
VOLUME 62 2002

# How does feeding meal affect growth of artificially reared East Friesian-cross dairy lambs?

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## Abstract

Artificial rearing is routinely used in large-scale dairy sheep farms. One approach is to offer milk replacer (MR) and meal *ad libitum* to lambs. Our aim was to evaluate growth performance of female lambs in the first 12 weeks of rearing with (M) and without (NM) grain-based meal access (n=30/group) during four feeding periods. In period 1 (wk 0-3) lambs were offered MR and meal *ad libitum*, and in period 2 (wk 4-5) were transitioned outdoors onto pasture with continued access to MR and meal. Lambs were weaned off MR in period 3 (wk 6-10), and meal in period 4 (wk 10-12). The NM lambs received identical management but meal was excluded. A treatment-by-time interaction was found whereby NM lambs had lower average daily gain (ADG) ($P<0.05$) in periods 1 (376±6 *vs*. 414±8 g/day) and 3 (146±7 *vs*. 241±7 g/day), no difference in period 2 ($P>0.05$), and higher ADG in period 4 (157±18 *vs*. -55±18 g/day, $P<0.05$) than M lambs. There was no difference ($P>0.05$) in live weight by week 12, and all lambs survived. These results indicate when lambs fed MR *ad libitum* are offered unrestricted access to good-quality pasture before weaning, meal may not be required to achieve a similar live weight at 12 weeks.

**Keywords:** lamb; growth; artificial rearing; weaning transition

## Introduction

The New Zealand sheep dairy industry is currently experiencing significant growth (Peterson & Prichard 2015). In the first 30 days of lactation, when lambs would normally be suckling, dairy ewes produce around 25% of their total milk yield, so artificial rearing of lambs is used on some farms to enable this milk to be harvested and sold (McKusick at al. 2001). One artificial rearing system that is used for lambs in New Zealand involves feeding milk replacer (MR) and meal *ad libitum*. Feeding meal or other solid feeds during the pre-weaning period can improve the lamb's adaptation to diets after weaning off milk and improve subsequent average daily gain (ADG) (Bimczok et al. 2005). Thus, the rationale behind feeding meal is that it allows earlier intake of solid feed and rumen development when lambs are reared indoors without pasture access.

The main factor affecting ability of lambs to grow quickly after weaning off milk is their rumen's ability to utilise solid feed (Joyce & Rattray 1970). Once lambs are weaned off milk, they rely on their rumen to ferment solid feeds and for absorption of volatile fatty acids (VFAs). Mature ruminants obtain approximately 70% of their energy from VFAs (Baldwin 2000), making it essential that lambs have a well-developed rumen that is capable of producing sufficient VFAs to support high ADG. In young ruminants, the amount of solid feed eaten and its composition (the quality and quantity of carbohydrates and proteins) dictate various behavioural, morphological, and physiological developments and, thereby, determine the transition success from milk to post-weaning diets (Khan et al. 2016). However, it is unclear how meal offered to lambs during the pre-weaning period affects their growth performance during transitions from milk to pasture. The aim of this experiment was to compare the growth performance of artificially reared lambs fed MR *ad libitum*, with and without access to meal during transitions from MR to pasture, when given early access to unrestricted pasture.

## Materials and methods

All procedures of this study were approved by the AgResearch Grasslands Animal Ethics Committee, Palmerston North, New Zealand .

### *Experimental design*

This study was conducted at AgResearch Limited Grasslands in Palmerston North, New Zealand. East Friesian cross-bred lambs (n=60, 3-day-old females) were sourced on the same day from a commercial farm and allocated to two groups (n=30/group) balanced for litter size (50% singles/twins and 50% triplets/quads) and average initial weight (4±0.2 kg). Lambs were sourced at three-days-old to allow them time to obtain colostrum from their mothers. Meal lambs (M) were given access to meal *ad libitum* from weeks 0 to 9 of the experiment, whilst lambs fed no meal (NM) received identical treatment except meal was excluded from their diets. There are three key transition phases in artificial lamb-rearing systems: moving outdoors, weaning off MR, and weaning off meal. To study these transitions, the experiment was divided into four periods. In period 1 (week 0-3), lambs were housed in an indoor temperature-controlled facility, with one pen of 30 lambs per treatment, and were allowed access to MR *ad libitum* (Anlamb, NZAgbiz Ltd, Timaru, New Zealand; mixed at 230 g/L) fed through an automatic feeder (CalfMom ALMA Urban Feeder, PPP industries, Tuakau, New Zealand) with one teat per pen. Individual intake of MR was recorded electronically and checked twice daily to ensure lambs had learned to use the automatic feeders and to identify any potential health issues that may be causing low intake. Additionally, while lambs were indoors, each lamb had an individual daily health check (e.g., incidence of lameness, bloat, navel infection, scours, and eye infections). All lambs survived and one lamb was treated for pneumonia and several treated for eye infections. Lambs fed meal were offered grain-based TLC lamb meal *ad libitum* designed by Animal Innovations Pty Ltd (Totness, South Australia 5250) and manufactured by Gavins Grain Ltd (Gordonton, Hamilton, New Zealand). A textured meal without a forage source was used and consisted of soy and canola meal, maize and barley grain, molasses, vegetable oil, and lamb additive mineral mix (details not available in addition to chemical composition). Meal was provided in feeders along the edge of the pen providing 20 cm head space per lamb and was replaced daily. In period 2 (week 4-5), after three weeks indoors, lambs were moved outdoors onto pasture into three cohorts per treatment (n=10/cohort) organised into three blocks with one pen per treatment in each block. Over this period, each cohort was fed MR *ad libitum* through one cafeteria feeder with four teats. Each morning and afternoon, the feeder was cleaned and new MR was provided. Over this period, M lambs continued to be provided meal *ad libitum* in troughs. Lambs were abruptly weaned from MR, as occurs in the large-scale lamb-rearing system being investigated, at the end of period 2 on day 38. In period 3 (week 6-10), M lambs continued to have access to meal *ad libitum* until week 9, at which point they were gradually weaned from meal. Meal provided was reduced by 10% of *ad libitum* intake per day for ten days over weeks 9 and 10 (all meal removed by day 68). In period 4 (week 10-12), both groups received unrestricted access to pasture until week 12 when the experiment ceased.

*Animal and feed measurements*

In Period 1, lambs were fitted with electronic identification collars that allowed individual daily MR intakes to be recorded by the automatic feeder, and group meal intake was recorded daily by refusals. In period 2, cohort MR intake was recorded daily by refusals and in period 2 and 3, cohort meal intake was recorded daily by refusals. Lambs were allowed access to water *ad libitum* at all times. Lambs were weighed at the beginning of the experiment without fasting and weekly thereafter at the same time of day. Samples of MR and meal were taken weekly and pooled for analysis to give a representative nutrient profile of the feeds over the experimental period. Composition of the MR was determined by the procedures of AOAC (1990) (Nutrition Laboratory, Massey University, Palmerston North, New Zealand). Composition (dry matter (DM) basis) was: 96.4% DM; 5.8% ash; 25.6% crude protein (CP); 25.5% fat; 21.6 MJ/kg metabolisable energy (ME). Composition of meal was evaluated using near-infrared spectroscopy (NIR) (RJ Hill Labs, Hamilton, New Zealand). Composition (dry matter basis) was: 87.2% DM; 17.0% CP; 4.7% ash; 4.1% fat; 2.7% nitrogen; 12.3% neutral detergent fibre; 5.9% acid detergent fibre and 14.0 MJ/kg ME. Metabolisable energy was calculated using AFRC (1993) and Lincoln University standard formulae. Pasture samples were taken weekly after lambs were moved outside. Ten random cuts using a 0.25 m x 0.25 m quadrant were taken from each paddock. Samples from each cohort were pooled for weeks 4-5 (period 2), weeks 6-9 (period 3), and weeks 10-12 (period 4) and underwent NIR analysis to determine composition (Table 1) (Nutrition Laboratory, Massey University, Palmerston North, New Zealand). Feed samples were collected in these periods to allow any changes in nutrient composition over the different transition periods to be observed. Pasture intake was not able to be measured but plate-meter readings were taken to give an indication of allowance. Thirty plate readings were taken in each cohort paddock weekly and there was usually no large difference between groups. Pasture allowance was between 1700 and 5000 kg DM/ha over the experimental period.

## Statistical analysis

A repeated-measure mixed-effects model was fitted for ADG with fixed effects of period, birth rank, and treatment group, and random effects of lamb nested in pen within block, with initial live weight fitted as a covariate. Lamb live weight at the end of each period was analysed by fitting a repeated-measure mixed-effects model and data were log-transformed to meet the assumptions of normality and homogeneity. Included were fixed effects of period, birth rank, and treatment group, and random effects of lamb nested in pen within block, with live weight at the beginning of each period fitted as a covariate. These

**Table 1** Composition of pasture grazed by lambs in two treatment groups (meal feeding (M) and no meal feeding (NM)) over three periods of milk and meal (M lambs) or milk feeding (NM lambs) (period 2), pasture (NM) or pasture and meal feeding (M) (period 3), and pasture feeding only in both groups (period 4).

| Nutritive component | Treatment group | Period 2 | Period 3 | Period 4 |
|---|---|---|---|---|
| Dry matter (%) | M | 17.1 | 16.7 | 16.9 |
| | NM | 17.1 | 16.4 | 15.1 |
| ME (MJ/kg DM) | M | 11.9 | 11.0 | 11.2 |
| | NM | 11.9 | 11.1 | 11.3 |
| Crude protein (%)* | M | 22.7 | 21.5 | 15.5 |
| | NM | 25.2 | 21.6 | 20.6 |
| Ash (%)* | M | 10.7 | 9.7 | 8.6 |
| | NM | 10.9 | 9.8 | 10 |
| NDF (%)* | M | 41.0 | 41.1 | 43.2 |
| | NM | 38.8 | 43.5 | 37.9 |
| ADF (%)* | M | 18.4 | 19.8 | 22.8 |
| | NM | 18.0 | 20.5 | 19.1 |

M= meal group; NM= no meal group; ME=Metabolisable energy; NDF=Neutral detergent fibre; ADF=Acid detergent fibre. *=as a percentage of DM. Composition was determined by NIR analysis (Nutrition Laboratory, Massey University, Palmerston North, New Zealand).

analyses were conducted using R (R Core Team 2016). All other analyses were completed using GenStat 18th edition (VSN International 2015). Two statistical programs were used due to different functionality being available in the different programs. MR intake for period 1 was analysed by analysis of variance (ANOVA) with fixed effects of birth rank and treatment group, and initial live weight used as covariate. Data for MR intake in period 1 were log-transformed to meet the assumptions of normality and

**Figure 1** Average daily gain (mean±SEM) of lambs fed meal (M; ■) or no meal (NM; □) over four feeding periods. In period 1 (wk 0-3), milk replacer (MR) was provided to both treatment groups and meal offered to M lambs. In period 2 (wk 4-5), all lambs were offered unrestricted pasture and MR *ad libitum*, and meal offered *ad libitum* to M lambs. In period 3 (wk 6-10), no milk was offered and M lambs had access to meal *ad libitum*. In period 4 (wk 10-12), all lambs had unrestricted access to pasture. There was a significant treatment-by-time interaction (P<0.001). [ab] Values with different superscripts within each period are significantly different (P<0.05).

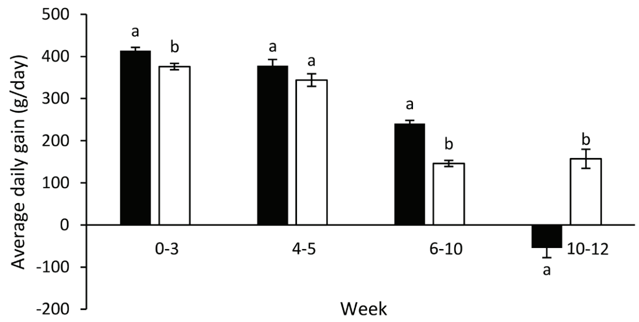
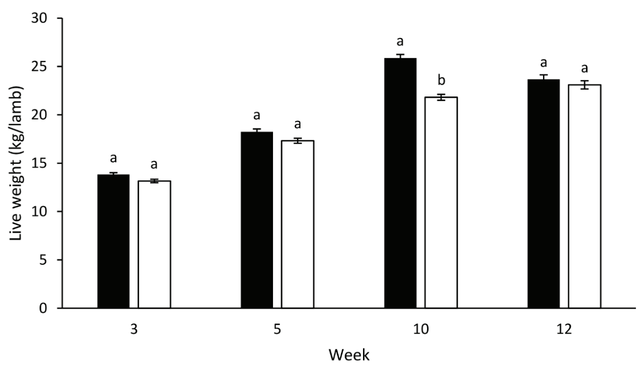



**Figure 2** Average live weight (mean±SEM) of lambs fed meal (M; ■) or no meal (NM; □) at weeks 3, 5, 10, 12. In period 1 (wk 0-3), milk replacer (MR) was provided to both treatment groups and meal offered to M lambs. In period 2 (wk 4-5), all lambs were offered unrestricted pasture and MR *ad libitum*, and meal offered to M lambs *ad libitum*. In period 3 (wk 6-10), no MR was offered and M lambs had access to meal *ad libitum*. In period 4 (wk 10-12), all lambs had unrestricted access to pasture. There was a significant treatment-by-time interaction (P<0.001). [ab] Values with different superscripts within each period are significantly different (P<0.001).




homogeneity. Average MR, DM, ME, and CP intake for period 2 was analysed by ANOVA with the fixed effect of treatment, and random effects of cohort nested within block. Overall daily average MR, DM, CP, and ME intake per lamb was analysed by ANOVA with fixed effects of treatment and random effects of block.

## Results

*Lamb average daily gain and live weight*

A treatment-by-time interaction (P<0.001) was observed such that NM lambs exhibited lower ADG in periods 1 and 3, similar ADG in period 2, and higher ADG in period 4 compared to M lambs (Figure 1). There was also a treatment-by-time effect on lamb live weight (P<0.001) such that in periods 1, 2, and 4, there were no differences between treatments, but in period 3 NM lambs were lighter than M lambs (Figure 2).

*Intake*

There was a treatment effect on MR intake, such that in period 1, NM lambs consumed less MR (P<0.01) than M lambs, but in period 2 there was no difference in MR intake (P>0.05) (Table 2). Overall NM lambs consumed less MR than M lambs (P<0.05). Due to the exclusion of meal from their diet, NM lambs potentially consumed less DM, ME, and CP from milk and meal sources (P<0.01) in period 2, and over the entire first three periods compared to M lambs (Table 2).

## Discussion

This study aimed to compare growth performance of lambs reared artificially with and without meal during weaning transitions. Feeding meal improved ADG before weaning, however, after meal weaning, M lambs had a growth check. Under our experimental conditions, meal feeding did not appear to benefit the transition to a pasture-only diet.

The lower ADG observed in NM compared to M lambs while indoors (period 1) was likely due to lower overall nutrient intakes, although individual meal intakes were not recorded. This agrees with the results of Poe et al. (1969), who reported that four-week-old lambs (kept with their mothers) that received corn and soy meal had higher ADG than lambs on a solely milk diet. In our study, upon transitioning outdoors (period 2), differences in ADG between groups disappeared, possibly because NM lambs may have consumed more pasture leading to a higher total nutrient intake (milk and pasture) compared to when they had no access to pasture. This may have resulted in ADG similar to M lambs. Additionally, gut fill can range from 6% of live weight in milk fed lambs to 30% in weaned lambs fed forage (National Research Council, 1985). Thus, we speculate there may be an effect of greater gut fill in NM lambs from pasture intake resulting in similar ADG to M lambs. Contrary to our results, Carrasco et al. (2009) found that naturally reared lambs fed meal on pasture had higher ADG compared to that of lambs with no meal provision

**Table 2** Average daily milk replacer (MR) and meal intake per lamb (mean±SEM) and intake (mean±SEM) of dry matter, metabolisable energy, and crude protein from MR and meal sources for M (fed meal) and NM (not fed meal). In period 1 (P1; wk 0-3), MR was provided to both treatment groups and meal offered to M lambs. In period 2 (P2; wk 4-5), all lambs were offered unrestricted pasture and MR *ad libitum*, and meal offered to M lambs *ad libitum*. In period 3 (P3; wk 6-10), no MR was offered and M lambs had access to meal *ad libitum*.

| P | MR intake (L/day) | | Meal intake (g/day) | DMI (g/day)[1] | | MEI (MJ/day)[1] | | CPI (g/day)[1] | |
|---|---|---|---|---|---|---|---|---|---|
| | M | NM | M | M | NM | M | NM | M | NM |
| P1 | 2.37±0.05[a] | 2.16±0.05[b] | 24 | 550 | 478 | 11.7 | 10.0 | 138 | 122 |
| P2 | 1.92±0.05[a] | 1.76±0.05[a] | 104±15 | 515±15[a] | 392±15[b] | 10.4±0.3[a] | 8.0±0.3[b] | 124±4[a] | 100±4[b] |
| P3 | - | - | 571±15 | 498±15 | - | 7.0±0.2 | - | 85±3 | - |
| 1-3 | 2.03±0.02[a] | 1.88±0.02[b] | 233±8 | 520±8[a] | 291±8[b] | 9.7±0.2[a] | 6.3±0.2[b] | 116±2[a] | 75±2[b] |

P=period; DMI=dry matter intake; MEI=metabolisable energy intake; CPI=crude protein intake. [1] Individual meal intakes were not recorded. Average DMI, MEI, CPI were estimated using milk intakes and estimated average meal intakes for each lamb.
[ab] Values within each period with different superscripts are significantly different (P<0.05).

on pasture. However, in their experiment, there were no transitions between environments, and milk and meal were fed for a longer period (nine weeks) than in our experiment. There are differences in the study by Carrasco et al. (2009) compared to our trial, as no ADG was reported after milk weaning and there was no meal weaning before the end of the experiment. It is likely that the combination of early weaning, transitioning outdoors, and pasture access caused differences in ADG between groups to disappear in our trial.

In the current study, both groups experienced declines in ADG upon the removal of MR (period 3). In calves, meal is considered important around MR weaning, as it allows a higher ADG to be maintained by providing stimulus for rumen development and more nutrients for an easier transition off MR to solid feed (Khan et al. 2016). In agreement, NM lambs had a lower ADG compared to M lambs, which could be due to lower intakes of ME and CP, as their only feed source was pasture, while M lambs on average continued to consume large quantities of meal (500 g DM /lamb/day), likely resulting in greater ME and CP intakes.

Lambs may prefer meal compared to pasture because it is a more energy-dense (De Araújo Camilo et al. 2012) and highly palatable feed (Baumont et al. 2000). Therefore, in our experiment, M lambs may have been substituting meal for pasture in periods 2 and 3, which has been observed in beef calves fed meal (Vendramini et al. 2006), although if there was substitution, it is not known as not measured in our trial. After meal weaning (period 4), M lambs experienced a sharp decline in ADG, likely due to a lower nutrient intake compared to that in the previous period. Brown (1964) reported that after early weaning onto pasture, feeding cereal-based meal improved ADG over the entire experimental period compared to that in lambs not offered meal. However, in their trial, lambs consumed less meal than those in our trial (270 *vs.*570 g/day), and were fed meal for a shorter period after weaning (23 *vs.* 31 days). Consequently, the amount of meal offered, or length of time lambs were offered meal, may affect the growth response and pasture intake. It is unclear if the severity of the growth check was due to a rumen or behavioural adaptation period, or a combination of both, after M lambs became reliant on pasture-only to meet their nutrient requirements. In this experiment, feeding meal did not appear to aid the transition to a pasture-only diet, although it is acknowledged that this was a relatively short-term study. The trial continued beyond the reported timeframes and rumen and metabolic development have been evaluated. The results of these studies will be published elsewhere.

In conclusion, while meal feeding has been previously used to improve ADG when transitioning young ruminants to pasture, in this experiment, the absence of meal feeding did not negatively affect lambs' overall growth to 12 weeks. Including meal in the diet before and after MR weaning improved ADG, however, upon meal removal, there was a large growth check. The results of this study indicate that when lambs are reared on MR *ad libitum* with unrestricted access to good-quality pasture and abruptly weaned, early access to meal may not be required to support growth to 12 weeks of age. Further studies are required to validate the findings of this study.

## Acknowledgements

This study was funded by the Ministry of Business, Innovation & Employment (MBIE; contract C10X1305), in partnership with Kingsmeade Artisan Cheese, Maui Milk, and Spring Sheep Dairy. The authors sincerely thank the Animal Nutrition & Physiology Team and Ulyatt-Reid Large Animal Facility staff for their assistance with animal care and data collection.

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