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The effect of maternal liveweight gain of 15-month-old beef heifers on foetal weight

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ABSTRACT

Dystocia in 2-year-old beef heifers is a major factor limiting the willingness of farmers to breed 15-month-old heifers in New Zealand. Foetal oversize relative to the size of the heifer is a contributor to dystocia. This study aimed to determine the effect on foetal weight of maternal liveweight change during joining and early pregnancy. Sixteen 15-month-old Angus heifers were allocated to moderate (444 ± 30 g/day) or low (109 ± 28 g/day) liveweight-gain treatments for 21 days prior to and 91 days after insemination. Gravid uteri were recovered on day 91 of pregnancy. Foetuses from the low-fed heifers tended to be heavier than foetuses from the moderate-fed heifers (215.6 ± 6.7 g and 198.4 ± 6.8 g, respectively; P=0.09). Foetal weight per 100 kg maternal weight was greater (P<0.01) in foetuses from the low treatment (58.9 ± 2.5 g/100 kg) than in foetuses from the moderate treatment (47.4 ± 2.6 g/100 kg). Weight of foetal membranes was greater (P<0.05) in the low treatment (262 ± 16 g) than the moderate treatment (213 ± 16 g). Foetal weight was correlated with cotyledon weight (r=0.59; P<0.05). Moderate compared with low maternal liveweight gain reduced foetal weight relative to maternal live weight.

Keywords: Foetal weight; nutrition; heifers; beef cattle; early pregnancy.

INTRODUCTION

Breeding heifers for the first time at 15 months of age instead of 27 months of age has been shown to increase the productivity of the beef breeding cow herd by 0.7 calves per cow lifetime (Nicol & Nicoll, 1987), yet it is not widely practiced in New Zealand, with only 30% of 15-month-old beef heifers joined with a bull in 2003 (Anonymous, 2003). The expectation of a high incidence of calving difficulty in beef heifers calving at 2 years of age has been suggested as one reason deterring farmers from breeding their beef heifers at 15-months of age (Hickson *et al.*, 2006).

Birth weight of the calf was the most important single contributor to dystocia in 2-year-old beef heifers (Rutter *et al.*, 1983; Rice, 1994; Arthur *et al.*, 2000), and lighter calves were less likely to experience dystocia than heavier calves (Laster *et al.*, 1973; Smith *et al.*, 1976). Therefore, reducing birth weight of calves should decrease the incidence of dystocia in 2-year-old beef heifers and, consequently, allow more farmers to breed beef heifers at 15 months of age.

Birth weight is determined by foetal growth rate throughout gestation, which is in turn determined by a combination of genetic and environmental factors (Hickson *et al.*, 2006). Substantial research has been carried out to determine the effects of feeding level or liveweight change of the dam in late pregnancy on birth weight of the calf and the incidence of dystocia (Laster, 1974; Wiltbank & Remmenga, 1982; Spitzer *et al.*, 1995); however, little is known about the effect of nutrition in early pregnancy on foetal and placental development in cattle. In adolescent ewes, over-nourishment during pregnancy was associated with decreased foetal and placental weight at days 95 and 128 of gestation (Wallace *et al.*, 1996; Wallace *et al.*, 2002).

The aim of this study was to determine the effect of maternal liveweight gain of 15-month-old Angus heifers on foetal and placental growth and development.

MATERIALS AND METHODS

Treatments

Liveweight gain treatments were imposed under pastoral grazing conditions on 56 fifteen-month-old Angus heifers from 21 days (1 oestrus cycle) prior to insemination until day 91 of pregnancy (end of first trimester). Treatments consisted of moderate maternal liveweight gain (target 500 g/day) and low maternal liveweight gain (target 100 g/day). Unfasted live weights were recorded at monthly intervals throughout the treatment period. Oestrus was synchronised in the heifers using progesterone-containing controlled internal drug release devices (1.38 g progesterone; Pharmacia Limited, Auckland, New Zealand) and heifers were inseminated to observed oestrus with semen from 5 Angus bulls.

Twenty-five heifers (45%; 12 moderate, 13 low) conceived to AI and all other heifers were removed from the trial at pregnancy diagnosis 42 days post insemination. On day 89 of pregnancy, 8 of the heaviest heifers in the low treatment were selected for slaughter. The heaviest heifers were selected to ensure that they met the processing plant's minimum carcass-weight requirement. Eight heifers from the moderate treatment were then selected so that the 2 slaughter groups were balanced for service sire and the liveweight difference between the 2 slaughter groups was consistent with the liveweight difference that existed between the treatment groups when all pregnant heifers were included.

Measurements

Unfasted maternal live weight was recorded on day 89 of pregnancy. On day 91 of pregnancy, heifers were slaughtered through a commercial processing plant, and the gravid uteri were recovered. The uteri were weighed immediately after removal from the heifers, then transported back to the laboratory and refrigerated overnight. The day after slaughter, excess tissue was trimmed from the uterus before the gravid uterus was weighed intact. The excess tissue was also weighed to confirm that no weight loss had occurred during refrigeration. The uterus was pierced and drained and the foetus removed. Placentomes were separated and the cotyledons were dissected from the foetal membranes. Weight of the foetal membranes and the total cotyledons was recorded. Number of cotyledons was also recorded. Foetuses were weighed and crown-rump length, head circumference, thoracic girth and right and left forelimb cannon bone length were measured. Foetal weight per 100 kg maternal weight was calculated as:

$$\frac{\textit{foetal weight}_{\textit{day }91}}{\textit{maternal live weight}_{\textit{day }89}} \times 100$$

Heifers were managed on Massey University's Tuapaka Farm (10 km east of Palmerston North, New Zealand) from the start of the experiment until day 21 of pregnancy, and on Massey University's Keeble Farm from day 21 of pregnancy until slaughter (5 km southeast of Palmerston North, New Zealand). The study was conducted in accordance with the Massey University Animal Ethics Committee.

Statistical methods

Data were analysed using the PROC MIXED procedure in SAS v8 (SAS Institute Inc, Cary, NC, USA, 2001). The model for uterine and placental parameters considered treatment as a fixed effect. The model for foetal weight and foetal weight per 100 kg maternal weight included treatment and sex of the foetus as fixed effects. Foetal weight was fitted as a covariate and the relevant interactions were added to the model for foetal size parameters, however, the inclusion of foetal weight in the model meant that sex of foetus and all interactions were not significant and were removed from the model. Correlations were calculated using the PROC CORR procedure in SAS v8.

RESULTS

Mean live weights of the two groups were not different at the start of the treatment period (367 ± 12 kg for the moderate treatment compared with 358 ± 11 kg for the low treatment). Heifers in the moderate group were heavier than heifers in the low group at insemination (384 ± 12 kg and 356 ± 12 kg, respectively; P<0.05) and at day 89 of pregnancy (413 ± 8 kg and 370 ± 6 kg, respectively; P<0.01). Mean liveweight gain during the treatment period was 444 ± 30 g/day for the moderate group and 109 ± 28 g/day for the low group.

Foetuses from heifers in the low group tended (P=0.09) to be heavier than foetuses from heifers in the moderate group, and foetal weight per 100 kg maternal weight was greater (P<0.01) in the low compared with the moderate group (Table 1). All foetal size parameters except mean forelimb cannon bone length were affected by foetal weight (Table 1). Thoracic girth was the only foetal size

Table 1: Weight and size parameters of foetuses recovered at day 91 of gestation from 15-month-old, Angus heifers that were on a moderate (444 g/day) or low (109 g/day) liveweight-gain treatment from 21 days prior to insemination until day 91 of pregnancy. Values are least squares means ± standard errors.

	Treatment group		P value		
	Moderate	Low	Treatment	Foetal weight	Sex of foetus
n	8	8			
Foetal weight (g)	198.4 ± 6.8	215.6 ± 6.7	0.09		**
Foetal weight/maternal live weight (g/100 kg)	47.4 ± 2.6	58.9 ± 2.5	**		**
Thoracic girth (mm) [a]	114.3 ± 1.2	118.7 ± 1.2	*	***	
Crown-rump length (mm) [a]	153.2 ± 1.7	152.5 ± 1.7	NS	**	
Head circumference (mm) [a]	120.6 ± 1.0	122.0 ± 1.0	NS	***	
Mean cannon bone length (mm) [a]	18.2 ± 0.8	18.6 ± 0.8	NS	NS	

NS = not significant, P>0.05; * P<0.05; ** P<0.01; *** P<0.001.

[a] Sex of foetus was not included in the model for these traits because it had no significant effect.

parameter that was affected by treatment, and was greater (P<0.05) in the low compared with the moderate group. This difference persisted regardless of whether or not foetal weight was fitted as a covariate (data not shown).

Weight of gravid uterus, total weight of cotyledons and number of cotyledons were not different between the groups. Weight of foetal membranes was greater for heifers in the low compared with the moderate liveweight gain treatment (262 ± 16 versus 213 ± 13 g; P<0.05). Foetal weight was correlated with total cotyledon weight (r=0.59; P<0.05) but not with total weight of foetal membranes (r=0.50; P=0.05).

DISCUSSION

The tendency for a greater maternal liveweight gain of heifers to be associated with a reduction in foetal weight that was observed in this study was consistent with that observed in hoggets (Wallace *et al.*, 1996). In contrast, Prior & Laster (1979) reported that differing levels of maternal dietary energy intake did not affect the weight of foetuses recovered at day 91 of gestation from 15-month-old beef heifers; however, feeding treatments were imposed on those heifers only from pregnancy diagnosis at day 35-42 of pregnancy. This result combined with the results of the present study indicated that a limiting effect of high maternal feed intake on foetal growth in cattle may occur prior to day 35 of gestation.

The increased weight of foetal membranes was consistent with the increased foetal weight of the low group; however, there were no differences in cotyledon weight or number between treatments. Cotyledon number was relatively fixed by day 70 of gestation in cattle, although placentomes increased in size and weight and accessory placentation occurred throughout pregnancy as a means of increasing the contact area between foetal and maternal membranes (Laven & Peters, 2001). Furthermore, in the present study, both groups had achieved almost complete caruncle utilisation (data not shown), so there was little scope for the number of cotyledons in the low group to increase beyond that of the moderate group.

Foetal weight was correlated with total cotyledon weight but not with foetal membrane weight, probably reflecting the role of the cotyledons rather than the foetal membranes in providing nutrient transfer capacity and consequently, nutrients, to the foetus. The greater foetal weight of the low group in the absence of an increase in cotyledon or caruncle weight indicated that more nutrients were being transferred from the dam to the foetus per gram of placentome tissue in these heifers. This was consistent with the results of Wallace *et al.* (2002) who reported that overnourished hoggets displayed reduced uterine blood flow, which restricted nutrient availability to the foetus. Rapidly growing adolescent dams may maintain an established anabolic drive to maternal tissue synthesis at the expense of the gradually evolving nutrient requirements of the gravid uterus (Wallace *et al.*, 1996). Reduction of foetal weight in overnourished hoggets was caused by an increase in total energy intake, rather than an increase in protein intake (Wallace *et al.*, 2006).

Heavier foetal membranes in concepti from the low group compared with the moderate group may indicate that these concepti were developing in such a way that they could withstand under-nourishment for the remainder of gestatoin, when greater placental surface area would be required to sustain foetal growth than if the dam was adequately nourished. If the 10% difference in foetal weight observed in this study was maintained until the end of gestation, over-nourishment of 15-month-old beef heifers during joining and early pregnancy may offer a means of managing dystocia by reducing the birth weight of calves in these animals. Further research is needed with greater numbers of animals to further elucidate this effect, and to determine whether differences in foetal weight persist until term.

In conclusion, a moderate rate compared with a low rate of maternal liveweight gain from 21 days prior to conception and for the first trimester of pregnancy tended to result in decreased foetal weight and resulted in decreased weight of foetal membranes in 15-month-old beef heifers. This difference occurred in the absence of any differences in the weight of cotyledons and may be explained by the finding of Wallace *et al.* (2002), that over-nourishment of adolescent dams led to decreased uterine blood flow. Additional studies are required to determine whether an accelerated rate of maternal liveweight gain in early pregnancy offers a practical tool to minimise the incidence of dystocia in 2-year-old beef heifers.

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REFERENCES

Anonymous. 2003: *Agricultural Production Statistics 2003.* www.stats.govt.nz/tables/2002-ag-prod/beef-cattle-tables.htm (accessed 25th August 2006). Statistics New Zealand, Wellington, NZ.

Arthur, P.F.; Archer, J.A.; Melville, G.J. 2000: Factors influencing dystocia and prediction of dystocia in Angus heifers selected for yearling growth rate. *Australian Journal of Agricultural Research* **51**: 147-153.

Hickson, R.E.; Morris, S.T.; Kenyon, P.R.; Lopez-Villalobos, N. 2006: Dystocia in beef heifers: a review of genetic and nutritional influences. *New Zealand Veterinary Journal* **54**: 255-264.

Laster, D.B. 1974: Factors affecting pelvic size and dystocia in beef cattle. *Journal of Animal Science* **38**: 496-503.

Laster, D.B.; Glimp, H.A.; Cundiff, L.V.; Gregory, K.E. 1973: Factors affecting dystocia and the effects of dystocia on subsequent reproduction in beef cattle. *Journal of Animal Science* **36**: 695-705.

Laven, R.A.; Peters, A.R. 2001: Gross morphometry of the bovine placentome during gestation. *Reproduction in Domestic Animals* **36**: 289-296.

Nicol, A.M.; Nicoll, G.B. 1987: Pastures for beef cattle. *In:* Nicol, A.M. *ed.* Livestock Feeding on Pasture Christchurch, NZ, New Zealand Society of Animal Production. pp. 145.

Prior, R.L.; Laster, D.B. 1979: Development of the bovine fetus. *Journal of Animal Science* **48**: 1546-1553.

Rice, L.E. 1994: Dystocia-related risk factors. Veterinary Clinics of North America, Food Animal Practice **10**: 53-68.

Rutter, L.M.; Ray, D.F.; Roubicek, C.B. 1983: Factors affecting and prediction of dystocia in Charolais heifers. *Journal of Animal Science* **57**: 1077-1083.

Smith, G.M.; Laster, D.B.; Gregory, K.E. 1976: Characterization of biological types of cattle. 1. Dystocia and preweaning growth. *Journal of Animal Science* **43**: 27-36.

Spitzer, J.C.; Morrison, D.G.; Wettemann, R.P.; Faulkner, L.C. 1995: Reproductive responses and calf birth and weaning weights as affected by body condition at parturition and postpartum weight gain in primiparous beef cows. *Journal of Animal Science* **73**: 1251-1257.

Wallace, J.M.; Aitken, R.P.; Cheyne, M.A. 1996: Nutrient partitioning and foetal growth in rapidly growing adolescent ewes. *Journal of Reproduction and Fertility* **107**: 183-190.

Wallace, J.M.; Bourke, D.A.; Aitken, R.P.; Leitch, N.; Hay, W.W. 2002: Blood flows and nutrient uptakes in growth-restricted pregnancies induced by over-nourishing adolescent sheep. *American Journal of Physiology-Regulatory Integrative and Comparative Physiology* **282**: R1027-R1036.

Wallace, J.M.; Milne, J.S.; Redmer, D.A.; Aitken, R.P. 2006: Effect of diet composition on pregnancy outcome in over-nourished rapidly growing adolescent sheep. *British Journal of Nutrition* **96**: 1060-1068.

Wiltbank, J.N.; Remmenga, E.E. 1982: Calving difficulty and calf survival in beef cows fed two energy levels. *Theriogenology* **17**: 587-602.