The effect of maternal nutrition during gestation on the reproductive success of female progeny as 2-tooths

R.A.CORNER, P.R.KENYON, K.J.STAFFORD, D.M. WEST AND S.T. MORRIS

Institute of Veterinary, Animal and Biomedical Sciences, Private Bag 11-222, Massey University, Palmerston North.

ABSTRACT

The inter-generational effect of birth rank and nutrition during pregnancy was assessed by examining the reproductive success of female progeny at their first mating at 2 years of age. Fifty-six ewes born as a twin or triplet and whose dam was maintained on 2 or 6 cm sward height from mid-pregnancy to parturition were synchronised and bred to Romney rams. Pregnancy diagnosis was conducted using ultrasound on day 71 from the start of mating (P71). All ewes were maintained as one mob under commercial farming conditions throughout pregnancy. Within 12 hours of birth lambs were ear tagged, weighed and body dimensions (CRL, girth, forelimb and hind limb lengths) were recorded. Lamb live weights were also recorded at day 48 after the mid-point of lambing (L48).

Fifty-one ewes lambed of the 56 ewes that were bred. Twin-born ewes had significantly longer gestation lengths (by 1.3 days) than triplet-born ewes. Singleton lambs born to triplet-born ewes were significantly ($P<0.05$) lighter (4.6 kg) at birth than singleton lambs born to twin-born ewes (5.1 kg). Singleton lambs whose grand-dams were maintained on 2cm pastures during pregnancy and whose dam was born as a twin had significantly ($P<0.05$) longer hind limbs than their counterparts whose grand dam was maintained on 6 cm and whose dam was born a triplet but they did not differ in birth weight. Dam birth rank and the nutritional treatment of their grand-dam had no significant effect on twin-lamb live weight and body dimensions at birth.

These results suggest that selecting triplet ewe lambs for breeding could have detrimental effects on flock productivity. In addition a previous study involving the same animals reported triplet born ewes displayed poorer maternal behaviour. To the authors knowledge this is the first finding of this kind and could have implications for ewe selection on New Zealand farms.

Keywords: reproduction; nutrition; lambs; birth weight.

INTRODUCTION

Relatively little is known about the intergenerational effects of maternal nutrition during pregnancy and birth rank. The long-term consequences of maternal undernutrition on the first generation of progeny have received a great deal of attention (Thomson & Thomson, 1949; Everitt, 1964; Mellor & Murray, 1981; Holst *et al.*, 1986; Moore *et al.*, 1986; Scales *et al.*, 1986; Gunn *et al.*, 1995; Heasman *et al.*, 1998; Morris & Kenyon, 2004). Undernutrition during pregnancy generally results in lighter lambs (Mellor & Murray, 1982; Holst *et al.*, 1992; Morris & Kenyon, 2004) and can also alter the lamb's body dimensions by increasing the crown-rump length (CRL) (Heasman *et al.*, 1999) and reducing girth size (Holst *et al.*, 1992; Morris & Kenyon, 2004) or both (Mellor & Murray, 1982). Reduced weight and body size at birth can reduce lamb survival (Dalton *et al.*, 1980; Scales *et al.*, 1986).

Little is known about the effects of maternal nutrition on the body size and birth weight of the second generation in sheep. In rats a low protein diet before mating and during pregnancy resulted in reduced birth weight, litter size and increased pup mortality (McLeod *et al.*, 1972). In addition the female progeny displayed reduced fertility and produced litters with reduced growth rates. Gunn *et al.* (1995) found that the female progeny of ewes on a high level of nutrition for the last 100 days of pregnancy or first 100 days of lactation displayed greater embryo and fetal losses at 3 and 4 years of age. Corner et al. (2005) showed that triplet born ewes had poorer maternal behaviour than twin-born ewes. In rats a low protein diet prior to and during pregnancy resulted in pups with retarded development and intelligence which persisted in the next generation (Cowley & Griesel, 1966). These combined results suggest that there is potential for pregnancy nutrition and ewe birth rank to have long-term effects on flock performance.

The present study was designed to determine if the progeny of twin or triplet born 2-tooth ewes whose dams were maintained on 2 or 6

cm sward heights differed in live weight and body size at birth.

MATERIALS AND METHODS

Fifty-six primiparous twin- and triplet-born ewe progeny born to dam's maintained on either 2 or 6 cm surface sward heights from day 64 of pregnancy to parturition (Morris & Kenyon, 2004) were bred as 2-tooths. Ewes were oestrus synchronised and bred to Romney rams. Breeding dates were determined from daily ram crayon marks. Pregnancy diagnosis was conducted using ultrasound on day 71 from the start of mating (P71). All ewes were maintained as one mob under commercial farming conditions throughout pregnancy. Ewe live weights were recorded twelve days prior to mating (P-12), P107 and P143.

Within 12 hours of birth lambs were ear tagged and their dam was identified. The lambs' live weight and body dimensions (CRL, girth, forelimb and hind limb lengths) were recorded. Forelimb length was the distance from the shoulder joint to the tip of the hoof on the left leg and hind limb length was the distance from the hip joint to the tip of the hoof on the left leg.

Statistical analyses

Data were analysed using the Proc Mixed procedure in SAS version 8.02 (SAS, 2005) with the fixed effects of ewe birth rank (twin vs triplet), grand-dam feeding regimes (2cm vs. 6cm) and lamb birth rank (single vs. twin) and the linear covariate effects of gestation length and lambing day (deviation from the start of lambing). The relationship between gestation length and lamb birth weight was determined using the Proc GLM procedure in SAS adjusting for the fixed effect of birth rank. Tables present least squares means ± standard error.

RESULTS

The live weight of ewes mated in this study did not differ between their birth rank or dam's nutritional treatment at mating and throughout pregnancy (Table 1). Of the 56 ewes mated, 50 ewes lambed producing 76 lambs. Lambing percentages were similar between ewe birth ranks (twin = 144% and triplet=159%) and dam nutrition treatments (2cm=154% and 6cm=150%).

Gestation lengths were significantly longer for twin-born (146.4 days) than triplet-born (145.2 days) ewes (Table 2). There was no variation in the gestation length of ewes bearing singleton or twin fetuses or between grand-dam feeding regimes.

TABLE 1: Least squares means ±S.E. of ewe live weight prior to mating and throughout pregnancy by ewe birth rank (twin vs. triplet) and their dam's feeding regime (2cm vs. 6cm) and ewe pregnancy rank (singleton vs.twin)

		Ewe live weights		
	n	**P-14**	**P107**	**P143**
Ewe birth rank				
Twin	28	52.2±1.1	56.7±1.1	59.1±1.2
Triplet	31	50.9±0.9	55.1±1.0	57.2±1.1
Dam nutrition regime				
2cm	35	51.2±0.9	55.1±0.9	57.7±1.0
6cm	24	51.9±1.1	56.6±1.1	58.7±1.3
Ewe Pregnancy rank				
Singleton	24	50.8±1.1	54.1±1.1	56.7±1.3
Twin	29	52.4±1.0	57.5±1.0	58.7±1.2
Birth rank x Dam nutrition regime				
Twin x 2cm	17	50.6^{a}±1.3	54.7^{a}±1.3	
Twin x 6cm	11	54.8^{b}±1.6	58.9^{b}±1.6	
Triplet x 2cm	18	51.4^{ab}±1.3	55.7^{ab}±1.5	
Triplet x 6cm	13	49.8^{a}±1.5	53.8^{a}±1.6	

Means within columns with different superscripts are significantly different (P<0.05)

TABLE 2: Least squares means ±S.E. of gestation length by lamb birth rank (single vs. twin), ewe birth rank (twin vs. triplet) and maternal grand-dam feeding regime (2cm vs. 6cm).

	n	Gestation length
Lamb birth rank		
Single	25	145.7±0.5
Twin	26	145.8±0.4
Ewe birth rank		
Twin	25	146.4^{b}±0.4
Triplet	26	145.2^{a}±0.4
Maternal grand-dam's feeding regime		
2cm	28	145.9±0.4
6cm	23	145.6±0.5

Means within columns with different superscripts are significantly different (P<0.05)

Singleton lambs born to triplet-born ewes were significantly (P<0.05) lighter (by 0.5kg) at birth than their counterparts born to twin-born ewes (Table 3). Lamb birth weight and ewe gestation length were related such that for every 1 day increase in gestation length (GL) above 142 days there was an average increase in birth weight of 0.148 kg (y = 3.3 + 0.148 GL). Hind limb length had a significant (P=0.05) 3-way interaction of lamb birth rank, ewe birth rank and grand-dam feeding regime. Therefore, singleton lambs born to twin- and triplet-born ewes whose grand-dam was maintained on 6 cm pastures during pregnancy had

TABLE 3: Least squares mean±S.E. of lamb birth weight, crown rump length (CRL), girth, forelimb (FL) and hind limb (HL) lengths by lamb birth ranks (single vs. twin), ewe birth ranks (twin vs. triplet) and maternal grand-dam feeding regime (2cm vs. 6cm).

			Lamb dimensions			
	n	**Birth weight**	**CRL**	**Girth**	**FL**	**HL**
Lamb birth rank (LBR)						
Single	25	4.7^{b}±0.1	52.3^{b}±0.8	36.3^{b}±0.6	28.5^{b}±0.4	34.7^{b}±0.5
Twin	27	3.6^{a}±0.1	48.0^{a}±0.5	33.1^{a}±0.39	27.5^{a}±0.3	32.4^{a}±0.3
Ewe birth rank (EBR)						
Twin	25	4.3±0.1	50.6±0.6	34.5±0.5	28.7±0.4	34.1±0.4
Triplet	26	4.1±0.1	49.7±0.7	34.9±0.5	27.3±0.4	33.0±0.4
Maternal grand-dam feeding regime (Feeding regime)						
2cm	28	4.1±0.1	49.7±0.6	34.6±0.4	27.9±0.4	32.9±0.4
6cm	23	4.3±0.1	50.5±0.7	34.9±0.5	28.1±0.4	34.2±0.4
Lamb birth rank x Ewe birth rank						
Single x Twin	14	5.1^{c}±0.2				
Single x Triplet	10	4.6^{b}±0.2				
Twin x Twin	11	3.6^{a}±0.2				
Twin x Triplet	16	3.6^{a}±0.1				
LBR x EBR x Feeding regime						
Single x Twin x 2cm	6					34.9^{bc}±0.9
Single x Twin x 6cm	8					35.7^{b}±1.0
Single x Triplet x 2cm	5					32.3^{ac}±1.1
Single x Triplet x 6cm	5					35.9^{b}±1.1
Twin x Twin x 2cm	6					32.2^{a}±0.7
Twin x Twin x 6cm	5					33.5^{abc}±0.8
Twin x Triplet x 2cm	9					32.3^{a}±0.6
Twin x Triplet x 6cm	7					31.7^{a}±0.7

Means within columns with different superscripts are significantly different (P<0.05)

significantly (P<0.05) longer hind limbs than singletons born to triplet-born ewes whose grand-dams were maintained on 2 cm sward heights. Singleton lambs were significantly heavier and larger in all measures of body dimension than their twin-counterparts (Table 3). Ewe birth rank and the grand-dam nutritional treatment had no significant effect on the live weight and body dimensions of twin lambs.

DISCUSSION

At 2 years of age ewe birth rank had a significant effect on the gestation length and birth weight of singleton lambs. Triplet born ewes had significantly shorter gestation lengths and gave birth to lighter singleton lambs that their twin-born counterparts. The relationship of gestation length to birth rank was such that for every 1 day increase in gestation length there was an increase of 0.148 kg in lamb birth weight which is close to the late gestation fetal growth rates described by Rattray *et al.* (1974).

Lamb survival is greatest in lambs with a birth weight of 3.5 – 5.5 kg (Dalton *et al.*, 1980). Small lambs have a higher mortality resulting from starvation-exposure due to increased heat loss resulting from a greater surface area to body weight ratio (McDonald, 1962) and low energy reserves with which to maintain homeothermy (Robinson, 1981). Small lambs cannot maintain high heat production without ingesting colostrum (Haughey, 1993). Triplet born ewes are at a greater risk of giving birth to lambs that weigh less than 3.5 kg which may result in decreased lamb survival.

The behaviour of these ewes was also influenced by their birth rank (Corner *et al.*, 2005) such that triplet-born ewes had significantly poorer maternal behaviour than twin-born ewes. Poor maternal behaviour within the first day after parturition is a major cause of lamb mortality (Alexander, 1984). Therefore poorer maternal behaviour of triplet born ewes may result in increase lamb mortality.

There was no significant effect of the maternal grand-dam's feeding regime on their

daughters lambing percentage or their daughters offspring's birth weight and body dimensions. The hind limb length of singleton lambs was the only variable significantly affected by grand dam nutrition. These findings are in agreement with a study on wild house mice (*Mus musculus*) which found no difference in the birth or weaning weight of offspring born to daughters of underfed females compared to daughters of control females (Meikle & Westberg, 2001).

CONCLUSIONS

These results suggest that selecting triplet ewe lambs as replacements could have detrimental effects on their ability to successfully rear a lamb as a 2-tooth. To these authors knowledge this is the first finding of this kind and could have implications for ewe selection on New Zealand farms.

ACKNOWLEDGMENTS

The authors would like to acknowledge the National Research Centre for Growth and Development (NRGCD) and Meat and Wool New Zealand for funding this project.

REFERENCES

Alexander, G 1984: Constraints to lamb survival. *Reproduction in Sheep* 199-209

Corner, RA; Kenyon, PR; Stafford, KJ; West, DM; Morris, ST; Blair, HT 2005: Does ewe nutrition during pregnancy affect the behaviour of ewe lambs at 1 and 2 years of age? *Proceedings of the New Zealand Society of Animal Production 65*: 29-32

Cowley, JJ; Griesel, RD 1966: Effect on growth and behaviour of rehabilitating first and 2nd generation low protein rats. *Animal Behaviour 14*: 506-&

Dalton, DC; Knight, TW; Johnson, DL 1980: Lamb survival in sheep breeds on New-Zealand hill country. *New Zealand Journal of Agricultural Research 23*: 167-173

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

Gunn, RG; Sim, DA; Hunter, EA 1995: Effects of nutrition in-utero and in early-life on the subsequent lifetime reproductive-performance of Scottish Blackface ewes in 2 management-systems. *Animal Science 60*: 223-230

Haughey, KG 1993: Perinatal lamb mortality - Its investigation, causes and control (Reprinted from Journal of the South-African Veterinary Association, Vol 62, Pg 78-91, 1991). *Irish Veterinary Journal 46*: 9-28

Heasman, L; Clarke, L; Firth, K; Stephenson, T; Symonds, ME 1998: Influence of restricted maternal nutrition in early to mid gestation on placental and fetal development at term in sheep. *Pediatric Research 44*: 546-551

Heasman, L; Clarke, L; Stephenson, TJ; Symonds, ME 1999: The influence of maternal nutrient restriction in early to mid-pregnancy on placental and fetal development in sheep. *Proceedings of the Nutrition Society 58*: 283-288

Holst, PJ; Killeen, ID; Cullis, BR 1986: Nutrition of the Pregnant Ewe and Its Effect on Gestation Length, Lamb Birth-Weight and Lamb Survival. *Australian Journal of Agricultural Research 37*: 647-655

Holst, PJ; Allan, CJ; Gilmour, AR 1992: Effects of a restricted diet during mid pregnancy of ewes on uterine and fetal growth and lamb birth-weight. *Australian Journal of Agricultural Research 43*: 315-324

McDonald, IW 1962: Ewe fertility and neonatal lamb mortality. *New Zealand veterinary journal 10*: 45-53

McLeod, KI; Whyte, HM; Goldrick, RB 1972: Effect of maternal malnutrition on progeny in rat - Studies on growth, body composition and organ cellularity in first and second generation Progeny. *Australian Journal of Experimental Biology and Medical Science 50*: 435-&

Meikle, D; Westberg, M 2001: Maternal nutrition and reproduction of daughters in wild house mice (Mus musculus). *Reproduction 122*: 437-442

Mellor, DJ; Murray, L 1981: Effects of placental weight and maternal nutrition on the growth-rates of individual fetuses in single and twin bearing ewes during late pregnancy. *Research in Veterinary Science 30*: 198-204

Mellor, DJ; Murray, L 1982: Effects of long-term undernutrition of the ewe on the growth-rates of individual fetuses during late pregnancy. *Research in Veterinary Science 32*: 177-180

Moore, RW; Millar, CM; Lynch, PR 1986: The effect of pre-natal nutrition and type of birth and rearing of lambs on vigour, temperature and weight at birth, and weight and survival at weaning. *Proceedings of the New Zealand Society of Animal Production 46*: 259-262

Morris, ST; Kenyon, PR 2004: The effect of litter size and sward height on ewe and lamb performance. *New Zealand Journal of Agricultural Research 47*: 275-286

Rattray, PV; Garrett, WN; East, NE; Hinman, N 1974: Growth, development and composition of ovine conceptus and mammary-gland during pregnancy. *Journal of animal science 38*: 613-626

Robinson, JJ 1981: Prenatal Growth and Development in the Sheep and Its Implications for the Viability of the Newborn Lamb. *Livestock Production Science 8*: 273-281

SAS 2005: SAS 8.02, SAS Inst. Inc.

Scales, GH; Burton, RN; Moss, RA 1986: Lamb mortality, birth-weight, and nutrition in late pregnancy. *New Zealand Journal of Agricultural Research 29*: 75-82

Thomson, AM; Thomson, W 1949: Lambing in relation to the diet of the pregnant ewe. *British Journal of Nutrition 2*: 290-305.