
THE PROCEEDINGS OF THE
NEW ZEALAND SOCIETY
OF
ANIMAL PRODUCTION
VOLUME 62 2002

Effect of maternal nutrition during early and mid-gestation on fetal growth

K. COOPER[1], S. T. MORRIS[1] AND S. N. MCCUTCHEON[2]

[1] Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Palmerston North, New Zealand.

ABSTRACT

Two studies were conducted to examine the effects of maternal nutrition during early and mid-gestation on fetal growth. In the first, crossbred heifers were managed for High (H, 0.6 kg/day) or Low (L, 0.1 kg/day) live weight gains from mating until day 140 of gestation. Treatments were then reversed so that effects of nutrition during early gestation were not confounded by differences in maternal live weight at calving. Maternal liveweights (kg, Mean±SE, n=30/group) were (L vs H) 350.6±4.9 vs 394.3±5.3 ($P<0.001$) at day 140 of gestation and 393.5±5.3 vs 394.4±5.8 ($P>0.05$) at term. Calf birth weights (L vs H) were 30.9±0.7 vs 29.9±0.8 kg ($P>0.05$).

In the second study, 60 Romney ewes were allocated to three nutritional treatments, 0.5 maintenance (M), 1.0M or 1.5M from days 21 to 101 of gestation. At day 101, ewe liveweights were 45.8±1.4, 56.8±1.4 and 69.1±1.4 kg respectively ($P<0.001$). Fetal weights at slaughter (day 101 of gestation) were 1249.9±40.6, 1280.8±38.0 and 1379.8±35.2 g respectively ($P<0.05$).

These results indicate that, although the fetus places a relatively small nutritional demand on the dam in early gestation, fetal development can in some situations be influenced by maternal nutrition, particularly when dams are over- rather than under-fed.

Keywords: Nutrition; fetus; placenta; birth weight; sheep; cattle. Maternal nutrition and fetal growth

INTRODUCTION

Excessively high or low birth weights in sheep and cattle are generally associated with an increase in neonatal mortality rates. Dams carrying large offspring are susceptible to dystocia, putting the life of both offspring and dam at risk (Laster and Gregory, 1973), while neonates with low birth weights suffer from exposure and starvation (McCutcheon *et al*., 1981).

Studies examining the effects of maternal nutrition on fetal growth and hence birth weight have traditionally focused on the second half of gestation. This is because fetal growth follows an exponential curve so that, in early gestation, the fetus has a small nutritional requirement relative to that of the dam. It is therefore generally assumed that differential maternal nutrition at this time is unlikely to influence fetal growth. However, this assumption does not take into account the fact that placental weight reaches its maximum at approximately days 90 and 140 of gestation in sheep and cattle respectively, and may set the pattern for later fetal growth (Alexander, 1964; Owens *et al*., 1995). Levels of maternal nutrition have been shown to have an effect on placental development (Everitt, 1964; Mellor, 1983). Therefore, nutritional modification of placental development in early gestation could lead to altered fetal growth during late gestation.

The objective of the studies reported here was therefore to examine the effects of maternal nutrition during early gestation on fetal and placental growth.

MATERIALS AND METHODS

Experiment One

Thirty-one Hereford x Friesian (H x F) and twenty-nine Hereford x Jersey (H x J) heifers (15 months old) were joined with two Angus bulls for one cycle and randomly allocated by live weight and breed-cross to two nutritional treatment groups until day 140 of gestation. Six did not conceive and were excluded from the final analysis.

Throughout the trial period one group of heifers were fed to gain live weight at 0.60 kg/day (High or H group), while those in the second group were fed to achieve a liveweight gain of 0.10 kg/day (Low or L group). From day 140 of gestation until term, the treatments were reversed so that the effects of early gestation nutrition were not confounded by differences in maternal live weight at calving. The heifers were weighed monthly, and at calving the dam's pre-calving live weight was recorded along with calf birth weight. Calving occurred during the period 27 August to 4 October 1994 (mean calving date 17 September). Although three calves died due to dystocia-related problems at parturition, all calves were weighed and tagged at birth whether they were alive or dead.

Experiment Two

The second study involved 60 mixed-age Romney ewes pregnant to the first cycle of a progesterone-synchronised oestrus. After stratification by live weight, the ewes were allocated to three nutritional treatment groups (Low, L; Control, C; High, H; n=20/group) which involved feeding levels of 0.5, 1.0 and 1.5 times maintenance respectively, from days 21 to 101 of gestation. Maintenance requirements for a 50 kg ewe were assumed to be 0.9 kg DM/ewe/day (10 MJ ME/day) at an energy concentration of 11 MJ ME/kg DM (Robinson, 1983). One ewe died and one other was, at slaughter, found to be carrying lambs conceived during the second cycle. These animals were subsequently excluded from the analysis

[2] Vice-Chancellor's Office, Massey University, Palmerston North, New Zealand.

Ewes were slaughtered on day 101 of gestation by captive bolt pistol and exsanguination. The uterus was removed from the ewe and ligated at the utero-cervical junction. An incision was made along the outer curvature of the gravid uterus and the fetus removed. Each fetus was gently squeezed by hand to remove amniotic fluid. Fetal weight, and the total weight of placentomes ("placental weight") were recorded.

Statistical analysis

Analysis of covariance was used to determine the effects of nutrition during early and mid-gestation on dam liveweights throughout the trial periods, and on calf birth and lamb fetal weights. Calf birth weights were adjusted to a common birth date, and lamb fetal weights adjusted to a common pregnancy rank (single vs twin). Data are expressed as least square means and standard errors for treatment groups and offspring. Statistical analyses were conducted using the computer package 'SAS' (SAS, 1988).

RESULTS

Different levels of maternal nutrition in cattle during early and mid-gestation resulted in maternal live weight differences between the two treatment groups at day 140 of gestation. Heifer liveweights recorded on days 105, 140, 174 and 202 of gestation were significantly ($P<0.05$) different (Figure 1), although no difference in calf birth weights was observed (Table 1).

High and low levels of maternal nutrition in Experiment Two significantly increased and decreased ewe liveweights at day 101 of gestation (Figure 2), the actual liveweights being very close to target weights.

Increased fetal and placental weights were observed in fetuses from H group ewes at day 101 of gestation (Table 2), while low levels of nutrition did not significantly reduce fetal or placental weight in the L group ewes.

TABLE 1: Effects of early gestation nutrition on selected dam and calf liveweights (Mean ± SE), Experiment One.

	Low	High
n	27	27
Dam weight (kg)		
Gestation day 0	340.3 ± 4.5	336.2 ± 4.9
Gestation day 105	365.1 ± 5.0^a	384.3 ± 5.4^b
Gestation day 140	350.6 ± 4.9^a	394.3 ± 5.3^b
Gestation day 252	393.5 ± 5.3	393.4 ± 5.8
Calf (kg)		
Birth weight	30.9 ± 0.7	29.9 ± 0.8

^{ab} Means with different superscripts in the same row are significantly different ($P<0.05$)

FIGURE 1: Mean liveweights of the High (-□-) and Low (-o-) treatment groups throughout gestation, Experiment One. Vertical bars represent the standard error of the mean.

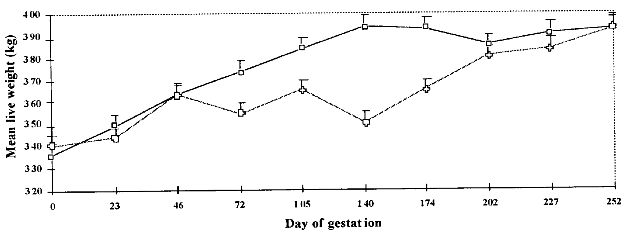
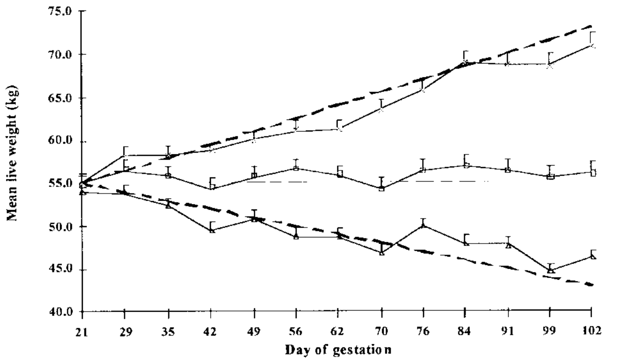


TABLE 2: Effects of nutritional treatment on ewe liveweight, fetal weight and placental weight at day 101 of gestation (Mean ± SE), Experiment Two.

	Low	Control	High
n	19	20	19
Ewe liveweight (kg)	46.1 ± 1.5^a	56.8 ± 1.4^b	69.1 ± 1.4^c
Fetal weight (g)	1249.9 ± 40.6^a	1280.8 ± 38.0^a	1379.8 ± 35.2^b
Placental weight (g)	584.9 ± 32.0^a	631.0 ± 30.7^a	702.9 ± 29.7^b

^{ab} Means with different superscripts are significantly different ($P<0.05$)

FIGURE 2: Liveweights of the three treatment groups, H (-x-), C (-o-), and L (-□-), Experiment Two. The vertical bars represent standard errors, and the dashed lines are the target liveweights for the three groups.



DISCUSSION

In Experiment One, a liveweight difference of 43.7 kg was achieved between the two groups of heifers as a result of differing levels of maternal nutrition during the first half of gestation. Despite this liveweight difference, calf birth weights were not different between the groups. This result is consistent with that of Prior and Laster (1979) who fed heifers three nutritional levels from day 42 of gestation until the heifers were progressively slaughtered between days 90 and 245 of gestation. Fetal weights at slaughter were not affected when heifers were fed for liveweight gains of 0.1, 0.6 and 1.1 kg/head/day. Thus, in cattle which are at least maintaining live weight, early pregnancy nutrition does not appear to influence fetal growth.

Experiment Two was designed to examine directly the effects of increased and decreased maternal nutrition on fetal growth during early and mid-gestation, while eliminating the potential for the dam to compensate for earlier treatments during late gestation. The nutritional treatments generated a difference of 23 kg live weight between the H and L groups. While a 7.9 kg (16.8%) liveweight decrease in the L group did not significantly reduce fetal or placental weights at day 101 of gestation, increased fetal and placental weights were observed in the H group ewes, which gained 15.6 kg (21.4%) live weight over the trial period.

McCrabb *et al*., (1991) fed ewes of 55 kg mating weight to gain ca. 3 kg or lose 12 kg live weight over the first 96 days of gestation. Fetal weights at day 96 were not influenced by treatment but placental weights were greater in the restricted group. This contrasts with the present results in which a similar difference in liveweight (10.7 kg medium vs low group) had no effect on placental weight, but provides no information on the impact of enhanced maternal nutrition. Faichney and White (1987) observed increased fetal and placental weights in ewes subjected to restricted nutrition from days 50-100 of gestation compared to those maintained over the same period. Again, however, they did not examine the effects of above-maintenance feeding.

Thus the unique aspect of our study lies in the observation that fetal weight may be increased by generous allowances during the first 100 days of gestation. That is, while fetuses at this stage do not require high levels of nutrition during this time (due to their small size), fetal growth may be enhanced by improved maternal nutrition. The concurrent increase in placental weight suggests that the effect may be mediated via enhanced placental development. It will now be important to determine whether such an effect, once established, can be maintained until term to the benefit of lamb growth and survival. The fact that the effect was observed in both single- and twin-bearing ewes suggests that it might be used in conjunction with pregnancy diagnosis to selectively enhance the growth and neonatal survival of twins.

ACKNOWLEDGEMENTS

The C. Alma Baker Trust Provided funds for Experiment One. This is gratefully acknowledged.

REFERENCES

Alexander, G. 1964. Studies on the placenta of the sheep (Ovis aries L.) Placental size. *Journal of Reproduction and Fertility* **7:** 289-305.

Everitt, G.C. 1964. Maternal undernutrition and retarded foetal development in Merino sheep. *Nature* **201:** 1341-1342.

Everitt, G.C. 1967. Residual effects of prenatal nutrition on the postnatal performance of Merino sheep. *Proceedings of the New Zealand Society of Animal Production* **27:** 52-68.

Faichney, G.J.; White, G.A. 1987. Effects of maternal nutritional status on fetal and placental growth and on fetal urea synthesis in sheep. *Australian Journal of Biological Science*, **40:** 365-377.

Holst, P.J.; Allan, C.J. and Gilmour, A.R. 1992. Effects of a restricted diet during mid-pregnancy of ewes on uterine and fetal growth and lamb birth weights. *Australian Journal of Agricultural Research* **43:** 315-324.

Laster, D.B. and Gregory, K.E. 1973. Factors influencing peri- and early postnatal calf mortality. *Journal of Animal Science* **37:** 1092.

McCrabb, G.J.; Egan, A.R. and Hosking, B.J. 1992. Maternal undernutrition during mid-pregnancy in sheep: Placental size and its relationship to calcium transfer during late pregnancy. *British Journal of Nutrition,* **65:** 157-168.

McCrabb, G.J.; Egan, A.R. and Hosking, B.J. 1992. Maternal undernutrition during mid-pregnancy in sheep: Variable effects on placental growth. *Journal of Agricultural Science,* Cambridge **118:** 127-132.

McCutcheon, S.N.; Holmes, C.W. and McDonald, M.F. 1981. The starvation-exposure syndrome and neonatal lamb mortality: A review. *Proceedings of the New Zealand Society of Animal Production* **41:** 209-217.

Mellor, D.J. 1983. Nutritional and placental determinants of foetal growth rate in sheep and consequences for the newborn lamb. *British Veterinary Journal* **139:** 307-324.

Owens, J.A.; Owens, P.B. and Robinson J.S. 1995. Experimental restriction of fetal growth. *In* Fetus and Neonate, Vol 3. Growth. (Ed. M.A. Hanson, J.A.D. Spencer and C.H. Rodeck), pp. 139-175. Cambridge University Press, Cambridge.

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

Robinson, J.J. 1983. Nutrition of the pregnant ewe. *In* Sheep production (Ed. H. Haresign), pp. 111-131. Butterworths, London.

SAS. 1988. User's guide statistics. Statistical Analysis Institute, Cary, NC, USA.

Wallace, L.R. 1948. The growth of lambs before and after birth in relation to the level of nutrition. Part I. *Journal of Agricultural Science,* Cambridge **38:** 93-153.