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Prepared by: Simon Quigley and Dennis Poppi
University of Queensland

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Meat & Livestock Australia Limited
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Factors associated with divergent post-weaning liveweight gain in northern Australian beef cattle

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Abstract

This project examined factors associated with divergence in post-weaning growth in *Bos indicus* steers in northern Australia. Steers that were similar in liveweight (145 kg) at weaning but different in liveweight 91 days after weaning (148 and 163 kg, for lowest and highest liveweight gain) had similar liveweight gain when fed either a low (Mekong grass hay; 0.28 kg/d) or moderate (cavalcade hay; 0.47 kg/d) protein diet in pens. Steers that gained more liveweight over this post-weaning period had higher liveweight gain over the subsequent wet season than steers that had the lowest liveweight gain post-weaning although the differences were small practically (0.58 vs. 0.55 kg/d respectively over the wet season). Approximately 12 months after weaning there was only 12 kg difference in liveweight between steers that had the highest and lowest liveweight gain after weaning. There were no differences in circulating concentrations of albumin, creatinine, glucose, insulin-like growth factor-1 or urea between steers of different post-weaning liveweight gain, at weaning, 91 days post-weaning or after feeding low or higher protein diets. Serum concentrations of insulin-like growth factor-1, urea and glucose were elevated in steers fed the higher protein diet. The reasons for the divergence in liveweight gain post-weaning are likely to be related to variability in responses to marking and weaning, grazing behaviour or supplement intake rather than genetics or health status.

Executive summary

A large variation in liveweight gain (LWG) exists in cattle grazing crude protein (CP) deficient pastures after weaning across northern Australia. This occurs even when N supplements are provided. It is anticipated that increasing the LWG of the tail 20% of weaners across northern Australia could have a significant impact on production and income of these enterprises. To address this issue the mechanisms responsible for this large variation need to be defined. This project examined a range of factors that may be associated with the divergence in liveweight gain evident in weaner cattle in northern Australian beef herds. It did this by measuring liveweight change of animals under commercial and experimental conditions and measuring the change in concentration of a range of circulating factors at key stages during the experiment.

The main findings of this project were:

- There was variation in liveweight change within a mob of *Bos indicus* steers after weaning. There was a 15 kg (10%) difference in liveweight between the heaviest 20% of the mob and lightest 20% of the mob, 91 days after weaning.
- There was no difference in LWG of the highest and lowest LWG steers post-weaning, when fed moderate (cavalcade; 0.47 kg/d) and low (Mekong grass; 0.28 kg/d) protein diets, within pens.
- Steers that had the highest LWG post-weaning, also had a small but significantly higher LWG (0.58 kg/d) than steers that had the lowest LWG post-weaning (0.55 kg/d) when grazing over the subsequent wet season.
- After approximately 12 months, steers that had the highest LWG post-weaning were 12 kg heavier than steers that had the lowest LWG post-weaning. This difference in liveweight over a 12 month period is unlikely to be of significance under commercial situations.
- There were no differences in circulating albumin, creatinine, glucose, insulin-like growth factor-1 (IGF-1) or urea concentration at weaning or 91 days post-weaning for steers of different post-weaning LWG.
- Circulating IGF-1 concentration decreased from weaning to post-weaning.
- There were no differences between steers of different post-weaning LWG in circulating albumin, creatinine, glucose, IGF-1 or urea concentration, when fed low or higher protein diets.
- Circulating glucose, IGF-1 and urea concentration were higher, and circulating creatinine concentration was lower, in steers fed a moderate protein compared with a low protein diet.
- Circulating IGF-1 at weaning and 91 days post-weaning was positively correlated with liveweight at weaning, 91 days post-weaning and at the end of the subsequent wet season,

although it was not correlated with average daily liveweight change at any stage of the experiment.

The results suggest that the variation in post-weaning LWG of weaner steers is probably related to variation in how animals respond to the stress of weaning and marking, supplement intake or grazing behaviour, rather than any inherent genetic difference.

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1 Background

A large variation in liveweight gain (LWG) exists in cattle grazing crude protein (CP) deficient pastures after weaning across northern Australia. This occurs even when N supplements are provided. It is anticipated that increasing the LWG of the tail 20% of weaners across northern Australia could have a significant impact on production and income of these enterprises. To address this issue the mechanisms responsible for this large variation need to be defined. As such, a large MLA funded epidemiological study (NBP.0390, Causal factors affecting liveweight gain in north Australian beef herds) has been conducted by the Department of Resources, Northern Territory, in association with other research groups, to investigate potential causes of this large divergence in post-weaning LWG.

Preliminary work on a small number of animals (n=16; 8, moderate post-weaning growth; 8 low post-weaning growth) conducted within the MLA project NBP.350 suggests that animals divergent in post-weaning LWG, after grazing low CP dry season pastures for 100 d, do not have differences in feed intake or rumen function when offered a low CP diet alone, or when offered non-protein nitrogen (NPN) or protein (cottonseed meal) supplements under controlled experimental conditions (Turnbull et al., 2008). In the preliminary study, LWG was not measured under controlled conditions. These results suggested that factors, other than intake driven by rumen conditions, may contribute to the variation in growth evident in cattle grazing low CP forages after weaning in northern Australia. These factors may include stress responses during the marking and weaning process, access to and willingness to consume supplements, grazing behaviour and range, disease or parasite burden and genetics, and are being investigated within NBP.0390. The preliminary study in NBP.350 found that cattle divergent in post-weaning growth had differences in the concentration of circulating insulin-like growth factor-1 (IGF-1), 100 days after weaning (Turnbull, pers. comm.). However, this was a single point measurement taken 100 days after weaning and does not provide information as to whether this difference was apparent at weaning and how circulating IGF-1 concentration responds to post-weaning nutrition, or if circulating IGF-1 concentration is determined by genotype of the animal.

The weaning and marking processes are stressful events for calves that can trigger an immune response with metabolic consequences. Already limiting amino acids are utilised for an immune response rather than for skeletal muscle protein accretion and hence depressed LWG under low CP diets. It is unknown if factors associated with protein synthesis and degradation are influenced by the weaning and marking process, if these effects persist post-weaning and if they are related to post-weaning LWG. Further, it is unknown how these factors respond to post-weaning nutrition. It is proposed that this project will make use of the existing animal resources and samples available within NBP.0390 and build on the information generated within that project by investigating the concentration of specific growth factors and metabolites both at weaning and 100 d after weaning in cattle grazing low CP pastures, and investigate how those growth factors and metabolites then respond to high or low CP diets. The LWG of these weaners will be measured under controlled pen conditions after selection for divergent growth rate three months after weaning.

A range of circulating factors have been used to indicate nutritional and metabolic status of animals and/or are key regulators of animal LWG. Insulin-like growth factor-1 acts in an autocrine, paracrine and endocrine manner on a range of cell types (muscle, bone, fat, mammary tissue and reproductive organs), mainly to enhance cellular proliferation and differentiation, as well as stimulating glucose and amino acid uptake. The primary site of IGF-1 production is the liver. Insulin-like growth factor-1 binds to specific binding proteins in the circulation and these maintain its stability and regulate its activity. Circulating IGF-1 has been reported to be moderately heritable (0.35; Moore et al., 2005) and has been previously implicated with residual feed intake (Moore et al., 2005) and post-weaning feed:gain of cattle (Bishop et al., 1989). Infusion of IGF-1 decreased protein degradation and increased protein gain in sheep (Oddy and Owens, 1996) and reduced the concentration of 3-methylhistidine in the plasma of cattle fed low protein diets (Hill et al., 1999). The concentration of circulating IGF-1 responds to energy intake but not the form of energy in the diet (Houseknecht et al., 1988). The concentration of IGF-1 in the circulation is also responsive to compensatory LWG after a restriction in energy intake (Hayden et al., 1993), feed deprivation (Wu et al., 2008), dietary protein supply (Liu et al., 1997),the administration of hormonal growth promotants (Pampusch et al., 2003) and bovine somatotropin (BST) (Lemal et al., 1989). The response of circulating IGF-1 to BST is itself dependent on the nutritional status of the animal (Elsasser et al., 1989; Rausch et al., 2002).

3-methylhistidine (3MH) is a product of muscle catabolism which is not reutilized by the animal. The concentration of 3MH in plasma (Yambayamba et al., 1996) and urine (McCarthy et al., 1983) have previously been used to estimate protein degradation rates in cattle (Gopinath and Kitts, 1984) and body protein loss in dairy cows (Phillips et al., 2003). Plasma albumin concentration typically reflects chronic protein status of an animal. Plasma creatinine concentration is associated with kidney filtration and muscle mass; creatinine is a breakdown product of muscle catabolism and the concentration typically reflects muscle mass. Glucose is the main energy substrate for all tissues in ruminants. The primary objective of most metabolic responses is to maintain a constant supply of glucose. Plasma urea concentration is an indicator of the response of ruminants to immediate dietary protein supply. Excess rumen ammonia is converted to urea in the liver and this then circulates before being excreted in urine, recycled back to the rumen or incorporated into milk (in the case of lactating animals). Plasma urea may also be elevated when muscle proteins undergo catabolism to supply amino acids for gluconeogenesis.

It was hypothesised that the variation in post-weaning LWG of cattle in northern Australia is related to variations in serum IGF-1, 3MH, albumin, creatinine, glucose and urea concentration in response to individual animal stress levels at weaning and the protein accretion in the skeletal muscle of those animals when grazing low CP diets post-weaning.

2 Project objectives

1. Quantify relationships between insulin-like growth factor-1 and metabolites associated with growth and nutrient status of animals and post-weaning liveweight gain of cattle grazing low and high crude protein pastures.

2. Improve understanding of the reasons for the divergence in post-weaning liveweight gain which exists in northern Australian cattle herds.

3. Provide data and results to the NBP.0390 project team for inclusion in their conclusions with regards to herd management to increase the liveweight gain of the tail of grower cattle.

3 Methodology

Experimental design and animals

The experiment was conducted in accordance with the Australian Code of Practice for the Care and Use of Animals for Scientific Purposes and was approved by the Charles Darwin University (CDU; A07038) and University of Queensland (UQ; CDU/SAS/233/10) Animal Ethics Committees. The experiment involved 3 phases,

- a post-weaning grazing phase (*Phase 1*),
- a pen study (*Phase 2*) and
- a wet season grazing phase (*Phase 3*),

This project was part of a larger epidemiological project (NBP.0390, 'Causal factors affecting liveweight gain in north Australian beef herds').

Phase 1

Male calves (n=203) from three calving mobs on Lakefield Station (Mataranka, NT) were weighed (after an overnight feed curfew), measured for hip height (HH), marked and then weaned in April 2010. Only Brahman type calves were included in the trial. Charbray type calves were removed from the mob. After weaning the calves were fed cavalcade (Centrosema pascuroum) hay and a mixture of calf pellets (Riverina Stockfeeds), copra meal and cracked sorghum in the yards for one week. The weaners then grazed native pastures (consisting of a mixture of Sorghum plumosum (perennial sorghum), Chrysopogon fallax (ribbon grass), Dichanthium sericum (Queensland bluegrass), Aristida latifolia (feather-top wiregrass) and Themeda triandra (kangaroo grass) as a single mob in the same paddock for 91 days. The paddock consisted of the Banjo (40%), Larrimah (40%) and Mering (20%) land systems. During the 91 day grazing period the weaners were offered the same concentrate as offered in the yards (described above) for two weeks and then a loose lick mix (10% urea, 26% salt, 15% kynofos, 10% gran-am, 15% copra meal, 20% limestone and 4% trace mineral mix) at 120 g/head.d for the remainder of the 91 day grazing period. Ninety one days after weaning the steers (n=183; 20 steers that were present at the first muster were not accounted for at the second muster) were weighed (after an overnight feed curfew) and post-weaning average daily liveweight gain (ADG) was determined. Blood samples were collected from steers at weaning and 91 days post-weaning. Faecal NIRS estimated a dietary CP content of 6.3% and a dry matter digestibility of 49.8%, approximately one week before completion of Phase 1.

Phase 2

After 91 days of post-weaning grazing on dry season pastures (Phase 1), 72 steers divergent in liveweight were selected for inclusion in a pen study. Steers were ranked on ADG over the 91 day grazing period and steers with the highest (n=5) and lowest (n=5) ADG were removed from the data set. Thirty six pairs of steers divergent in post-weaning ADG were selected for the pen study by pairing steers with the highest post-weaning ADG (H-ADG) with steers with the lowest post-weaning ADG (L-ADG), that were of similar liveweight at weaning. If there were no steers in the H-ADG group within 10 kg weaning liveweight of steers in the L-ADG, they were omitted from the study. The selected steers were then transferred to the Katherine Research Station (KRS; Katherine, NT) and grazed as one mob on Sabi grass (Urochloa mosambicensis) dominant pasture, with cavalcade hay provided, for three weeks. The steers were then allocated to one of 24 pens with n=3 steers/pen (based on paired weaning liveweight) with diets randomly allocated to pens.

The treatment diets were a low protein Mekong grass hay (Brachiaria brizantha) (30 g CP and 931 g OM/kg DM) and a higher protein cavalcade hay (108 g CP and 939 g OM/kg DM), both fed ad libitum. Urea and ammonium sulphate (US) (20 g/head.d) and 200 g/head.d of copra meal (240 g CP and 940 g OM/kg DM) were added to the Mekong grass to provide a diet with a final CP content of approximately 70 g/kg DM. The animals were adapted to treatment diets and pen feeding over the first three weeks, and data over this period has been omitted from the data analysis. The steers were fed in their group pens at the same time each day. Supplements were offered to the Mekong grass treatments by mixing thoroughly through the hay when offered each morning (US supplement was dissolved in water and sprayed over and mixed through the hay). Hay residues were collected from the feed trough every seven days or more frequently on some occasions depending on the amount of residue and weather.

At the commencement of the pen experiment all steers were weighed, HH measured and blood samples collected. Rumen fluid was collected from one animal from each pen, selected at random, to determine rumen ammonia (NH3N) concentration and the microbial genetic profile. The steers were weighed once each week for 10 consecutive weeks, with hip height recorded at the same time, and blood and rumen fluid samples (same animals as at the commencement of the experiment) were collected after 10 weeks of treatment feeding. Liveweight and HH data at week 10 were omitted from the data analysis due to rain affecting intakes during that week. Liveweight and HH change were determined by regression over weeks 3 to 9 and 0 to 9 of the experiment, respectively.

Phase 3

On completion of Phase 2, the steers were transferred to Berrimah research farm (Darwin, NT) and grazed Digitaria eriantha dominant pastures for six months, from October 2010 to April 2011. Liveweight and HH were recorded once each month, with animals mustered and measured within one morning each month.

Analytical

Serum albumin, creatinine, glucose, and urea concentrations were determined on an Olympus AU400 auto-analyser (Beckman Coulter Diagnostic Systems Division; Melville, NYC, USA) using

Beckman Coulter Diagnostic Systems kits. Insulin-like growth factor-1 concentration in serum was determined using the Bioclone IGF-1 radioimmunoassay kit according to the manufacturer's instructions (Bioclone; NSW, Australia), with radioactivity counted on a Perkin Elmer 2470 gamma counter. Ammonia-N concentration in rumen fluid was determined by titration with 0.01 M HCl using a TIM 840 Titration workstation manager (Radiometer Analytical SAS; Villeubanne, Cedex, France) after distillation (Büchi 321 distillation unit Flawil, St Gallen, Switzerland). Dry matter content of feeds offered and residues was determined each week by drying bulked samples to a constant weight at 65oC.

Statistical analysis

Change in liveweight and HH during each of the three phases of the experiment was determined by linear regression. The data were analysed using the GLM procedure in SAS (SAS v9.2) within each phase of the experiment. The model included Growth (H- or L-ADG) in Phase 1 and Phase 3, and Growth, Diet (Mekong or cavalcade) and their interaction in Phase 2.

Concentration of IGF-1 and metabolites was analysed within each Phase of the experiment using the GLM procedure in SAS (SAS v9.2). The model included Growth and Stage (weaning or post-weaning) and their interaction in Phase 1, and Growth and Diet and their interaction in Phase 2. Correlations between metabolites and liveweight, HH and rate of change of both were determined using the CORR procedure in SAS, and partial correlations were also conducted between metabolite concentration and average daily LWG, controlling for liveweight. In all cases, significant differences, or correlations, were accepted at $P<0.05$.

4 Results

Phase 1

The average liveweight of the entire mob of steers at weaning was 138.7 □ 1.8 kg (ranging from 78 to 206 kg). The average liveweight of the mob 91 days after weaning was 152.4 □ 1.7 kg (ranging from 88 to 222 kg). Average daily LWG of steers in the entire mob over this period was 0.12 □ 0.01 kg/d (ranging from -0.22 to 0.44 kg/d). The average liveweight of the steers selected for Phase 2 of the experiment was 144.8 □ 2.7 at weaning, which was similar to the average liveweight of the entire mob from which they were selected. The average liveweight of H-ADG and L-ADG steers 91 days after weaning was 163.0 □ 3.8 and 147.8 □ 3.7 kg, respectively, with an ADG of 0.21 □ 0.01 and 0.03 □ 0.01 kg/d, respectively, over this period. The change in HH of the steers selected for Phase 2 of the experiment was 28.2 and 24.7 □□0.04 mm/100 d for L-ADG and H-ADG steers, respectively, between weaning and the commencement of Phase 2 (112 d), with no significant difference between the two groups.

There was no difference in the concentration of IGF-1, albumin, creatinine, glucose or urea, or the urea:creatinine (U:C), in the serum of L-ADG and H-ADG steers at weaning or 91 days post-weaning (Table 1). Serum concentration of IGF-1, albumin and urea and the U:C were all higher at weaning than 91 days post-weaning and the serum creatinine concentration was higher 91 days after weaning than at weaning.

There was a positive correlation between liveweight and HH at weaning ($r=0.70$; $P<0.001$) and 112 days after weaning ($r=0.68$; $P<0.001$). Serum IGF-1 was positively correlated with liveweight at weaning ($r=0.49$; $P<0.001$) and 91 days after weaning ($r=0.47$; $P<0.001$). There was no relationship between serum albumin, creatinine, glucose and urea and liveweight or LWG over the post-weaning period. Change in IGF-1 concentration between weaning and 91 days post-weaning was positively correlated with liveweight change over that period ($r=0.27$; $P<0.05$) with a stronger relationship evident when controlling for liveweight 91 days after weaning ($r=0.38$; $P<0.05$).

Table 1. Concentration of insulin-like growth factor-1 (IGF-1), 3-methylhistidine (3MH), albumin, creatinine, glucose and urea concentrations and the urea:creatinine (U:C) of weaner steers of the lowest (L-ADG) and highest (H-ADG) liveweight gain after 91 days of post-weaning grazing (*Phase 1*) at weaning and 91 days after weaning. *Values are least-square means and pooled standard error of the mean (SEM). Columns with a different alphabetical superscripts are significantly different (P < 0.05). NS, interaction term was not significant (P>0.05) and was removed from the model.*

Parameter	Weaning		91 days after weaning			P-value		
	L-ADG	H-ADG	L-ADG	H-ADG	SEM	Stage (S)	Growth (G)	SxG
IGF-1 (ng/mL)	46.7^{b}	38.8^{b}	14.5^{a}	14.6^{a}	3.1	0.001	0.21	NS
Albumin (mmol/L)	36.5^{b}	36.4^{b}	33.7^{a}	34.4^{a}	0.4	0.001	0.44	NS
Creatinine (mmol/L)	148.4^{a}	147.6^{a}	162.7^{b}	159.1^{b}	3.2	0.001	0.50	NS
Glucose (mmol/L)	0.98	1.13	1.19	1.27	0.1	0.18	0.39	NS
Urea (mmol/L)	4.72^{b}	4.53^{b}	3.89^{a}	3.96^{a}	0.1	0.001	0.66	NS
U:C	0.032^{b}	0.031^{b}	0.024^{a}	0.025^{a}	0.001	0.001	0.97	NS

Phase 2

Between the end of Phase 1 and the commencement of Phase 2, there was no change in liveweight of L-ADG steers (147.8 vs. 147.3 kg, respectively) however, H-ADG steers lost liveweight (163 vs. 155.2 kg, respectively) over the three week period. There was no difference in LWG between L-ADG and H-ADG steers (0.37 and 0.39 □ 0.02 kg/d, respectively) during the pen study (weeks 3 to 9) (Table 2). Steers fed the higher protein cavalcade hay had greater LWG than steers fed the lower protein Mekong grass treatment (0.47 and 0.28 □ 0.02 kg/d, respectively) over weeks 3 to 9 of the pen study. Change in HH was almost 2-fold higher for H-ADG steers compared to L-ADG steers when fed the Mekong grass based diet but there was no difference in HH change between L- and H-ADG fed cavalcade hay.

Serum albumin, creatinine, glucose and urea concentration and U:C were not significantly different between H-ADG and L-ADG steers at the commencement of the pen study. At the end of the pen study there was no difference in the concentration of IGF-1, metabolites and the U:C in the serum of steers of different post-weaning growth rates (Table 2). The concentration of IGF-1 (27.3 □ 3.2 and 42.3 □□3.1 ng/mL), albumin (31.2 and 34.1 □□0.3 mmol/L), glucose (1.23 and 3.49 □□0.11 mmol/L) and creatinine (116.1 and 128.3 □ 2.01 mmol/L) in the serum was lower at the start compared to the end of the pen study. The concentration of urea (6.43 and 3.97 □ 0.19 mmol/L) and the U:C (0.056 and 0.032 □ 0.002) were higher at the start compared to the end of the pen study. At the end of the pen study, steers fed cavalcade hay had higher serum IGF-1, glucose and urea concentration and higher U:C than steers fed Mekong grass. In contrast, the serum creatinine

concentration was higher in steers fed Mekong grass compared to those fed cavalcade. Serum albumin concentration did not differ between steers fed either cavalcade or Mekong grass diets.

Rumen ammonia-N concentration was not significantly different between H-ADG (86.9 □ 4.6 mg/L) and L-ADG (83.2 □ 4.6 mg/L) steers at the commencement of the pen study. At the end of the pen study rumen ammonia-N concentration was greater for steers fed cavalcade hay (84.1 □ 3.8 mg/L) compared to the Mekong grass treatment (29.9 □ 3.8 mg/L) and was greater for H-ADG (63.0 □ 3.8 mg/L) compared with L-ADG (51.0 □ 3.8 mg/L) steers.

Table 2. Liveweight gain (LWG), change in hip height (HH change) and the concentration of serum insulin-like growth factor-1 (IGF-1), 3-methylhistidine (3MH), albumin, creatinine, glucose, urea and the urea:creatinine (U:C) and 3MH:creatinine (3MH:C) and the concentration of rumen ammonia-N of steers of the lowest (L-ADG) and highest (H-ADG) average daily gain after 90 days of post-weaning grazing (*Phase 1*) fed either low protein Mekong grass (Mek) or higher protein cavalcade (Cav) hay *ad libitum* in pens (*Phase 2*). *Values are least-square means and pooled standard error of the mean (SEM). Different alphabetical superscripts across a row indicate significances between treatments (P<0.05). NS, interaction term was not significant (P>0.05) and was removed from the model.*

Parameter	Treatment					P-value		
	L-ADG Mek	H-ADG Mek	L-ADG Cav	H-ADG Cav	SEM	Diet (D)	Growth (G)	DxG
Animal measurements								
LWG (kg/d)	0.291[a]	0.274[a]	0.447[b]	0.499[b]	0.03	0.001	0.49	NS
HH change (mm/100 d)	24.9[a]	42.6[b]	35.1[ab]	41.1[ab]	6.1	0.056	0.42	NS
Serum IGF-1 and metabolites								
IGF-1 (ng/mL)	36.0[ab]	29.4[a]	55.0[b]	48.7[ab]	7.1	0.009	0.36	NS
Albumin (mmol/L)	34.1	34.7	33.8	34.0	0.63	0.53	0.37	NS
Creatinine (mmol/L)	134.8[b]	139.0[b]	119.6[a]	119.7[a]	4.09	0.001	0.60	NS
Glucose (mmol/L)	3.1[a]	2.9[a]	4.0[b]	3.9[b]	0.27	0.001	0.63	NS
Urea (mmol/L)	1.8[a]	2.2[a]	6.0[b]	5.8[b]	0.21	0.001	0.63	NS
U:C	0.014[a]	0.016[a]	0.051[b]	0.049[b]	0.002	0.001	0.87	NS
Rumen ammonia-N (NH_3N)								
Rumen NH_3N (mg/L)	22.9[a]	36.9[a]	79.0[b]	89.1[b]	5.5	0.001	0.038	NS

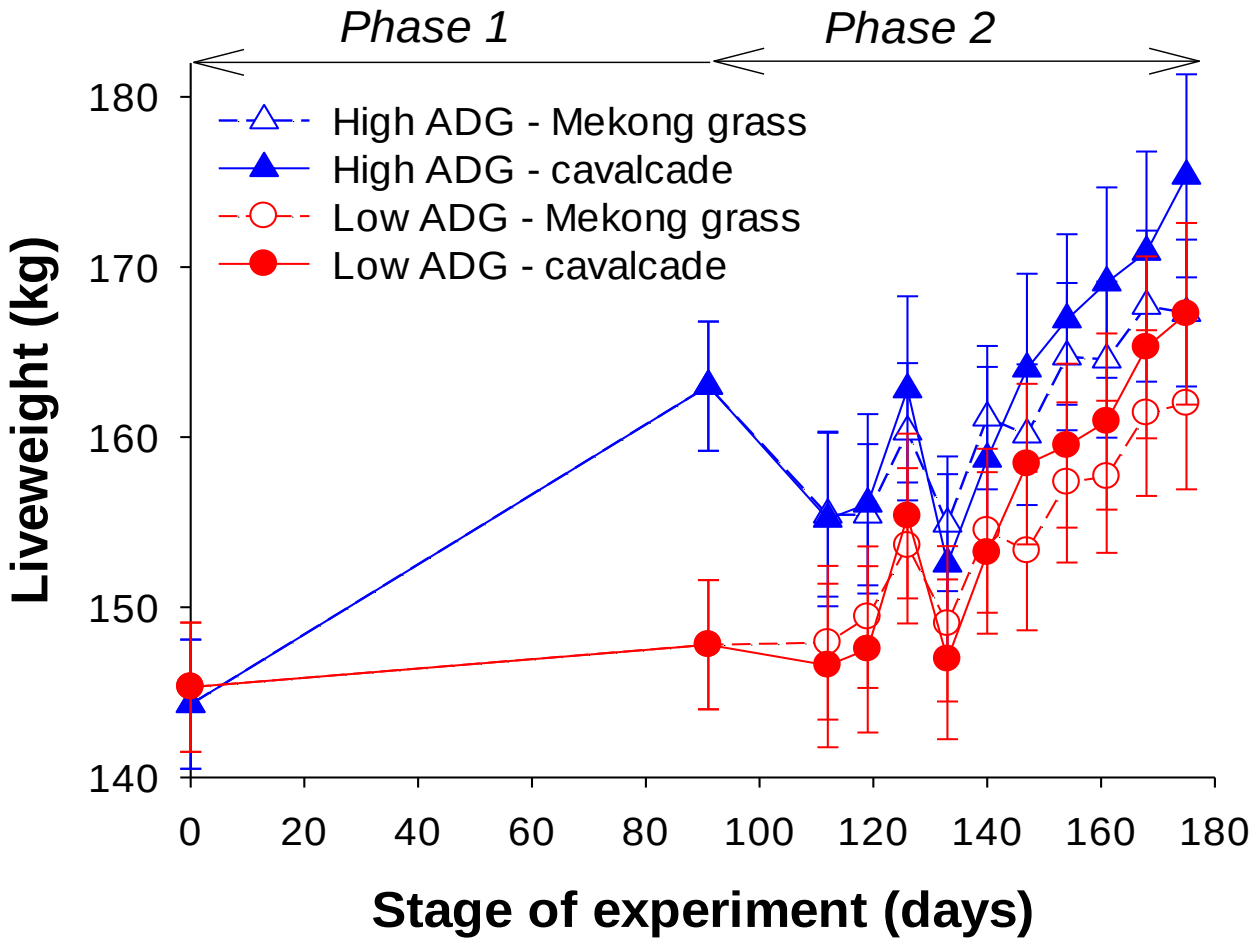

Figure 1. Liveweight of weaner steers of the lowest (Low) and highest (High) average daily liveweight gain (ADG) grazing dry season pastures for 91 days post-weaning (*Phase 1*) and then fed low protein Mekong grass or higher protein cavalcade hay in pens (*Phase 2*) for 63 days.

Phase 3

Steers that had higher LWG during Phase 1, had higher LWG than L-ADG steers when grazing wet season pasture as a single mob during Phase 3 although the difference was quite small (0.58 and 0.55 □ 0.01 kg/d, respectively; P<0.05). Steers fed the Mekong grass diet during Phase 2 tended to have a higher LWG than steers fed cavalcade hay, when subsequently grazing wet season pasture as a single mob during Phase 3 (0.58 and 0.55 □ 0.01 kg/d, respectively; P=0.066), once again the difference being quite small. Over the wet season (early October to early April) H-ADG tended to gain more liveweight than L-ADG steers (99.6 and 94.4 □ 2.1 kg liveweight; P=0.09). At the end of the experiment, H-ADG steers were approximately 12 kg heavier than L-ADG steers (271.6 and 259.8 □ 4.5 kg, respectively; P=0.07). The final average liveweight of steers at the end of the experiment was 258.5, 261.0, 267.8 and 275.3 kg for L-ADG Mekong grass, L-ADG cavalcade, H-ADG Mekong grass and H-ADG cavalcade, respectively (Figure 2). There was no significant

difference in HH change between L-ADG and H-ADG steers grazing wet season pastures (71.2 and 75.7 □ 2.0 mm/100 d, respectively).

There was positive correlation between liveweight and HH of steers at the end of the wet season grazing period (r=0.63; P<0.001). Liveweight at the end of Phase 3 was positively correlated with liveweight (r=0.74; P<0.001) and HH (r=0.49; P<0.001) at weaning. Serum IGF-1 concentration at weaning was positively correlated with liveweight (r=0.40; P<0.001) but not HH at the end of Phase 3.

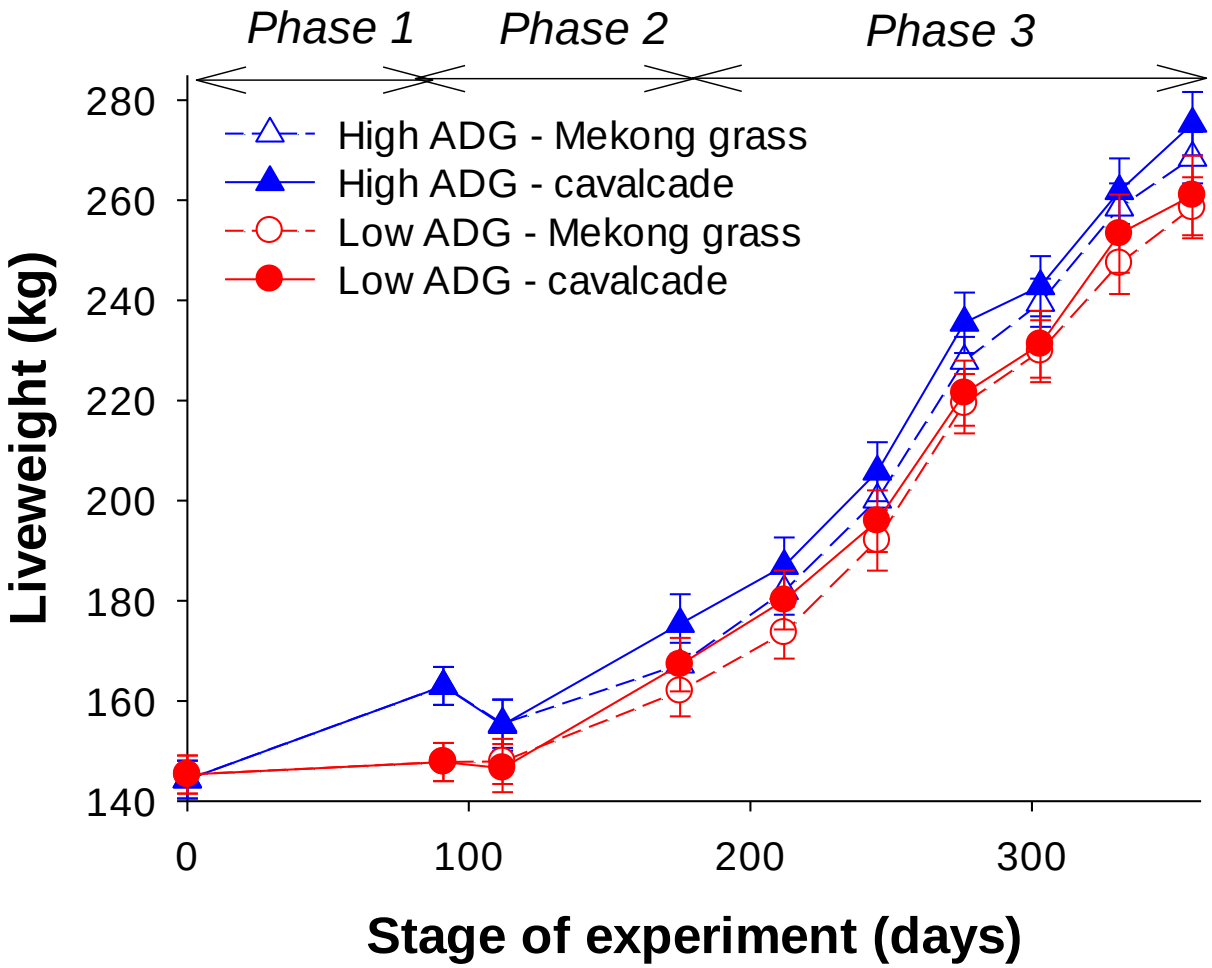

Figure 2. Change in liveweight of weaner steers of the lowest (Low) and highest (High) average daily liveweight gain (ADG) grazing dry season pastures for 91 days post-weaning (*Phase 1*), followed by a 63 day period in pens fed low protein Mekong grass or higher protein cavalcade hay (*Phase 2*) and a 180 day period grazing wet season pastures (*Phase 3*).

5 Discussion

The results confirm that within a mob, Bos indicus weaner growth rates in commercial beef herds in northern Australia may be highly variable. This variability does not appear to be related to the nutrient status of the animals, as there were no differences in plasma albumin, creatinine, glucose or urea concentrations between the fastest and slowest growing steers at weaning or 91 days later. A response to dietary protein was evident regardless of growth rate during the post-weaning grazing period. Possible reasons for the variation in post-weaning growth may include stress responses to the weaning and marking processes, which result in negative impacts on weaner performance in the period immediately after weaning setting up a weight difference which is never regained completely in the subsequent periods. It is unlikely that the variability in post-weaning growth rate is genetic or a genotype x diet quality interaction given that the animals responded similarly when provided with identical diets under pen feeding conditions.

Change in liveweight and hip height

Steers that grew at higher (0.21 kg/d) and lower (0.03 kg/d) growth rates over the 91 day period after weaning, grew at similar rates when fed a higher protein cavalcade hay (0.47 kg/d) or moderate protein Mekong grass based diet (0.28 kg/d) in pens. This suggests that the variability in LWG 91 days after weaning is not permanent. However, when the animals subsequently grazed wet season pastures as a single mob, they tended to separate into their post-weaning growth rate groups but these small differences would not be practically important. While a genetic reason for the difference in growth rates post-weaning and over the wet season grazing period cannot be ruled out, it appears unlikely and is probably not related to differences in intake, maintenance energy requirements or the efficiency of use of energy per se, as the animals performed the same when fed two different diets under controlled experimental conditions. There is a possibility that the differences observed between the two groups over the two grazing periods are related to grazing behaviour and energy expenditure associated with that, albeit to achieve a similar metabolic status either through differences in grazing activity (i.e. some animals may expend less energy grazing to achieve the same nutrient intake as other animals in the mob), or differences in the energy substrates used to maintain a similar metabolic state. Another possible factor responsible for the immediate divergence after weaning could be the variable response to the weaning process and also in supplement intake, both of which are known to vary between animals. Nevertheless, during the wet season grazing period a difference of only 30 g/head.d was detected between the two groups and by the end of the experiment (~12 months) there was only approximately 12 kg (i.e. <5%) difference in liveweight between steers that were of higher and lower growth rates during the post-weaning period. This 12 kg at the end of 12 months is comparable to the 15 kg difference in liveweight evident in the extreme divergent liveweight steers selected 91 days after weaning. This suggests that while those slower growing weaners do not catch up to the faster growing weaners, they do not continue to diverge. While this difference of 12 kg over 12 months tended to be statistically different (P<0.07), it is unlikely to be biologically or economically meaningful under commercial scenarios.

Skeletal size is linked to liveweight in cattle. In the present study HH was correlated to liveweight at each stage of the experiment, in addition HH at weaning was correlated with both liveweight and HH of animals approximately 12 months after weaning. A strong genetic correlation has been reported

between HH and liveweight at weaning, and HH at 18 months of age in Brahman cattle (Vargas *et al*., 2000), suggesting that manipulations of HH at an early age (around weaning) will result in greater liveweight approximately 12 months later. Interestingly, change in HH was similar for L- and H-ADG steers over the 91 day post-weaning period, despite the difference in LWG, and the rates measured here (26 mm/100 d for the entire group) are comparable to the low change in HH measured for *Bos indicus* steers fed a low P diet (27 mm/100 d; Quigley, *unpublished*). Similarly, there was no difference in HH between the L- and H-ADG steers during the wet season grazing period (73 mm/100 d for the entire group). The rate of skeletal elongation during the wet season was almost 3-fold higher than that in the dry season. Given that it appears that there are no compensatory gains in HH change in cattle (Quigley, *unpublished*) and the strong link between liveweight and HH, strategies that can increase HH change during the post-weaning period may increase LWG over the subsequent wet season. The reason for the difference in HH change between L- and H-ADG steers fed Mekong grass during *Phase 2* is unknown. This is in contrast to the result during *Phase 1*, where no difference was measured between the L- and H-ADG steers when grazing a similarly low protein basal diet.

Change in metabolites

Serum concentration of albumin, creatinine, glucose and urea and the U:C did not differ between L-ADG and H-ADG steers, either at weaning or 91 days post-weaning. The results suggest that the L-ADG and H-ADG animals were metabolically similar at both time points, and indicate that there was no difference in the animal's nutritional status, or at least the ability of the two groups of animals to maintain relatively similar metabolic states. As measurements and samples were collected 91 days after weaning, rather than closer to weaning, we cannot say what the immediate effects of weaning and marking were on the performance of these animals over the 91 day period after weaning.

Steers fed the Mekong grass diet had lower rumen ammonia concentrations and lower serum urea concentrations indicative of an immediate dietary protein deficiency, which was unable to be overcome through muscle catabolism, decreased urinary N excretion or increased urea recycling. The lack of a difference in the plasma albumin concentration between steers fed the two diets suggests that these differences are not chronic and could be overcome through provision of additional protein in the diet. A reduction in serum albumin was only detected after 13 weeks of feeding a protein deficient diet to sheep (Sahoo et al., 2009), suggesting that albumin may be a suitable indicator of longer-term protein status of ruminants, rather than immediate protein status. The elevated creatinine concentration in steers fed the Mekong grass based diet would suggest that these animals were undergoing muscle catabolism to meet energy requirements, or alternatively that kidney filtration and urinary excretion of creatinine was decreased in these animals, in an attempt to recycle urea back into the rumen in response to the lower protein content and intake of the diet. Despite the increased serum creatinine concentration, serum glucose concentration was lower in steers fed the Mekong grass based diet, suggesting that not only was energy intake lower for these animals but they were also unable to maintain energy homeostasis from alternate pathways (e.g. gluconeogenesis).

Insulin-like growth factor-1

Insulin-like growth factor-1 concentration did not differ between animals that were divergent in LWG during the post-weaning period, at any stage of the experiment, which is in contrast to the findings of Turnbull (*pers*. *comm*.). The result of Turnbull was based on a single sample collected 100 days after weaning and on a small number of animals only, which may account for the different findings between the experiments. Differences in IGF-1 concentration were measured between weaning and 91 days after weaning, and also in response to the higher and lower protein content diets and were positively correlated with steer liveweight at each stage of the experiment at which it was measured. The actual IGF-1 concentration measured in this experiment was lower than most other values reported in the literature, which are typically greater than 100 ng/mL (Moore *et al*., 2005; Barwick *et al*., 2009; Wu *et al*., 2009). Although this is variable and is influenced by genotype (*Bos indicus* tend to have higher IGF-1 concentration than *Bos taurus*; Caldwell *et al*., 2011), age (IGF-1 concentration tends to increase with increasing age; Plouzek and Trenkle, 1991), sex (IGF-1 concentration is higher in bulls than castrated males and females; Poulzek and Trenkle, 1991) and nutritional status (Houseknecht *et al*., 1989; Liu *et al*., 1997) of the animals. The concentration measured in the current experiment was similar to that measured for a similar class of cattle (Turnbull, *pers*. *comm*.), *Bos indicus* and *Bos taurus* cows during the post-partum period (Spicer *et al*., 2002), 18 month old *Bos indicus* heifers (Hill *et al*., 1999) and Holstein calves less than 3 months of age (Graham *et al*., 2010).

In the present study, circulating IGF-1 concentration decreased between weaning and 91 days post-weaning. Serum IGF-1 concentration in cattle generally increased with age prior to weaning and then decreased at weaning and returned to pre-weaning concentration when previously fed calves were re-fed milk replacer (Breier *et al*., 1988). The decrease in IGF-1 concentration post-weaning is likely to be temporary and may be related to a change in diet, colostrum and milk (Elfstrand *et al*., 2002) contain high and low concentrations of IGF-1 respectively, or more likely to a reduction in feed intake that occurs immediately after weaning. However, this does not appear to be the case in the present experiment with the concentration remaining lower 91 days after weaning, compared with at weaning. It is likely that this decrease is related to protein status or dry matter intake of the animals (Houseknecht *et al*., 1989; Liu *et al*., 1997), as indicated by lower serum albumin and urea concentrations evident 91 days post-weaning and the response of circulating IGF-1 to the higher protein cavalcade hay during *Phase 2*. The response of IGF-1 to dietary protein content of the diet was evident during *Phase 2* of this experiment, where steers fed cavalcade hay had higher circulating IGF-1 concentration than steers fed the Mekong grass based diet. The results emphasise the importance of dietary protein supply to weaned calves over the dry season to increase serum IGF-1 concentration and LWG. It is unclear if IGF-1 concentration is affected differently by the form of dietary N (i.e. true protein vs non-protein-N), and this warrants further investigation, as do other nutritional strategies to manipulate circulating IGF-1 concentration of weaner cattle in northern Australian beef cattle herds.

Given the strong evidence that supports a direct effect of IGF-1 on protein accretion in ruminants and the influence of nutrient status on IGF-1 concentration, it is not surprising that the steers monitored in this experiment had low LWG and low serum IGF-1 concentration. A decrease in circulating IGF-1 in response to nutrient restriction would reduce tissue accretion and allow limited

nutrient supply to be directed to maintenance rather than production. If IGF-1 is involved in the regulation of post-weaning LWG, and there was a positive correlation between change in IGF-1 concentration and liveweight change between weaning and 91 days after weaning, any strategies that can increase the circulating IGF-1 concentration, inhibit the effect of binding proteins or decrease degradation rates may result in increases in LWG of steers over the dry season after weaning. Hormone growth promotants (Revalor-S) have increased serum IGF-1 concentration, feed:gain and ADG of steers fed a concentrate based diet (Pampusch *et al*., 2003). Treatment with bST similarly increased circulating IGF-1 in ruminants, with the response dependent on the nutritional status of the implanted animals (Elsasser *et al*., 1989; Rausch *et al*., 2002). Increased protein supply (Liu *et al*., 1997) and increased energy intake (Houseknecht *et al*., 1989; Hayden *et al*., 1993) also increase the circulating IGF-1 concentration in ruminants, so any supplementation or management strategies that can increase protein supply to, or energy intake of, weaners will increase circulating IGF-1 and LWG.

6 Conclusions

1. Variation exists in post-weaning LWG of *Bos indicus* steers grazing dry season pastures under commercial conditions. However, within this mob after approximately 12 months of grazing together there was only 12 kg difference in liveweight between steers that had different LWG over three months post-weaning, which is unlikely to be of biological or economic significance.

2. Differences in liveweight 91 days after weaning are essentially maintained over 12 months. Any management strategies implemented that aim to increase the tail of the weaner mob, would need to consider the costs and benefits associated with implementation in relation to a modest 12 kg increase in liveweight over a 12 month period measured in the present experiment.

3. There are no differences in LWG of weaner steers that had different LWG post-weaning, when fed either higher or lower CP forages in pens (steers fed higher protein diets in pens had higher LWG than steers fed lower protein diets, regardless of post-weaning LWG). Suggesting that the differences in liveweight observed after weaning are not genetic in origin but are a function of differences which emerge during the weaning process.

4. There are no differences between weaners selected post-weaning on LWG in rumen ammonia-N concentration, which was higher for steers fed a higher protein compared to a lower protein diet. This indicates that differences in post-weaning LWG are not related to rumen function, in support of earlier work by Turnbull *et al*. (2008).

5. Insulin-like growth factor-1 concentration was positively correlated with liveweight at all stages of the experiment. Strategies to increase the IGF-1 concentration in weaned cattle grazing low protein pastures during the dry season should promote LWG.

6. Measurements of the metabolites examined in the current experiment provide little or no information on the variation in LWG evident in northern Australian beef cattle after weaning.

7. Variation in LWG in cattle after weaning is probably related to the stress response and recovery associated with weaning and marking, or possibly grazing behaviour and supplement intake of young steers, rather than any genetic or disease factors.

8. A more detailed examination of the response of animals to weaning and marking in the period immediately after these events is warranted to develop strategies to better manage animals during that time. It is likely that implementation of management strategies around weaning will improve the liveweight of weaners during the immediate post-weaning period and at approximately 12 months after weaning.

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8 References

Barwick SA, Wolcott ML, Johnston DJ, Burrow HM and Sullivan MT. 2009. Genetics of steer daily and residual feed intake in two tropical beef genotypes, and relationships among intake, body composition, growth and other post-weaning measures. *Animal Production Science* **49**, 351-366.

Bishop MD, Simmen RCM, Simmen FA and Davis ME. 1989. The relationship of insulin-like growth factor-1 with postweaning performance of Angus beef cattle. *Journal of Animal Science* **67**, 2872-2880.

Breir BH, Glukman PD and Bass JJ. 1988. Plasma concentrations of insulin-like growth factor-1 and insulin in the infant calf: ontogeny and influence of altered nutrition. *Journal of Endocrinology* **119**, 43-50.

Caldwell LC, Chase Jr. CC, Riley DG, Coleman SW, Phillips WA, Spicer LJ, Welsh Jr. TH and Randell RD. 2011. The influence of tropical adaptation on plasma concentrations of IGF-1 in purebred and crossbred beef cattle. *Journal of Animal Science* **89**, 4017-4022.

Elfstrand L, Lindmark-Mansson H, Paulsson M, Nyberg L and Akesson B. 2002. Immunoglobulins, growth factors and growth hormone in bovine colostrum and the effects of processing. *International Dairy Journal* **12**, 879-887.

Elsasser TH, Rumsey TS and Hammond AC. 1989. Influence of diet on basal and growth hormone-stimulated plasma concentrations of IGF-1 in beef cattle. *Journal of Animal Science* **67**, 128-141.

Gopinath R and Kitts WD. 1984. Growth, N□-methylhistidine excretion and muscle protein degradation in growing beef steers. *Journal of Animal Science* **59**, 1262-1269.

Graham TW, Breher JE, Farver TB, Cullor JS, Kehrli Jr. ME and Oberbauer AM. 2010. Biological markers of neonatal calf performance: The relationship of insulin-like growth factor-1, zinc, and copper to poor neonatal growth. *Journal of Animal Science* **88**, 2585-2593.

Hayden JM, Williams JE and Collier RJ. 1993. Plasma growth hormone, insulin-like growth factor-1, insulin and thyroid hormone association with body protein and fat accretion in steers undergoing compensatory gain after diet energy restriction. *Journal of Animal Science* **71**, 3327-3338.

Hill RA, Hunter RA, Lindsay DB and Owens PC. 1999. Action of Long(R^3)-insulin-like growth factor-1 on protein metabolism in beef heifers. *Domestic Animal Endocrinology* **16**, 219-229.

Houseknecht KL, Boggs DL, Campion DR, Sartin JL, Kiser TE, Rampacek GB and Amos HE. 1988. Effect of dietary energy source and level on serum growth hormone, insulin-like growth factor-1, growth and body composition in beef heifers. *Journal of Animal Science* **66**, 2916-2923.

Lemal D, Renaville V, Claes V, Ruelle L, Fabry J, Burny A, Underwood LE and Ketelslegers J-M. 1989. Effect of pituitary somatotropin injections on plasma insulin-like growth factor-1 and somatotropin profiles in growing heifers. *Journal of Animal Science* **67**, 2715-2723.

Liu SM, MacLeod NA, Luo QJ, Chen XB, Kyle DJ, Nicol P, Harbron CG and Orskov ER. 1997. The effects of acute and chronic protein depletion and accretion on plasma concentrations of insulin-like growth factor-1, fibronectin and total protein for ruminants nourished by intragastric infusion of nutrients. *British Journal of Nutrition* **78**, 411-426.

McCarthy FD, Bergen WG and Hawkins DR. 1983. Muscle protein turnover in cattle of differing genetic backgrounds as measured by N□-methylhistidine excretion. *Journal of Nutrition* **113**, 2455-2463.

Moore KL, Johnston DJ, Graser, H-U and Herd R. 2005. Genetic and phenotypic relationships between insulin-like growth factor-1 (IGF-1) and net feed intake, fat and growth traits in Angus beef cattle. *Australian Journal of Agricultural Research* **56**, 211-218.

Oddy KH and Owens PC. 1996. Insulin-like growth factor-1 inhibits degradation and improves retention of protein in hindlimb muscle of lambs, *American Journal of Physiology (Endocrinology and Metabolism)* **34**, E973-E982.

Pampusch MS, Johnson BJ, White ME, Hathaway MR, Dunn JD, Waylan AT and Dayton WR. 2003. Time course changes in growth factor mRNA levels in muscle of steroid-implanted and non-implanted steers. *Journal of Animal Science* **81**, 2733-2740.

Phillips GJ, Citron TL, Sage JS, Cummins KA, Cecava MJ and McNamara JP. 2003. Adaptations in body muscle and fat in transition dairy cattle fed differing amounts of protein and methionine hydroxyl analog. *Journal of Dairy Science* **86**, 3634-3647.

Plouzek CA and Trenkle A. 1991. Insulin-like growth factor-1 concentrations in plasma of intact and castrated male and female cattle at four ages. *Domestic Animal Endocrinology* **8**, 73-79.

Rausch MI, Tripp MW, Govoni KE, Zang W, Webert WJ, Crooker BA, Hoagland TA and Zinn SA. 2002. The influence of level of feeding on growth and serum insulin-like growth factor-1 and insulin-like growth factor binding proteins in growing beef cattle supplemented with somatotropin. *Journal of Animal Science* **80**, 94-100.

Sahoo A, Pattanaik AK and Goswami TK. 2009. Immunobiochemical status of sheep exposed to periods of experimental protein deficit and realimentation. *Journal of Animal Science* **87**, 2664-2673.

Spicer LJ, Chase Jr. CC and Rutter LM. 2002. Relationship between serum insulin-like growth factor-1 and genotype during the postpartum interval in beef cows. *Journal of Animal Science* **80**, 716-722.

Turnbull KE, Quigley SP, Kidd JF, McLennan SR and Poppi DP. 2008. Differences in utilisation of low-quality hay between cattle selected on growth rate after weaning. *Proceedings of the Australian Society of Animal Production* **27**, 53.

Vargas CA, Elzo MA, Chase Jr. CC and Olson TA. 2000. Genetic parameters and relationships between hip height and weight in Brahman cattle. *Journal of Animal Science* **78**, 3045-3052.

Wu MZ, Wang AH, Bernard GC, Hall JB, Beal WE, Akers RM, Boisclair YR and Jiang HL. 2008. Increased degradation of insulin-like growth factor-1 in serum from feed-deprived steers. *Domestic Animal Endocrinology* **35**, 343-351.

Yambayamba ES, Price MA and Foxcroft GR. 1996. Hormonal status, metabolic changes, and resting metabolic rate in beef heifers undergoing compensatory growth. *Journal of Animal Science* **74**, 57-69.