more weight than heifers between initial weight and first weight at Tullimba (-9.7 kg *cf.* -8.1 kg; $P<0.05$). Thereafter, steers gained more weight than heifers ($P<0.001$). In straightbred Belmont Red and Santa Gertrudis, herd of origin within breed had a significant effect on initial weights and liveweight changes over the transit and recovery period. Steers were substantially heavier than heifers at initial weights, but there were no differences between sexes in weight gains during transit and the recovery period. Amongst Brahmans, herd of origin had no effect on initial weight or gain to first weight at Tullimba, but had a significant effect ($P<0.01$) on gains to second, third and fourth weights at Tullimba. Steers were significantly ($P<0.001$) heavier than heifers at initial weight, but lost more weight than heifers ($P<0.05$) during transit. After first weight at Tullimba though, there were only minor advantages in weight gains of steers to fourth weight at Tullimba.

Discussion and commercial implications

The main outcomes from these experiments can be summarised as follows:

- Nutricharge treatment, when offered at a rate of > 2 kg / head / day for 2 days prior to transport had no effect on weight changes during, or recovery after, long distance transport;
- Temperament was significantly related to weight loss during transit and for the initial recovery period, but was not related to subsequent weight gains, with docile animals losing less weight during transit and recovering that lost weight more rapidly than their more temperamental contemporaries;
- Breed of sire (in the crossbred group) and breed of calf (Belmont Red and Santa Gertrudis in the first straightbred group) effects on weight changes reflected the better initial adaptation to the cooler New England environment by British and Continental crossbreds and the higher British-breed component of Santa Gertrudis when they were compared to their more tropically adapted contemporaries;
- Nutricharge treatment failed to modify the effect of transport stress on haematological parameters.

From these and other studies in northern Australia, there are few, if any, benefits from pre-transport supplementation with electrolytes, sugars, amino acids or vitamins in reduction of weight loss or on carcass and meat quality attributes following long distance transport.

The exception to this generalisation is the third study reported by Phillips (1997) which reported increased carcass hydration and dressing percentages in steers that were treated before and after transport with electrolytes and sugars. Phillips (1997) attributed these higher dressing percentages to a 33% increase in water consumption before transport in treated steers (39.7 *cf.* 29.8 litres for treated and control steers respectively). This explanation would tend to support results from the Canadian studies, all of which supplemented their experimental animals at point of slaughter, rather than before transport as occurred in other northern Australian studies. Lending emphasis to this explanation are results from the Schaefer *et al.* (1990) study, that allocated animals to one of four treatment groups, namely no water, water alone, water supplemented with an electrolyte solution and water supplemented with a glucose solution. When weight immediately before slaughter was expressed as a proportion of weight of animal on farm, the results for each of these treatments was 95, 95, 101 and 100% respectively, indicating that animals offered water supplemented by either electrolytes or glucose may have increased post-transport water intakes.

It is therefore suggested that future studies should focus on post-transport, rather than pre-transport supplementation, although the possibility of a combined pre-transport and post-transport supplementation regime should not be ignored (as in the third experiment of Phillips, 1997). Further studies could include transfer of animals from property to abattoir for slaughter (investigating effects of treatment on carcass and meat quality), the effects of treatment during and after live animal export (investigating the effects of treatment on morbidity and subsequent performance in Asian feedlots) and also investigation of the effects of supplementation after transport on adaptation to feedlot and other finishing environments within Australia.

On the basis of the third study reported by Phillips (1997) and the Schaefer *et al.* (1990) study, it is unlikely that critical ingredients of an effective supplement include amino acids, as suggested by Phillips (1997). Hence the cheaper and more readily available ingredients used in the Phillips (1997) experiments may be economically more viable than imported, premixed products such as Nutricharge. However further development of methods of supplementation (water medication, pelleted products or products mixed with molasses etc.) should be considered for use in different transport situations (e.g., pelleted products may offer substantial advantages to animals that are exported live to South East Asia, if supplementation was offered during the boat transport, when other options such as medicated water or molasses-based mixes may not be feasible options).

From these results, temperament of individual animals and possibly of groups of animals is significantly related to their response to long-distance transport. Management options therefore need to consider temperament of individual animals to ensure that animal performance is maximised during transport and slaughtering processes.

This study provided the opportunity to examine relationships between transport and haematological values for a large group of cattle. Total white cell counts before transport were higher than anticipated, suggesting that values may have been elevated by stresses associated with handling, particularly in straightbred groups. These stresses at Duckponds prior to transport may have confounded response to transport. Based on genetic correlations between flight speed score and haematological values, the traits were generally related. However, phenotypically, the relationships were close to zero for most traits, indicating that expression of the traits was affected by environmental factors. It is possible that haematological values reflect acute stress of animals being bled and the location of that bleeding, rather than chronic stress associated with transport, as the only prior exposure the straightbred animals had to the headbail used for bleeding was associated with the unpleasant experiences of being crossbranded, eartagged, vaccinated and castrated. On the other hand, crossbred calves had been processed in a branding cradle and their experiences with the headbail had previously been non-threatening. This may explain differences between relationships between temperament scores and haematological values and weight loss during long distance transport.

Substantially more values measured in blood collected following transport were associated with weight gain after transport than were values measured in blood before transport. Numerically the difference was 28 significant associations for haematology values after transport versus 12 before transport. This difference reflects the greater ease of measuring the effect of stress than predicting the likely impact of stress. While haematology and measures of immune function may provide valuable research tools for studies on the stresses associated with particular management procedures, the greatest value to industry is likely to lie in their ability to predict responses to future stresses such as transport or feedlot entry rather than their ability to measures responses after the event. A predictive test, for instance, might permit the selection of animals suited to the feedlot environment. The present study has thus proven valuable for focusing future research efforts on developing a standardised stress test for such prediction and selection.

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References

Boldman, K.G., Kriese, L.A., Van Vleck, L.D. and Kachman, S.D. (1993) A manual for use of MTDFREML. A set of programs to obtain estimates of variances and covariances [Draft]. U.S. Department of Agriculture, Agricultural Research Service.

Burrow, H.M., Seifert, G.W. and Corbet, N.J. (1988) A new technique for measuring temperament in cattle. *Proceedings of the Australian Society of Animal Production* **17**, 154-157.

Burrow, H.M. (1991) Effect of intensive handling of zebu crossbred weaner calves on temperament. *Australian Association of Animal Breeding and Genetics,* **9**, 208-211.

Burrow, H.M. (1997) Measurements of temperament and their relationships with performance traits of beef cattle. *Animal Breeding Abstracts*, **65**, 477-495.

Burrow, H.M. and Dillon, R.D. Relationships between temperament and growth in a feedlot and commercial carcass traits of *Bos indicus* crossbreds. *Australian Journal of Experimental Agriculture*, **37**, 407-411.

Burton, J.L. Kerhli, M.E., Kapil, S., and Horst, R.L. (1995) Regulation of L-selectin and CD18 on bovine neutrophils by glucocorticoids: effects of cortisol and dexamethasone. *Journal of Leukocyte Biology*, **57**, 317-325.

Colditz, I.G., Eisemann, C.H., Tellam, R.L., McClure, S.J., Mortimer, S.I. and Husband, A.J. (1996) Growth of *Lucilia cuprina* larvae following treatment of sheep divergently selected for fleece rot and fly strike with monoclonal antibodies to T lymphocyte subsets and interferon γ. *International Journal for Parasitology*, **26**, 775-782.

Fell, L.R., Walker, K.H., Reddacliff, L.A., Vallance, H.J. and Davies, L. (1997) Reducing feedlot costs by preboosting: a tool to improve the health and adaptability of feedlot cattle. *Meat Research Corporation Final Report DAN.069.*

George, A., Liu, J. and Ng, E. (1980) User guide for SPARSPAK : Waterloo sparse linear equations package. CS-78-30, Department of Computer Science, University of Waterloo, Ontario, Canada

Grandin, T. (1980) The effect of stress on livestock and meat quality prior to and during slaughter. *International Journal for the Study of Animal Problems*, **1**, 33-52.

Jones, S.D.M., Schaefer, A.L. and Tong, A.K.W. (1992) The effects of fasting, electrolyte supplementation and electrical stimulation on carcass yield and meat quality in bulls. *Canadian Journal of Animal Science*, **72**, 791-798.

Jubb, T.F., Pinch, D.S. and Petty, S.R. (1993) Treatment with vitamins A, D and E did not reduce weight loss in transported cattle. *Australian Veterinary Journal*, **70**, 171-173.

Meyer, K. (1989) Restricted maximum likelihood to estimate variance components for animal models with several random effects using a derivative-free algorithm. *Genetics, Selection, Evolution*, **21**, 317-340.

Phillips, A. (1997) Electrolyte and sugar supplements for slaughter cattle transported long distances. *Meat Research Corporation Project NTA020 Final Report.*

SAS Institute Inc. (1989) SAS/STAT® User's Guide, *Version 6, Fourth Edition, Volume 2.*

Schaefer, A.L., Jones, S.D.M., Tong, A.K.W. and Vincent, B.C. (1988) The effects of fasting and transportation on beef cattle. 1. Acid-base electrolyte balance and infrared heat loss of beef cattle. *Livestock Production Science*, **20**, 15-24.

Schaefer, A.L., Jones, S.D.M., Tong, A.K.W. and Young, B.A. (1990) Effects of transport and electrolyte supplementation on ion concentrations, carcass yield and quality in bulls. *Canadian Journal of Animal Science*, **70**, 107-119.

Schaefer, A.L., Jones, S.D.M., Tong, A.K.W., Young, B.A., Murray, N.L. and Lepage, P. (1992) Effects of post-transport electrolyte supplementation on tissue electrolytes, hematology, urine osmolality and weight loss in beef bulls. *Livestock Production Science*, **30**, 333-346.

Warriss, P.D. (1994) Animal handling. *Meat Focus International*, April 1994, 167-172.

Table 1. Summary attributes of the three experimental groups transferred from Duckponds to northern NSW

Attribute	Crossbreds	Straightbreds	Straightbreds
Breed	Calves out of Brahman cows by 9 sire breeds representing British, Continental, Brahman-derived, Sanga-derived and Brahman breeds	Belmont Red (BR) Santa Gertrudis (SG)	Brahman
Number of animals	207	232 (BR = 158; SG = 74)	93
Sex	Steers and heifers	Steers and heifers	Steers and heifers
Dates of birth	September 1996 - January 1997	August 1996 - January 1997	September 1996 - April 1997
Properties of origin	Brigalow Research Station, Duckponds (both Central Qld)	3 BR herds (Central Qld) 4 SG herds (Central Qld)	4 Brahman herds (Central Qld)
Start of protocol	30th July 1997	5th August 1997	8th October 1997
Date of transfer	27th August 1997	10th September 1997	5th November 1997
Average age at start of protocol	243 days	BR - 286 days SG - 258 days	305 days
Treatments	Control or Nutricharge	Control or Nutricharge	Control or Nutricharge
Control treatment	> 2 kg head/day molasses + 10% cottonseed meal (CSM) offered	> 2 kg head/day molasses + 10% cottonseed meal (CSM) offered	> 2 kg head/day molasses + 10% cottonseed meal (CSM) offered
Nutricharge treatment	> 2 kg head/day molasses + 10% CSM + 10% Nutricharge offered	> 2 kg head/day molasses + 10% CSM + 10% Nutricharge offered	> 2 kg head/day molasses + 10% CSM + 10% Nutricharge offered
Estimated intake (Cont)	50% of supplement offered	100% of supplement offered	100% of supplement offered
Estimated intake (Nutr.)	40% of supplement offered	100% of supplement offered	100% of supplement offered

Table 2. Definition and mean haematological values for the three experimental groups transferred from Duckponds to northern NSW

Haematological value		**Crossbred**			**Belmont Red and Santa Gertrudis**			**Brahman**		
Abbreviation	Definition	Pre	Post	Difference	Pre	Post	Difference	Pre	Post	Difference
WBC	white cell count (x 10^9/litre)	10.13	11.05	0.92	12.50	11.89	-0.60	11.44	10.35	-1.09
RBC	red cell count (x 10^{12}/litre)		9.61		8.99	8.83	-0.15	10.15	9.17	-0.98
HGB	haemoglobin (g/dL)	12.18	11.94	-0.24	11.20	11.10	-0.09	12.08	11.06	-1.01
HCT	haematocrit (%)		29.57		28.89	28.52	-0.37	31.19	28.23	-2.97
MCV	mean corpuscular volume (fL)		30.76		32.25	32.34	0.09	30.73	30.75	0.02
PLT	platelets (x 10^9/litre)		3549.47		2331.29	2215.27	-116.02	3290.05	3061.68	-228.37
lym	lymphocytes (%)	76.64	70.85	-5.78	66.83	67.78	0.95	66.67	64.09	-2.57
mono	monocytes (%)	7.91	9.36	1.45	7.33	8.63	1.30	5.64	7.19	1.56
neut	neutrophils (%)	10.35	15.74	5.39	18.59	19.27	0.69	19.62	21.51	1.89
eos	eosinophils (%)	5.01	4.21	-0.80	7.45	4.50	-2.95	8.28	7.33	-0.95
CD8%	CD8 positive lymphocytes	10.09	8.40	-1.69	12.55	10.95	-1.60	12.76	12.23	-0.53
LSel%	L-selectin positive neutrophils	94.08	94.25	0.17	95.90	96.39	0.50	96.68	93.10	-3.58
LSel M	L-selectin mean fluorescent intensity	36.77	33.46	-3.31	36.25	36.02	-0.23	33.73	34.57	0.84
T19%	T19 positive lymphocytes	18.88	16.11	-2.77	9.80	9.19	-0.61	11.93		

Table 3. Least squares mean (± s.e.) effect of Nutricharge treatment on liveweight change following the transfer of crossbred, straightbred Belmont Red and Santa Gertrudis, and straightbred Brahman weaners from Duckponds to northern NSW (1st weight is the weight taken 36 hours after arrival at Tullimba or Longford; 2nd to 4th weights were recorded each week thereafter).

Treatment	*n*	Initial Weight (kg)	Gain to 1st weight (kg)	Gain to 2nd weight (kg)	Gain to 3rd weight (kg)	Gain to 4th weight (kg)
Crossbreds						
Control	105	214 ± 4	-8.95 ± 1.06	2.77 ± 1.12	7.67 ± 1.28	11.85 ± 1.37
Nutricharge	102	215 ± 4	-8.78 ± 1.06	2.65 ± 1.12	6.77 ± 1.28	10.22 ± 1.37
Significance		n.s.	n.s.	n.s.	n.s.	n.s.
Belmont Red and Santa Gertrudis						
Control	113	198± 3	2.40 ± 0.66	8.04 ± 0.64	9.85 ± 0.84	24.26 ± 1.02
Nutricharge	119	196± 2	2.41 ± 0.62	8.29 ± 0.60	9.71 ± 0.79	25.46 ± 0.96
Significance		n.s.	n.s.	n.s.	n.s.	n.s.
Brahmans						
Control	46	210 ± 5	-7.42 ± 1.15	12.85 ± 1.36	19.81 ± 1.75	28.87 ± 1.71
Nutricharge	47	208 ± 5	-5.79 ± 1.13	14.43 ± 1.34	22.22 ± 1.73	29.82 ± 1.68
Significance		n.s.	n.s.	n.s.	n.s.	n.s.

Table 4. Least squares mean (± s.e.) effect of sire breed on liveweight change following transfer of crossbred calves from Duckponds to Tullimba (1^{st} weight is the weight taken 36 hours after arrival at Tullimba; 2^{nd} to 4^{th} weights were recorded each week thereafter).

Sire Breed	*n*	Initial Weight (kg)	Gain to 1^{st} weight (kg)	Gain to 2^{nd} weight (kg)	Gain to 3^{rd} weight (kg)	Gain to 4^{th} weight (kg)
Angus	17	215 ± 6	-10.3 ± 1.6	3.1 ± 1.7	7.6 ± 1.9	12.9 ± 2.0
Belmont Red	48	207 ± 5	-8.5 ± 1.1	0.8 ± 1.2	4.6 ± 1.4	7.8 ± 1.5
Brahman	17	199 ± 6	-7.5 ± 1.5	1.6 ± 1.6	4.2 ± 1.9	7.6 ± 2.0
Charbray	19	206 ± 6	-6.9 ± 1.5	2.4 ± 1.6	6.6 ± 1.8	10.5 ± 1.9
Charolais	23	230 ± 5	-10.4 ± 1.4	5.2 ± 1.5	8.7 ± 1.7	13.6 ± 1.8
Hereford	19	219 ± 6	-10.6 ± 1.6	2.2 ± 1.6	8.2 ± 1.9	12.0 ± 2.0
Limousin	43	213 ± 5	-7.4 ± 1.2	6.4 ± 1.3	11.4 ± 1.5	15.9 ± 1.6
Santa Gertrudis	9	220 ± 8	-11.0 ± 1.9	0.1 ± 2.0	5.1 ± 2.3	5.9 ± 2.5
Shorthorn	12	220 ± 7	-7.2 ± 1.7	2.5 ± 1.8	8.6 ± 2.1	13.0 ± 2.2
Significance		$P<0.001$	n.s.	$P<0.001$	$P<0.001$	$P<0.001$

Table 5. Least squares mean (± s.e.) effect of breed on liveweight change following transfer of straightbred calves from Duckponds to Longford (1st weight is the weight taken 36 hours after arrival at Longford; 2nd to 4th weights were recorded each week thereafter).

Breed	*n*	Initial Weight (kg)	Gain to 1st weight (kg)	Gain to 2nd weight (kg)	Gain to 3rd weight (kg)	Gain to 4th weight (kg)
Belmont Red	158	196 ± 2	2.09 ± 0.56	7.17 ± 0.54	7.52 ± 0.72	22.09 ± 0.87
Santa Gertrudis	74	197 ± 3	2.72 ± 0.87	9.16 ± 0.84	12.04 ± 1.11	27.63 ± 1.34
Significance		n.s.	n.s.	P<0.06	P<0.001	P<0.001

Table 6. Relationships between blood values and initial weight and gains from initial weight to first to fourth weights post-transport for three groups of cattle trucked from Duckponds to northern NSW

Blood value[a]	Initial bleed v initial weight			Initial bleed v gains from initial weight to 1st to 4th weights post transport			Post transport bleed v gain from initial weight to first weight post transport			Post transport bleed v gain from initial weight to 2nd to 4th weights post transport		
	Crossbred	Brahman	SG+BR	Crossbred	Brahman	SG+BR	Crossbred	Brahman	SG+BR	Crossbred	Brahman	SG+BR
WBC		**↑**[c]		▒	**↑**	**↓**					**↑**	
ΔWBC[b]							▒					
RBC						▒						▒
ΔRBC									▒		**↓**	▒ **↑**
HGB			**↑**			▒			↑			↑
ΔHGB							▒	↓	▒	▒ **↑**	↓	▒
HCT						▒			▒			▒
ΔHCT											**↑**	▒ **↓**
MCV	▒	↓	▒		↑	**↑**						▒ **↑**
ΔMCV											**↓**	↓
PLT			**↓**		**↓**	▒ **↑**	↓	**↑**			**↑**	
ΔPLT							▒	**↑**			**↑**	
Lym	▒		**↑**	▒		▒ ↓					**↑**	↑
Δlym							▒					
Mono				▒		▒ ↓					**↑**	↑
Δmono							▒				**↓**	**↑**
Neut				▒		▒ ↓					**↑**	↑
Δneut							**↓**					↑
Neut:lym				▒		▒						
Δneut:lym												
Eos			↓	▒		▒					**↑**	↑
Δeos							▒					↑
CD8%						▒				▒ **↓**		▒
ΔCD8%								**↓**		▒		▒
LSel%				▒		▒					**↑**	▒
ΔLsel%								**↑**			↑	
LSel M		**↓**			**↑**						**↓**	
ΔLSelM								↓			**↓**	▒
T19%	▒		▒	▒ **↓**						▒		
ΔT19%							↑		▒ ↓	**↑**		▒ **↓**

[a] See Table 2 for definitions of blood values;

[b] Δ Change in blood value between first and second bleeds;

[c] Arrows indicate the relationship between the blood value and initial weight or on weight gain after transport. Up arrows represent effects with positive regression coefficients and down arrows represent effects with negative regression coefficients. Bold arrows signify significant effects and arrows in normal text represent effects with 0.05<p<0.10. Shaded cells represent effects for which there were significant differences between breeds

Table 7. Genetic (r_g) and phenotypic (r_p) relationships between flight speed scores and haematological values in crossbred and straightbred cattle transferred from Duckponds to northern NSW

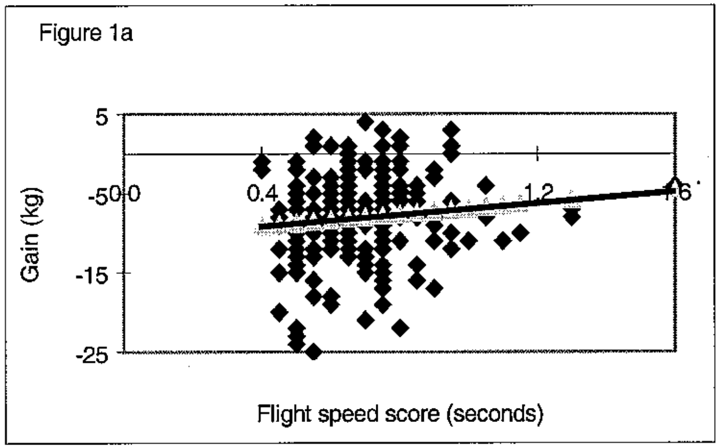
Haematological value	r_g	r_p	Haematalogical value	r_g	r_p
WBC : pre-transport	-0.39	0.02	eos : pre-transport	0.01	0.03
WBC : post-transport	-0.23	-0.02	eos : post-transport	-0.90	0.03
ΔWBC[b]	0.44	-0.02	Δeos	-0.12	0.01
RBC : pre-transport	-0.42	-0.05	CD8% : pre-transport	-0.01	-0.09
RBC : post-transport	-0.32	-0.05	CD8% : post-transport	0.34	-0.08
ΔRBC	0.11	0.02	ΔCD8%	0.42	0.03
HGB : pre-transport	-0.50	-0.09	lym : pre-transport	0.41	0.04
HGB : post-transport	-0.25	-0.07	lym : post-transport	0.31	0.14
ΔHGB	n.e.	0.06	Δlym	-0.51	0.11
HCT : pre-transport	-0.27	-0.06	mono : pre-transport	-0.28	-0.08
HCT : post-transport	-0.06	-0.06	mono : post-transport	0.52	0.00
ΔHCT	0.75	0.04	Δmono	0.41	0.07
MCV : pre-transport	0.27	-0.03	neut : pre-transport	-0.32	-0.10
MCV : post-transport	0.43	-0.03	neut : post-transport	0.21	-0.19
ΔMCV	0.83	0.00	Δneut	n.e.	-0.09
PLT : pre-transport	-0.39	-0.02	neut:lym pre-transport	n.e.	0.10
PLT : post-transport	-0.46	-0.02	neut:lym post-transport	n.e.	0.08
ΔPLT	-0.37	-0.01			
LSel% : pre-transport	n.e.	0.06	T19% : pre-transport	-0.07	-0.02
LSel% : post-transport	n.e.	0.00	T19% : post-transport	0.06	-0.01
ΔLsel%	n.e.	-0.06	ΔT19%	0.10	0.09
LSel M : pre-transport	-0.09	0.00			
LSel M : post-transport	n.e.	-0.03			
ΔLSelM	0.05	-0.03			

[a] See Table 2 for definitions of blood values

[b] Δ Change in blood value between first and second bleeds

n.e. Genetic correlation between flight speed score and this blood value could not be estimated

Figure 1. Relationships between flight speed score of crossbred calves and liveweight change between a) initial weight and first weight at Tullimba ($P<0.01$), and b) initial weight and second weight at Tullimba ($P<0.01$ - low flight speed scores indicate animals with least desirable temperaments). The data points (♦) shown on the graphs are the actual data points, whilst the plotted regression equations have been adjusted for the effects of calf age, sex, breed of sire, herd of origin, dam's property of origin and treatment using Proc GLM (SAS/STAT, 1989).



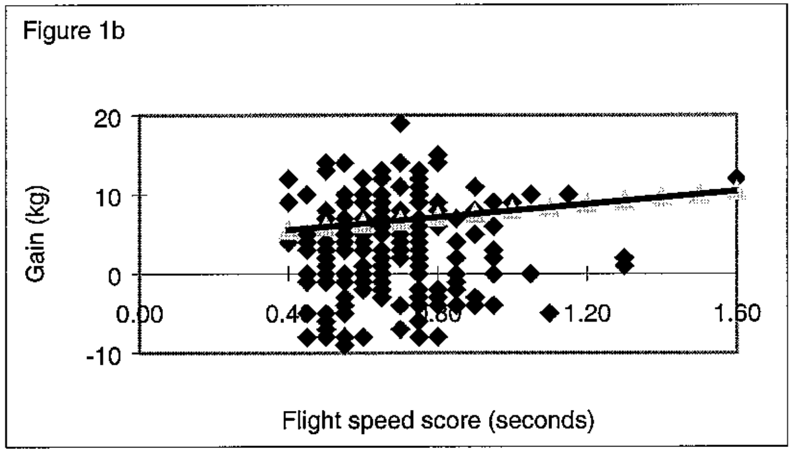


Figure 2. Relationship between flight speed score of Belmont Red and Santa Gertrudis calves and liveweight change between initial weight and first weight at Longford (*P*<0.10 - low flight speed scores indicate animals with least desirable temperaments). The data points (♦) shown on the graph are the actual data points, whilst the plotted regression equation has been adjusted for the effects of calf age, sex, breed, herd of origin and treatment using Proc GLM (SAS/STAT, 1989)

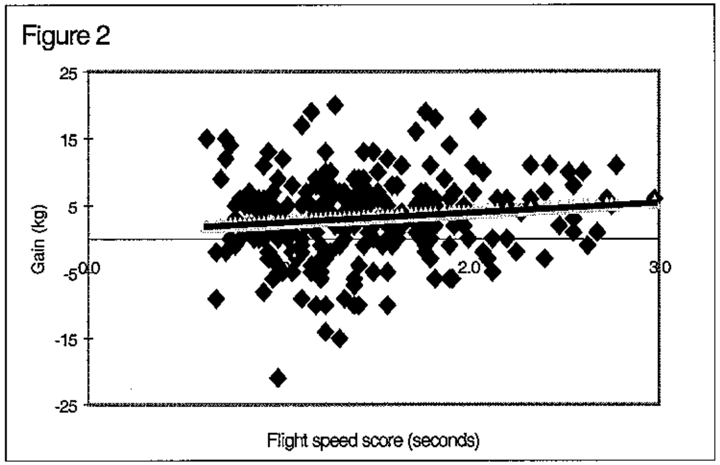


Figure 3. Relationships between flight speed score of Brahman calves and liveweight change between a) initial weight and first weight at Tullimba ($P>0.05$); b) initial weight and second weight at Tullimba ($P<0.05$); and c) initial weight and third weight at Tullimba ($P<0.05$ - low flight speed scores indicate animals with least desirable temperaments). The data points (♦) shown on the graphs are the actual data points, whilst the plotted regression equations have been adjusted for the effects of calf age, sex, breed of sire, herd of origin, dam's property of origin and treatment using Proc GLM (SAS/STAT, 1989)