The influence of perinatal undernutrition of twin-bearing ewes on milk yields and lamb performance and the effects of postnatal nutrition on live weight gain and carcass composition

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1. Studies were conducted to measure the influence of perinatal undernutrition of twin-bearing ewes on ewe milk yields and lamb performance in early lactation. Comparative studies were conducted with lambs to measure the effects of postnatal nutrition on lamb performance and carcass composition. The major objective of this work was to determine the extent of the influence of postnatal nutritional deprivation of lambs.

2. From 8 weeks prepartum to 4 weeks postpartum each of forty twin-bearing ewes was given daily 0·30 MJ of ME/kg body-weight $(W)^{0.75}$. Measurements were made of ewe body-weight changes, milk yields during the first 4 weeks of lactation, and of lamb performance.

3. There were three postnatal experiments with lambs of 'light' and 'normal' birth weights, weaned from the ewes at 72 h. One hundred and four lambs were used and they were individually reared on separate allowances of lamb milk-substitute for 8 weeks. They were subsequently given a lamb concentrate ration. In Expts 1 and 2 the lamb concentrate was fed *ad lib.* to 'slaughter' live weight. In Expt 3 the concentrate was restricted for 8 weeks post weaning and then fed *ad lib.* A carcass analysis (bone, muscle, fat content) was conducted on all lambs after slaughter. In the first experiment, half the lambs were slaughtered at 8 weeks of age on being weaned off the milk substitute, and a carcass analysis was carried out.

4. The mean net body-weight loss per ewe from commencement of late pregnancy to 28 d post partum was 23·8 kg. The over-all mean daily milk yield was 843 g/d. The mean growth rate of the lambs was 97 g/d during the 4-week measurement of ewe milk yields.

5. Live weight gain of lambs subjected to restricted milk-substitute allowance (125 g/dry matter (DM) per d) was low, irrespective of lamb birth weight. The average daily gain over the 8-week postnatal period was 86·5 g/d on restricted milk allowance compared with 244 g/d for those fed *ad lib.* Conversely, the food intake and growth rate of these lambs were almost identical during feeding on *ad lib.* concentrates. This clearly reflected a response to compensatory food intake which was independent of either birth weight or postnatal milk allowance. The average daily gain of lambs, before weaning, on the restricted milk allowance was very similar to that of the lambs being suckled by ewes subjected to perinatal undernutrition. The effects of postnatal undernutrition of lambs was particularly reflected in the time required to reach 'slaughter' live weight. The period of time varied from 117 d for those on *ad lib.* food intake to 169 d for lambs on restricted food intake.

6. The major effect of postnatal undernutrition on carcass composition was evident in the lambs slaughtered at 8 weeks in Expt 1. The percentage carcass fat was 4·7 for those on the low milk allowance. The carcass composition of all lambs at 'slaughter' live weight was similar. It would appear that lambs on a restricted milk intake before weaning deposited more fat during the subsequent period of compensatory food intake.

7. It is evident from the present results that postnatal growth retardation in lambs reflects either perinatal undernutrition of twin-bearing ewes, or postnatal undernutrition of the lambs due to inadequate milk availability from the dam.

Studies to improve the commercial viability of sheep production have involved increasing research inputs from animal breeders and reproductive physiologists in recent years. The major emphasis has been on improving ewe prolificacy by selection and cross-breeding and on the introduction of accelerated or multiple lambing. Consequently, the perinatal nutrition of twin- and multiple-bearing ewes, as well as postnatal nutrition in accelerated intensive lamb fattening, has assumed increasing importance.

A major problem associated with traditional lamb production has been a high incidence of poor growth in lambs resulting in lamb fattening not meeting production targets. Ill-thrift is a term used to describe poor performance associated with lambs being fattened on pasture and often affected with parasitism and mineral disorders. In contrast, postnatal growth retardation leading to the phenomenon referred to by Findlay & Heath (1969) as 'tail-endness' is probably of nutritional origin and associated with low milk availability from the ewe. While there has been no precise quantitative determination of the economic consequences of these problems, it would appear that lamb production on hill and marginal land is the most seriously affected. In farming practice it is reasonable to assume that postnatal nutritional retardation may predispose lambs to parasitic infections or metabolic disorders when they are weaned on to pasture.

Apart from studies on pregnancy toxaemia (Gill & Thomson, 1954; Blaxter, 1957; Reid, 1960) most of the research on ewe nutrition has been devoted to examining the effects of different levels of energy in late pregnancy on lamb birth weights, live weight gain and the associated milk production of the ewe (Wallace, 1948; Thomson & Thomson, 1949; Guyer & Dyer, 1954; Peart, 1967; Treacher, 1970). In many of these studies the ewes were fed *ad lib.* post partum. Recently, Sheehan *et al.* (1977) have studied the energy requirements of twin-bearing ewes in late pregnancy and suggest a value of 0·42 MJ of ME/kg body-weight $(W)^{0.75}$.

The objectives of the present studies were twofold. The first was to study the effects of perinatal undernutrition of twin-bearing ewes on lamb birth weight, ewe milk production and the subsequent performance of the lambs. The second was to examine the interaction of lamb birth weights and postnatal undernutrition on lamb growth and carcass composition to weaning at 8 weeks and to 'slaughter' live weight.

MATERIALS AND METHODS

Perinatal studies with twin-bearing ewes

These studies were conducted over three lambing seasons. In each instance between fifty and sixty ewes were selected from a flock of Suffolk-cross ewes being used in an out-of-season lambing programme. This involved treating the ewes with 60 mg Medroxy Acetate Progesterone (MAP) intravaginal pessaries, followed by 500 I.U. pregnant mare's serum (PMS) in June, and subsequently hand-mating them in early July. The ewes were grazed at pasture up to 10 weeks before lambing and then brought indoors and individually penned. They were given 1 kg high-quality pelleted dried grass meal. This had an in vitro dry matter (DM) digestibility of 0·762 and crude protein (nitrogen × 6·25; CP) content of 207 g/kg. The calculated metabolizable energy (ME) value based on in vivo DM digestibility studies was 10·8 MJ/kg DM.

The ewes were X-rayed to determine the number which were twin-bearing. From 8 weeks prepartum to 4 weeks post partum each twin-bearing ewe was given an allowance of the dried-grass cubes supplying daily 0·3 MJ of ME/kg body-weight $(W)^{0.75}$. The ewes were weighed at 2-week intervals pre- and postlambing. A final live weight was taken 4 weeks after lambing when the lambs were weaned. Lamb birth weights were recorded and the ewe milk yields were measured during the 4 weeks of lactation using the 'lamb-suckling' method (Lawlor *et al.* 1974). This involved measuring ewe milk production three times weekly. The lambs were separated from the ewes overnight and then allowed 15 min access to their dams at 8, 12 and 16 h. At each observation the lambs were weighed immediately before and after being suckled. The daily milk yields were calculated by the summated weight differences of the lambs. Total milk production over the 4-week period was estimated from extrapolation of the three weekly measurements. The lambs were weaned at the end of the 4-week period and then given a pelleted commercial lamb fattening ration until they reached an average slaughter live weight of 36 kg. Food intakes were recorded daily and the lambs were weighed weekly.

Postnatal studies with lambs

These studies involved three separate experiments.

Expt 1. Twenty-four Greyface lambs were weaned at 72 h from the ewes. They were selected on the basis of uniformity of weight, the main criterion was that the weights conformed to the average or normal for the breed.

The lambs were penned individually on slatted floors and given a ewe milk-substitute. They were trained to suck from individual bottles fitted with teats and after 3–4 d were randomly allocated to two treatments. Twelve of the lambs were each given a high allowance of the milk-substitute consisting of 240 g DM/lamb per d, while the remaining twelve lambs were each given a low allowance of 125 g DM/d. The reconstituted milk-substitute contained 200 g DM/kg. The lambs were given the milk substitute exclusively over a period of 56 d. A supply of fresh water was available in each pen. The lambs were weighed weekly and any variation in individual milk-substitute intake was recorded daily. At the end of the 56 d period, six lambs on each treatment were slaughtered and the carcass composition was analysed. The remaining lambs were then given a commercial lamb fattening ration *ad lib.* to a slaughter live weight of 36 kg. Food intakes were recorded daily. The composition of each carcass was analysed.

Dissection and chemical composition of lamb carcasses

The entire carcass of each lamb weaned and slaughtered at 56 d in Expt 1 was dissected. However, in the instance of those reaching slaughter live weight in all three experiments, only the left side of the carcass was dissected. The method of dissection was that described by Carroll & O'Carroll (1964). Each joint was deboned and the meat sampled for proximate analysis using the methods described by Hill & O'Carroll (1962). The percentage bone, fat and lean (muscle) was determined.

Expt 2. Sixty-four Greyface lambs were used in this experiment and distributed on the basis of 'normal' and 'light' birth weights. Owing to a low incidence of multiple births in the flock, there were forty lambs of 'normal' and twenty-four of 'light' birth weights available. As in the previous experiment, the lambs were weaned at 72 h, individually penned and given ewe milk-substitute. On being trained to suck from the teats each group of lambs was randomly divided into two sub groups. Thus, twenty 'normal' and twelve 'light' birth weight lambs were given the milk-substitute *ad lib.* while the remaining twenty and twelve lambs were given an allowance of 125 g DM milk-substitute/lamb daily. They were reared on milk-substitute for 56 d. All four sub groups were subsequently weaned on to the commercial lamb-fattening ration which was fed *ad lib.* until the lambs attained an average live weight of 35 kg. Food intakes were recorded daily and the lambs were weighed weekly. The composition of each lamb carcass was analysed.

Expt 3. This involved sixteen lambs of 'normal' birth weight. The procedure was identical to that in the previous experiments. In this experiment, all sixteen lambs were given the restricted milk-substitute allowance (125 g DM/lamb per d) up to 56 d of age, followed by a restricted allowance (470 g DM/lamb per d) of the lamb fattening ration for a further 56 d. They were then allowed the lamb ration on an *ad lib.* basis until they reached a slaughter live weight of 35 kg. The composition of each lamb carcass was again determined.

The results of each study were subjected to analysis of variance.

RESULTS

Table 1 shows a summary of the results relating to the body-weight changes and milk yields of the twin-bearing ewes subjected to pre- and postpartum undernutrition. The mean birth weights of the lambs and their live-weight gains during the 4-week suckling period are also included.

Table 1. *Body-weight changes and milk yield of twin-bearing ewes subjected to undernutrition and and the growth rates of their lambs*

		Ewe body changes (kg)						Milk yields		Lamb performance			
		Last 8 weeks of pregnancy		Immediate post-lambing		28 d post-lambing		Daily milk yield (g/d)		Birth wt (kg)		Daily live-wt gain (g/d)	
Expt no.	No. of animals	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
1	8	−6·60	1·08	−9·45	0·94	−5·95	1·60	929	78	3·01	0·15	107	16
2	12	+0·15	0·88	−10·64	0·77	−15·27	1·31	911	64	3·15	0·13	89	13
3	20	−0·54	0·68	−12·08	0·59	−10·94	1·02	1089	49	3·30	0·10	96	10

Table 2. *Expts 1 and 2. Summary of performance results of lambs*

Feeding regimen*...			Postnatal milk feeding up to 56 d					*Ad lib.* concentrate feeding to slaughter				
	Lamb details		Milk allowance (kg)	Initial live wt (kg)	Final live wt (kg)	Daily wt gain (g)		Final live wt (kg)	Daily wt gain (g)		Mean daily food intake (kg)	Food conversion ratio (kg intake/kg wt-gain)
Expt no.	Group	No.				Mean	SE		Mean	SE		
1	'Normal'-birth-wt	6	0·128	4·56	9·33	85	8·7	Slaughtered at 56 d				
		6	0·124	4·57	9·50	88	8·7	37·20	317	10·0	1·14	3·60
		6	0·234	4·49	14·93	190	9·5	Slaughtered at 56 d				
		6	0·248	4·92	15·14	183	8·1	37·50	347	9·0	1·25	3·62
2	'Light'-birth-wt	9	0·137	2·84	7·39	82	10·0	36·44	290	17·0	1·03	3·52
		10	0·336	2·63	16·55	250	9·0	36·40	283	16·0	1·07	3·87
2	'Normal'-birth-wt	9	0·140	4·72	9·78	91	10·0	36·66	296	17·0	1·05	3·52
		16	0·344	4·74	18·06	238	7·0	38·05	338	13·0	1·11	3·35

* For details, see p. 581.

Table 3. *Expt 3. Summary of performance results of sixteen 'normal-birth-weight lambs*

Feeding regimen*	Mean daily feed intake (kg)	Initial live wt (kg)	Final live wt (kg)	Daily wt gain (g)		Food conversion ratio (kg intake/kg wt gain)	
				Mean	SE	Mean	SE
Restricted milk allowance to 56 d	0·123	4·05	7·84	68	8·0	1·82	0·16
Restricted concentrate feeding allowance to 56 d	0·470	7·84	18·19	184	8·0	2·58	0·16
Ad lib. concentrate feeding	1·447	18·19	37·64	347	8·0	4·11	0·16

* For details see p. 581.

Table 4. *Expts* 1, 2 *and* 3. *Carcass composition of the lambs*

Expt no.	Group	Feeding regimen*	Hot carcass wt (kg)	Killing out percentage	Bone (%)		Lean (%)		Fat (%)	
					Mean	SE	Mean	SE	Mean	SE
1	Pre-slaughter group at 56 d	Low milk allowance	4·52	48·3	27·2	0·76	68·1	1·22	4·7	1·25
		High milk allowance	7·87	52·7	21·2	0·84	68·3	1·34	10·5	1·37
1	Fattened on *ad lib.* conc.	Low milk allowance	17·60	47·3	16·65	0·76	63·4.	1·22	20·0	1·25
		High milk allowance	18·52	50·0	16·96	0·71	64·0	1·13	19·0	1·15
2	'Light'-birth-wt lambs	Restricted	18·06	50·9	15·64	0·49	58·4	1·18	26·0	1·52
		Ad lib.	18·49	51·8	15·04	0·47	62·3	1·12	22·6	1·44
2	'Normal'-birth-wt lambs	Restricted	17·85	50·7	15·61	0·49	59·8	1·18	24·6	1·52
		Ad lib.	18·49	49·9	16·15	0·37	63·6	0·89	20·3	1·14
3	'Normal-birth-wt lambs	Restricted milk conc. 112 d	18·93	50·6	14·80	0·36	58·2	0·67	27·0	0·92

* For details, see p. 581.

During the last 8 weeks of pregnancy most of the ewes lost body-weight (Expt 1 and 3). The net body-weight losses at 28 d postlambing were very large, particularly in Expt 2. In all three experiments ewe milk yields were low. The small live-weight gains of the lambs during the first 4 weeks of lactation reflected the low milk yields of the ewes.

The performance results during the 56 d postnatal milk feeding period of the lambs and the subsequent *ad lib.* feeding on concentrates in Expts 1 and 2 are summarized in Table 2.

As expected, the low and high milk allowances fed during the postnatal period resulted in highly significant differences ($P < 0.01$) in growth rates. These differences resulted in the live weights of the lambs given the low milk allowance being markedly lower at the conventional weaning age of 8 weeks. During the subsequent *ad lib.* feeding on the concentrate in both experiments, the lambs whose growth rate had been retarded demonstrated a remarkable compensatory growth effect. This was true of lambs of both 'normal' and 'light' birth weights. Nevertheless, with the exception of the 'light'-birth-weight lambs in Expt 2, the lambs whose growth rate was retarded did not perform quite as well as those given the higher milk allowance during the 8-week postnatal period.

Table 3 shows the performance results for lambs in Expt 3, subjected to both a low milk-substitute allowance for 8 weeks after birth and a low concentrate intake for a further 8 weeks before *ad lib.* feeding.

As in Expts 1 and 2, restricting food intake both in terms of ewe milk-substitute and creep feed, retarded growth considerably. The mean live weight of the lambs after the 16-week restricted feeding period was similar to that of the average weaning weight at 8 weeks. Despite the prolonged period of underfeeding, the growth rates of lambs during *ad lib.* feeding of concentrates were very good.

The carcass values for the lambs on all three experiments are summarized in Table 4. The twelve lambs in Expt 1 which were slaughtered at 8 weeks of age showed large differences in carcass composition. Apart from the obvious differences in the hot-carcass weights and killing-out percentages of the lambs given the low milk allowance, the percentage bone was higher ($P < 0.01$) and the percentage fat lower ($P < 0.01$) than in the instance of the lambs given the higher milk allowance. The percentage of lean meat was almost identical in both instances. Those lambs given either the low or high milk-substitute allowance during the first 8 weeks and subsequently given the concentrates *ad lib.* showed no major changes in carcass composition at slaughter live weight. There was, nevertheless, a definite tendency for the carcasses of lambs whose growth rate was restricted postnatally to deposit more fat during the compensatory growth period.

DISCUSSION

The major emphasis in previous studies with pregnant ewes has been to determine quantitatively the effects of different planes of nutrition in late pregnancy on lamb birth weights. This is quite understandable where the production of a healthy crop of lambs is more important than ewe milk production. Furthermore, in traditional sheep production systems, lambing usually takes place at a time when an adequate supply of herbage is available to the ewes. This is not necessarily so with lambs produced out-of-season, or in the instance of marginal and hill land sheep production.

The body-weight changes of the twin-bearing ewes subjected to undernutrition varied considerably during the last 8 weeks of pregnancy (Table 1). This was due largely to variations in the body condition of the ewes at commencement of the experiments. The net body-weight losses from commencement of the trials to 28 d postpartum were 22·0, 25·8 and 23·60 kg for Expts 1, 2 and 3 respectively. The mean birth weights of the lambs in all three experiments were low and were similar to those obtained by Tissier & Thesiez (1979) with twin-bearing ewes fed at maintenance level in late pregnancy, and by Sheehan *et al.* (1977).

The over-all mean daily milk yields of the ewes were particularly poor during the 28 d lactation period. The values were half to one-third the daily milk yields obtained by Peart *et al.* (1979) where different breeds of ewe were compared. The effect of the prolonged undernutrition was such that towards the end of the 28 d measurement period, several of the ewes had virtually ceased to produce any milk and were extremely emaciated. These low milk yields were clearly reflected in the very poor growth rates of the lambs which were almost identical to those of the lambs given a low level of milk-substitute.

The results (Table 2) serve to emphasize the fact that milk intake by the lamb is probably more important than lamb birth weight. The 'light'-birth-weight lambs used in Expt 2 were weaned from ewes with multiple births. When given the milk-substitute *ad lib.* their mean daily intakes and live-weight gains were almost identical to those of 'normal'-birth-weight lambs during the 56 d suckling period. The results of the perinatal study with twin-bearing ewes (Table 1) highlight the importance of milk availability from the ewe. Despite the birth weights of the individual twin lambs, their very poor performance in early lactation directly reflected the inadequate milk supply available from the dam. Sheehan *et al.* (1977) in their studies on the energy requirements of twin-bearing ewes found that the live-weight gains of twin lambs were closely related to the level of feeding of the ewe in early lactation.

The compensatory food intake and growth rate of the lambs on the restricted milk allowances was remarkable when they were subsequently given the concentrate diet *ad lib.* Irrespective of the birth weight of the lambs, their performance from weaning at 56 d to 'slaughter' live weight was almost identical. This is particularly evident in Expt 2 (Table 2) in relation to the 'light'-birth-weight lambs given a restricted milk allowance and those of 'normal' birth weight given the milk-substitute *ad lib.* during the first 8 weeks after birth. In Expt 3 (Table 3) where lambs of 'normal' birth weight were given a restricted milk allowance for 56 d, followed by a restricted allowance of concentrates for a further 56 d, the compensatory intake and growth rates of the lambs was not adversely affected during the subsequent *ad lib.* feeding period.

One of the objectives of the present studies was to measure the effect of immediate postnatal undernutrition on the length of time it took lambs to reach slaughter live weight when fed *ad lib.* during the postweaning phase. In Expts 1 and 2, where the 'normal'-birth-weight lambs were given the low milk allowances, the total period of time to slaughter was 144 and 147 d respectively. The corresponding values for the lambs on the high or *ad lib.* intakes were 121 and 117 d. The 'light'-birth-weight lambs in Expt 2 when given a restricted milk allowance took 155 d to reach 'slaughter' live weight compared with 128 d for those fed *ad lib.* In Expt 3 it took 169 d for the 'normal'-birth-weight lambs restricted postnatally and 8 weeks on the creep feed to reach 'slaughter' live weight when subsequently fed *ad lib.* These results emphasize the importance of postnatal nutrition in relation to lamb production, particularly in so far as tail-endness is concerned.

The main objective in studying the lamb carcass composition was to ascertain if postnatal undernutrition of the lamb affected composition in the long term. The results indicate that the major effect on carcass composition during the 8-week period of restricted milk feeding was a significant ($P < 0{\cdot}01$) reduction in the percentage fat. There was no difference in the percentage of muscle and the differences in bone content of the preslaughter group reflected the differences in the carcass weights of the lambs (4·5 *v.* 7·87 kg). There were no significant differences in the carcass composition irrespective of birth weight or postnatal level of feeding when the lambs were subsequently fed *ad lib.* to 'slaughter' live weight. Data suggest that there was a tendency for the fat content of the postnatally underfed lambs to be higher. This was particularly evident in the instance of those lambs which were underfed for 112 d postnatally.

The percentage lean meat was also lowest in those carcasses. It is therefore possible that lambs subjected to prolonged postnatal undernutrition may have a reduced muscle content and a higher percentage of carcass fat when they are ultimately fattened to a 'slaughter' live weight (Lodge, 1969).

Despite the many studies which have been conducted on the effects of nutritional deprivation and compensatory growth in lambs in relation to carcass composition, the results are inconsistent. As Thornton *et al* (1979) concluded, there is considerable disagreement on the patterns of loss of body water, fat and protein associated with nutritional restriction. It is apparent from the present results that the pattern of changes in carcass composition of postnatally underfed lambs which are subsequently fed *ad lib.* are somewhat different from the mature animals subjected to undernutrition and compensatory growth.

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