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Effects of extended grazing during mid, late or throughout pregnancy, and winter shearing of housed ewes, on ewe and lamb performance

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A flock of March-lambing ewes was used to evaluate the effects of (i) extended (deferred, winter) grazing of pasture during mid, late or throughout pregnancy, and (ii) winter shearing of ewes housed during mid and late pregnancy, on lamb birth weight and subsequent growth to weaning. Ewes (n = 265) were allocated at random to five treatments for the period from 7 December (~ day 47 of pregnancy) to lambing. The treatments were: housed shorn (HS), housed unshorn (HU), grazing throughout (EG), grazing to 20 January followed by housing (EGH), housed to 20 January followed by grazing (HEG). From 1 March to lambing the HEG and EG ewes were dispersed on the paddocks intended for grazing post lambing. All ewes were offered a concentrate supplement during the final 6 weeks of pregnancy. Housed ewes were offered grass silage while ewes on extended grazing were allocated 1.3 kg herbage dry matter per head per day from swards that had been closed for approximately 10 weeks. Ewes plus lambs (except triplet-rearing ewes which were grazed separately) from all treatments were grazed together post lambing, grouped according to lambing date. For treatments HS, HU, EGH, HEG and EG gestation lengths were 147.0, 145.6, 146.3, 146.6 and 146.9 (s.e. 0.34, $P < 0.001$) days, lamb birth weights were 4.9, 4.3, 4.4, 4.6 and 5.0 (s.e. 0.10, $P < 0.001$) kg, and lamb weaning weights were 34.6, 32.1, 33.3, 33.8 and 34.9 (s.e. 0.66, $P < 0.001$) kg, respectively. Extended grazing in mid and late pregnancy resulted in 35% and 65%, respectively, of the increase in lamb birth weight associated with extended grazing throughout. Treatment effects on lamb birth weight were associated with those on weaning weight ($P < 0.01$, $R^2 = 0.93$). It is concluded that extended grazing or shearing of housed ewes increased lamb birth weight and subsequent weaning weight. The increased lamb birth weight from deferred grazing in mid pregnancy was probably due to improved protein utilisation from the grazed herbage. Meanwhile, the increased

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lamb birth weight from grazing in late and throughout pregnancy, and shearing at housing was probably due to reduced heat stress associated to the outdoor environment and removal of the fleece, respectively.

Keywords: birth weight, extended (deferred/winter) grazing, gestation length, lamb growth, winter shearing

Introduction

The decoupling of subsidy payments from farm production within the European Union (EU) and the proposed reduction of tariffs by the World Trade Organization are predicted to lead to a reduction of 24% in the Irish ewe flock (Binfield *et al*., 2006) due primarily to reduced financial returns to the producer in the absence of market support. In the annual sheep production cycle feed is the major variable cost. To support higher stocking rates on sheep units, ewes are removed from pasture and housed during the winter period and offered either grass silage or hay.

Studies at this Centre (Flanagan, 1994, 2003) led to the development of production systems based on extending the grazing season into the winter (extended/deferred grazing) so as to reduce or eliminate the requirement to house ewes during pregnancy. These systems, whilst reducing the cost of maintaining the flock, also reduce the potential stocking rate by up to 26% (Keady, Hanrahan and Flanagan, 2008). One of the principal and most consistent effects of extended grazing is an increased lamb birth weight (Flanagan, 2003; Keady *et al*., 2008). This may be due to a higher feed value of grazed herbage and/or the difference between indoor and outdoor environments. Keady, Murphy and Harrington (1995) and Keady and Murphy (1998) demonstrated that, when herbage of the same growth stage was offered either grazed or as silage, ensiling *per se* did not affect the performance of dairy cows. However, silage is normally harvested at a more mature stage of growth than grazed herbage and consequently has a lower feeding value (Keady and Murphy, 1993). Keady (2000) reported that, for Irish silages, the mean metabolisable energy (ME) concentration in the dry matter (DM) was 10.5 MJ/kg, ranging from 8 to 12.7 MJ/kg. Whilst improvements in lamb birth weight due to extended grazing in mid (Flanagan, 2003) and throughout (Keady *et al*., 2008) pregnancy have been reported, there have been no reports on whether the response to extended grazing depends on the stage of gestation or on the duration of extended grazing.

Winter conditions in Ireland are characterised as being relatively mild. Consequently, ewes that are housed unshorn may have difficulty in dissipating body heat due to the insulating properties of the fleece, leading to heat stress. Previous studies with housed ewes have shown that removal of the fleece in mid to late pregnancy increases lamb birth weight (Black and Chestnutt, 1990; Kirk, Cooper and Chapman, 1984; Vipond, King and Inglis, 1987).

The aims of the present study were: (i) to establish whether the effects of extended grazing depend on the stage of pregnancy, and (ii) to compare the response to shearing of housed ewes with the response from extended grazing, with respect to ewe and lamb performance traits.

Materials and Methods

Forages

Grass silage was produced from the primary growth, of predominantly perennial ryegrass swards, on 25 May after a 24 h wilting period. The herbage was cut using a mower fitted with a V-spoke grass conditioner, baled and ensiled in big bales without additive. The bales were transported immediately to the storage area, wrapped with four layers of plastic film and stacked three high.

One 3.0 ha paddock of predominantly perennial ryegrass was closed each week between 8 September and 1 October for grazing between 7 December and early March. Each paddock received fertiliser N (30 kg/ha) at the time of closing.

Animals and management

The ewes involved in the study comprised those that did not return to first service, in a flock joined (at pasture) with rams on 11 October, and were pregnant at ultrasonic scanning (on 6 December). A total of 265 ewes (192 Belclare × Cheviot, 22 Suffolk-X and 51 Belclare) were allocated at random to one of five treatments subject to the restriction that expected litter size and ewe breed were equally represented (as far as possible) on each treatment. The five treatments were: housed unshorn (HU), housed shorn (HS), grazing throughout pregnancy (extended grazing - EG), grazing during mid pregnancy (to 20 January) and then housed (EGH), and housed during mid pregnancy (to 20 January) followed by grazing until lambing (HEG). The sheep on the HS treatment were shorn on 11 December. Ewes on the HU, EG, EGH and HEG treatments remained unshorn. The HU and HS treatments continued until lambing, which occurred indoors. The HEG and EG treatments continued until 1 March when the ewes were dispersed for lambing across the area intended for subsequent grazing. The ewes on the EGH treatment lambed indoors. Lambing occurred between 3 and 31 March (mean 17 March).

While indoors, the ewes were accommodated on straw bedding in groups of 26 or 27 (1.8 m^2 per ewe). Housed ewes were offered grass silage *ad libitum* daily for the duration of the study and supplemented with a proprietary concentrate [crude protein (CP) 180 g/kg, ether extract 35 g/kg, crude fibre 110 g/kg, ash 80 g/kg] during the final 6 weeks of pregnancy. The level of supplementation was 250, 400 and 600 g per ewe per day during weeks 6 and 5, 4 and 3, and 2 to lambing (relative to the due date of the first lambs). These ewes also received a daily allowance of 100 g of soya bean meal from week 2 until lambing.

While on extended grazing, ewes were offered a daily herbage DM allowance of 1.3 kg. Triplet-bearing ewes on extended grazing were managed separately from those bearing singles or twins during the last 6 weeks of pregnancy to allow different supplementation levels. During weeks 6 and 5, and weeks 4 to lambing, ewes in the single- and twin-bearing group were offered a daily concentrate supplement of 250 and 400 g/head, respectively. The triplet-bearing ewes were offered supplement at 250, 400 and 600 g/day during weeks 6 and 5, 4 and 3, and 2 to lambing, respectively.

Ewes that lambed indoors were turned out to pasture within 3 days. All ewes (regardless of treatment) rearing singles or twins were grazed together, grouped according to lambing date, until weaning. Ewes rearing triplets were grazed separately and offered a concentrate supplement (1 kg/ewe daily) for 5 weeks after lambing. Creep feed was available to triplets from birth to weaning and to all lambs from week 5 to weaning at a mean age of 14 weeks. A maximum of 300 g creep was offered per lamb per day.

Measurements

Pre grazing herbage mass was estimated by cutting 0.25 m^2 quadrats, chosen at random. Fifteen quadrats were cut to ground level on 2 December on the pasture to be grazed between 7 December and 20 January. The swards to be grazed between 21 January and pre-lambing dispersal were sampled (15 quadrats) on 12 January. Herbage was cut using a battery-powered hand shears (Gardena, Ulm, Germany). A representative sample of herbage from each quadrat was taken for the determination of DM (oven drying at 98 °C for 16 h) after which these samples were milled and analysed for CP, ash, *in vitro* DM digestibility (DMD) and acid detergent fibre (ADF). The daily herbage allocation was based on the DM yields obtained in December and January, as appropriate.

Five silage bales were chosen at random and sampled. The samples were bulked for the determination of pH and oven DM, then milled and analysed for CP, ash, DMD and ADF. Silage DM concentration was determined by oven drying (40 °C for 48 h). Other methods of analysis of herbage and silage were as described by Keady and O'Kiely (1996).

Ewe live weight and condition score (Russel, Doney and Gunn, 1969) were recorded at the start of the study, at the change over from grazing to housing (mid study), at 5 weeks post lambing and at weaning. In addition, ewe condition score was recorded within 24 h after lambing.

Mating and lambing dates were recorded for all ewes. Live lambs were tagged in duplicate and all lambs were weighed within 24 h of birth. Lambs were weighed again at 5, 10 and 14 (weaning) weeks of age. Lamb growth rate was calculated for the periods 0 to 5, 5 to 10, 10 to 14 and 0 to 14 weeks.

Statistical analysis

The data were analysed using Proc MIXED of SAS (SAS, 2000). For all traits, the model included fixed effects for treatment, ewe genotype and age (2 to 5 years). In the case of lamb traits the individual ewe was included as a random term. Birth type (1 to 3) and sex were also included as fixed effects for lamb birth weight while these effects plus an effect for rearing type (1 to 3) were included in the models for subsequent lamb weights and growth rates. Models for ewe live weight and condition score included pre-experimental values of live weight and condition score, respectively, as a covariate.

Differences among the four treatments applied to unshorn ewes were evaluated using orthogonal contrasts representing the effects of housing or grazing in mid or late pregnancy and their interaction. The *a priori* contrast between housed unshorn ewes (HU) and ewes shorn at housing (HS) was also evaluated.

Results

The chemical composition of the winter-grazed herbage and the silage offered are presented in Table 1. The silage was well preserved and of moderate feeding value based on pH and the concentrations of DM and DMD. The grass offered pre and post 20 January had similar concentrations of CP, ADF, predicted ME and ash, while DMD was higher for the herbage offered post 20 January.

The mean herbage DM yield of the swards grazed between 7 December and 20 January, and 21 January and dispersal for lambing, were 3,020 and 1,897 kg/ha, respectively.

The effects of the shearing and extended grazing treatments on ewe body condition and live weight are presented in Table 2. There were no significant interactions between the treatments applied to unshorn ewes in mid-pregnancy and those applied in late pregnancy with

Table 1. Chemical composition of winter grazed herbage and silage

	Grazed herbage		Silage
	7 Dec to 20 Jan	21 Jan to 1 Mar	
Dry matter (DM, g/kg)	123	153	271
pH	–	–	4.2
Composition of DM (g/kg)			
Crude protein	260	271	155
Ash	131	133	97
Acid detergent fibre	258	250	304
In vitro DM digestibility	678	725	741
Metabolisable energy (MJ/kg DM)	11.4[1]	11.6[1]	10.7[2]

[1] Determined using equations of Givens, Everington and Adamson (1990).
[2] Determined using equations of Givens, Everington and Adamson (1989).

respect to ewe live weight or condition score traits, apart from condition score at weaning. Relative to ewes housed and unshorn throughout, ewes shorn at housing had a higher condition score at the mid-study stage ($P < 0.01$) and a higher live weight at weaning ($P < 0.05$). Ewes grazed during mid pregnancy had a higher live weight ($P < 0.001$) and condition score ($P < 0.001$) at the mid-study stage and a higher condition score at lambing ($P < 0.05$) than those housed unshorn during mid pregnancy. Ewes grazed in late pregnancy had a higher condition score at lambing ($P < 0.001$) and a higher live weight at 5 weeks post lambing ($P < 0.001$) than unshorn ewes housed during late pregnancy. There was a significant interaction between the effects of mid pregnancy and late pregnancy treatments on condition score at weaning. At weaning, ewes which were extended grazed in mid pregnancy had a higher condition score, whilst those which were extended grazed in late pregnancy had a lower condition score.

The effects of shearing at housing and extended grazing treatments on gestation length, prolificacy traits and litter weight are presented in Table 3. There were no significant interactions between the effects of treatments applied in mid and late pregnancy for any of the variables. The gestation period was significantly ($P < 0.001$) longer for shorn ewes housed throughout the study than for housed unshorn ewes. There were no significant effects associated with either the mid-pregnancy or late-pregnancy treatments. Shearing ewes at housing significantly increased litter weight ($P < 0.01$) compared with ewes unshorn and housed throughout the study. Likewise ewes on extended grazing in late pregnancy had significantly ($P < 0.05$) heavier litters than ewes that were housed unshorn during this period. Treatment had no significant effects on litter size, number of lambs born dead or on number weaned per ewe.

The effects of shearing at housing and of the treatments applied during mid and late pregnancy on lamb birth weight and on subsequent growth traits are presented in Table 4. There was no interaction between the effect of treatment applied in mid pregnancy and that due to treatment applied in late pregnancy for any of the growth traits. Shearing ewes at housing increased lamb birth weight ($P < 0.001$), weaning weight ($P < 0.01$) and daily live-weight gain from birth to 5 weeks ($P < 0.05$) and birth to weaning ($P < 0.01$). Lambs from ewes

Table 2. Effects of shearing and extended grazing on ewe body condition score and live weight

Variable	Treatment[1]					s.e.	Significance of contrasts[2,3]		
	Housed		EGH	HEG	EG		Shearing	Extended grazed *v* Housed in	
	Shorn	Unshorn						Mid pregnancy	Late pregnancy
Live weight (kg)									
Initial	71.4	72.1	71.7	72.0	71.1	1.16			
Mid study	77.8	77.8	73.8	80.1	73.4	0.51		***	
Week 5 post lambing	73.9	73.9	75.2	79.0	77.3	0.95			***
Weaning	73.7	71.6	72.3	73.9	72.5	0.89	*		
Change – start to week 5 post lambing	0.02	0.06	1.30	5.10	3.46	0.955			***
Condition score									
Initial	3.56	3.57	3.47	3.57	3.46	0.066			
Mid study	3.78	3.59	3.43	3.83	3.48	0.052	**	***	
Lambing	3.33	3.30	3.20	3.60	3.47	0.061		*	***
Week 5 post lambing	3.31	3.64	3.29	3.47	3.79	0.312			
Weaning	3.34	3.35	3.42	3.61	3.37	0.087			
Change									
– Start to lambing	–0.26	–0.29	–0.33	0.01	–0.06	0.071			***
– Start to week 5 post lambing	–0.28	0.05	–0.24	–0.13	0.27	0.313			

[1] EGH = unshorn ewes extended grazed (7 December to 20 January) and then housed, HEG = unshorn ewes housed (7 December to 20 January) and then extended grazed, EG = unshorn ewes extended grazed throughout, HU = unshorn and housed throughout, HS = shorn and housed throughout.

[2] Contrasts: shearing = HS *v* HU, mid pregnancy = HU+HEG *v* EG+EGH, late pregnancy = HU+EGH *v* EG+HEG.

[3] The only interaction detected was between effects of mid-pregnancy and late-pregnancy treatment on condition score at weaning.

Table 3. Effects of shearing and extended grazing on gestation length, litter size, litter weight and viability of lambs

Variable	Treatment[1]					s.e.	Significance of contrasts[1,2]		
	Housed		EGH	HEG	EG		Shearing	Extended grazed *v* Housed in	
	Shorn	Unshorn						Mid pregnancy	Late pregnancy
Gestation length (days)	147.0	145.6	146.3	146.6	146.9	0.34	***	P = 0.09	**
Litter size	2.24	2.25	2.18	2.10	2.12	0.111			
Lambs born dead (no. per ewe)	0.17	0.17	0.16	0.14	0.14	0.059			
Litter weight (kg)	9.93	8.58	8.88	9.08	9.73	0.363	**		*
Lambs weaned (no. per ewe)	1.93	1.87	1.92	1.88	1.75	0.120			

[1] See footnotes to Table 2.
[2] There were no interactions involving the mid-pregnancy and late-pregnancy treatments.

Table 4. Effects of shearing and extending grazing of ewes on subsequent lamb performance

Variable	Treatment[1]					s.e.	Significance of contrasts[1,2]		
	Housed		EGH	HEG	EG		Shearing	Extended grazed *v* Housed in	
	Shorn	Unshorn						Mid pregnancy	Late pregnancy
Birth weight (kg)	4.88	4.25	4.40	4.62	4.96	0.104	***	**	***
Weaning weight (kg)	34.6	32.1	33.3	33.8	34.9	0.66	**	*	***
Live-weight gain (g/d)									
Birth to 5 weeks	308	285	299	307	318	8.0	*	P = 0.07	**
Weeks 5 to 10	344	339	333	334	348	10.0			
Weeks 10 to 14	254	233	237	218	230	10.8			
Birth to weaning	306	286	297	301	310	6.3	**	P = 0.07	**

[1] See footnotes to Table 2.
[2] There were no interactions involving the mid-pregnancy and late-pregnancy treatments.

that were grazed during mid pregnancy had a higher birth ($P < 0.01$) and weaning weight ($P < 0.01$), and tended ($P = 0.07$) to have higher live-weight gain from birth to 5 weeks and birth to weaning, than lambs from ewes that were housed unshorn during this stage. Lambs born to ewes that were grazed in late pregnancy were heavier at birth ($P < 0.001$) and weaning ($P < 0.001$) and had higher daily live-weight gain from birth to 5 weeks ($P < 0.01$) and birth to weaning ($P < 0.01$) than lambs from ewes housed unshorn during late pregnancy. Treatment had no significant effects on live-weight gain from weeks 5 to 10 or weeks 10 to 14.

Discussion

The current study is novel in that it included a comparison of ewes shorn at housing and ewes grazed during pregnancy. The herbage offered had similar crude protein, ash and estimated ME concentrations to those reported by Flanagan (1994) for autumn saved pastures. The grass silage offered had a similar composition to the average silage produced in Ireland. Thus, Keady (2000) quoted mean pH and concentrations of DM, CP and ME of 4.1, 230 g/kg, 127 g/kg DM and 10.5 MJ/kg DM, respectively, for grass silages produced in Ireland. It is worth noting that the grass silage was conserved unchopped in big bales as Dulpy and Dermarquilly (1972) and Fitzgerald (1996a, b) demonstrated that longer chop length reduced silage intake, and consequently its feeding value, for ewes.

Results from previous studies have shown that lamb birth weight is increased following grazing in mid (Flanagan, 2003) and throughout (Keady *et al*., 2008) pregnancy, relative to unshorn housed ewes offered grass-silage based diets. This study has quantified the proportional increase in birth weight due to extended grazing. The treatments commenced on about day 47 of gestation and the changes in diet for treatments HEG and EGH occurred at about day 90. At day 90, foetal weight is approximately 15% of ultimate birth weight but placental growth is virtually complete (Robinson and Aitken, 1977). The increase in foetal weight due to grazing up to day 89 of pregnancy was 0.14 kg which is 35% of the increased birth weight due to grazing for the duration of gestation. Faichney and White (1987) and Russel *et al*. (1981) observed that, relative to ewes offered maintenance, those receiving 0.6 maintenance during mid pregnancy produced lambs of 17% and 13% higher birth weights, respectively. In the present study, when availability of ME from estimated live weight change and from the level of concentrate offered is considered, it is possible to predict mean daily forage and ME intakes. The treatments that produced the heaviest lambs (namely ewes shorn and housed, and those grazed throughout pregnancy) had estimated ME intakes of about 1.2 maintenance. Bell *et al*. (1989) reported that the uptake of amino acids by the foetus was considerably greater in mid pregnancy than in late pregnancy, while Lippert, Milne and Russel (1983) suggested that amino acid supply was more important in alleviating adverse effects on lamb birth weight, arising from undernutrition of the ewe in mid pregnancy, than ME supply. Although estimated mid pregnancy ME intake did not differ greatly between treatments, the composition of the protein intake from the silage and grazed diets probably did differ. During ensiling, considerable protein degradation occurs and Keady (1991) reported that true protein accounted for 790 and 553 g/kg N, respectively, for the herbage at ensiling and the resultant silage. Furthermore, Keady and Murphy

(1998) observed that ensilage increased protein degradation in the rumen and reduced microbial protein supply. Thus, the increased lamb birth weight due to grazing in mid pregnancy was probably due to increased true protein intake leading to a greater supply of amino acids to the conceptus.

The increase of 0.46 kg in lamb birth weight due to grazing in late pregnancy was 65% of the total increase in birth weight due to grazing for the full duration of the study. This increase in birth weight was probably due to either reduced heat stress (Alexander and Williams, 1971; Skelton and Huston, 1968), higher intake characteristics of grazed grass relative to long chop silage (Keady and Murphy, 1993), or to improved protein nutrition (Keady, 1991; Keady and Murphy, 1998). Of these, the major factor was probably reduced heat stress, as the shorn housed ewes produced lambs of similar birth weight to ewes grazed on pasture throughout, after a similar gestation length, whilst being offered the same diet as the housed unshorn ewes which produced lighter lambs.

The increased lamb birth weight due to shearing recorded in the present study is similar to that reported by Black and Chestnutt (1990) and Vipond *et al*. (1987), but contrary to the results of Russel, Armstrong and White (1985). Whilst it has been reported that winter shearing increased food intake (Maund, 1980; Vipond *et al*., 1987), the data from the present study indicate that live-weight change was similar and that the estimated ME requirements per ewe for the study were 1,238 and 1,299 MJ, and forage DM intakes were 0.83 and 0.89 kg/day, for ewes housed unshorn and shorn, respectively. Black and Chestnutt (1990) observed that improving silage feed value and winter shearing increased silage DM intake by 0.28 and 0.08 kg/day, respectively, and subsequent lamb birth weights by 0.02 and 0.78 kg, respectively, supporting the hypothesis that change in intake cannot fully account for the increased birth weight due to shearing. Furthermore, whilst Vipond *et al*. (1987) reported increased intake due to shearing, the intake response to shearing increased as the concentrate proportion of the diet increased. The increased birth weight due to winter shearing in the present study may be associated with improved protein digestion and utilisation, increased gestation length and reduced heat stress in late pregnancy. Ngongoni *et al.* (1987) observed that winter shearing increased the quantity of UDP available for absorption in the small intestine and potentially contributes approximately 0.3 of the daily net accretion of protein in the gravid uterus of the twin-bearing ewe in late pregnancy. Shearing ewes decreases heat stress as indicated by lower rectal temperature (Black and Chestnutt, 1990; Vipond *et al*., 1987) and respiration rate (Black and Chestnutt, 1990; Kirk *et al*., 1984). The increased gestation length (1.4 days) in the shorn group was probably due to reduced heat stress. Skelton and Huston (1968) and Alexander and Williams (1971) observed increased gestation length of up to 5.3 days when heat stress was reduced. Whilst it is noted that the ambient temperatures in the current study were not as high as those in the studies of Skelton and Huston (1968) or Alexander and Williams (1971), mild heat stress may have occurred in the unshorn ewes due to the insulating properties of wool. The longer gestation length does not fully explain the increase in lamb birth weight. Using the equations of Koong, Garrett and Rattray (1975) and Robinson *et al*. (1977) for foetal growth, increasing gestation length from 145.8 to 147.5 days would increase foetal growth by 0.14 kg and 0.21 kg, respectively. These values account for 23 and 34, and 20 and 30%, respectively, of the increased birth weight of the lambs from the shorn and grazed ewes.

The observation that ewes that were grazed in either late or throughout pregnancy had a higher body condition score at lambing is consistent with the results of Keady *et al*. (2008). Body condition score is likely to be a more accurate predictor of body energy reserves than live weight which may be affected by differences in gut fill and the weight of the gravid uterus. Although the ewes were not weighed at lambing, post lambing live weight can be estimated from changes in body condition score as Hanrahan (1990) found that for similar genotype ewes, a one unit change in body condition score was equivalent to approximately 12 kg in live-weight change. The ME requirements for maintenance, activity and pregnancy, and for estimated live-weight change, calculated using the methods of AFRC (1993) are also presented in Table 5. The ewes which were housed and grazed in late pregnancy, grazed throughout pregnancy and shorn at housing had higher estimated ME requirements by proportionately 0.03, 0.08 and 0.05, respectively, than the housed unshorn ewes. This was due primarily to the increased requirements for pregnancy associated with heavier lamb birth weight. Treatment had little effect on calculated maintenance requirements. Extended grazing in late or throughout pregnancy is estimated to increase activity requirements (Table 5), by proportionately 0.53 and 2.1, respectively, relative to the housed unshorn ewes. Whilst these ewes were grazed outdoors and the area allocated daily was similar to the space allowance of the housed ewes, they probably had a greater ME requirement for the maintenance of body temperature.

Utilisation rate is one of the main factors affecting the cost of grazed grass (Keady *et al.*, 2002). In the present study, the DM allocation per ewe was 1.3 kg and the estimated mean daily forage DM intake was 0.92 kg, resulting in an estimated

Table 5. Estimated metabolisable energy requirements and predicted availability for each treatment†

	Treatment[1]				
	Housed		EGH	HEG	EG
	Shorn	Unshorn			
Live weight change until lambing[2] (kg)	–3.1	–3.5	–4.2	0.1	–0.72
ME requirements (MJ/ewe for the study)					
Maintenance	763	760	751	770	759
Activity	55	55	81	84	112
Pregnancy	480	422	421	422	462
Total	1299	1238	1253	1276	1332
ME availability (MJ)					
Concentrate	270	270	270	238	238
LW change	77	74	103	17	36
ME required from forage (MJ)	954	891	880	1022	1059
Predicted forage DM intake (kg/day)	0.89	0.83	0.79	0.92	0.92

† Calculations based on AFRC (1993).
[1] See footnotes to Table 2.
[2] Live weight loss until lambing based on change in condition score, where each 1 unit change in condition score is equivalent to a change of 12 kg in live weight (Hanrahan, 1990).

herbage utilisation rate of 71%. This is similar to the values of 78% and 71% by single- and twin-bearing ewes, reported by Keady and Hanrahan (2007a). Likewise, Keady and Hanrahan (2007b) reported herbage utilisation rates of 81% and 70% for ewe lambs offered herbage DM allowances of 0.75 and 1.75 kg daily, respectively. However, Keady and Hanrahan (2008) reported much lower utilisation rates of 45% and 34% as daily herbage allocation increased from 1.0 to 1.8 kg DM, for ewes in mid pregnancy.

The relationship between the effects of treatment on lamb birth weight and on weaning weight was linear ($P < 0.01$) and is described by the equation:

$$WW = 17.88 + 3.35\ BW\ (\text{s.e. } 0.563)\quad (R^2 = 0.93^{**})$$

where

WW = weaning weight (kg) and
BW = birth weight (kg)

It is concluded that grazing in mid, late or throughout pregnancy, and shearing housed ewes increased lamb birth and weaning weights, relative to housed unshorn ewes. The increased lamb birth weight from grazing in mid pregnancy was probably due to improved protein utilisation from the grazed herbage, whereas the increased lamb birth weight from grazing in late and throughout pregnancy, and from shearing at housing, was probably due mainly to reduced heat stress, and removal of the fleece in mid pregnancy, respectively.

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