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Compensatory growth in lambs undernourished from birth

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ABSTRACT

There is evidence to suggest that lambs on restricted nutrition from birth fail to show compensatory growth. In this indoor trial, lambs were allocated to one of three treatments and fed on lamb milk formula, then sheep pellets. Lambs were started on high (H) or low (L) rates of intake from 3 days of age. Groups of L lambs were subsequently placed on H intakes (low-high; L-H) at 2, 4 and 8 months of age and killed at 4, 8 and 15 months of age respectively. At 15 months H lambs weighed 86.2 kg and L lambs 28.6 kg. The growth rates of L-H ranged between 224 and 242 g/d during compensatory growth. The H lambs averaged 186 and L lambs 50 g/d during the experiment. At slaughter, there was no difference between H and L-H lambs for hot carcass weight when adjusted for final live weight, and little change in the weight and length of M. *semitendinosus*. Hind limb dissection also demonstrated no effect of nutritional treatment on proportions of muscle, bone and fat in H and L-H lambs. These results suggest that lambs on restricted nutrition from birth retain their potential to grow if provided with improved nutrition.

Keywords: lamb; compensatory growth; carcass; live weight; muscle; fat; bone.

INTRODUCTION

Compensatory growth has been defined as when animals grow faster following a period of nutritional restriction (Hogg, 1991). Ryan (1997) expanded this definition to "the greater than normal liveweight change sometimes observed following a period when nutritional restriction is imposed on an animal such that liveweight increases only slowly, is maintained or is reduced, and that this restriction is maintained for sufficient time to allow adaptation to the lower nutritive state".

Three important variables affecting compensatory growth are the age or stage of development, the severity of the nutritional restriction and the duration of the restriction. Further, the growth response of individual animals to re-feeding after nutritional restriction is highly variable (Hogg 1991, Ryan 1997).

Nutritional restriction from birth may compromise future growth rate in young sheep and cattle. However, after 4-6 months of age complete compensatory growth can occur following a period of nutritional deficit (Morgan, 1972, Ryan, 1997), although the extent of compensation then declines as animals approach maturity (Hight & Barton, 1965). Severe nutritional restriction is thought to give rise to a longer period required for compensatory growth (Scales & Lewis, 1971), whereas increasing the duration of nutritional restriction results in higher rates of compensatory weight gain (Graham & Searle, 1975).

Overall, growth of an animal is the result of a coordinated increase in weight of organs, tissues and gut fill. With re-feeding after nutritional restriction, gut fill increases from 7.0-10.5% of liveweight during early compensatory growth (Baker *et al*., 1985). Internal organs, particularly liver, kidney, heart and digestive tract are sensitive to changes in nutrition. They do, however, take time to adapt to increased feeding after a restricted diet and it has been reported that sheep on a 60% *ad libitum* diet had not fully recovered their liver weight some 73 days after resuming *ad libitum* intake (Ledin, 1983).

Carcass tissues also vary in the extent of time taken to restore normal proportions during re-feeding. Protein deposition tends to be higher during the initial stages of compensation while the restoration of carcass fat takes longer (Hood & Thornton, 1980). Generally, the evidence indicates that there are few differences in body composition, regardless of growth path, as long as the period of compensation is of sufficient length (Krausgrill *et al*., 1997).

The present study examined the effect of age on compensatory growth in young sheep, with respect to live weight gain, muscle growth and carcass composition.

MATERIALS AND METHODS

Ewe lambs aged three days were divided into two groups which were balanced for live weight (n = 78). They were fed milk replacer designed for sheep (Denkavit, Skellerup Stock Foods, Auckland, NZ) at two concentrations, High (H, as per manufacturer's recommendations) and Low (L, 50% concentration of manufacturer's recommendations), until weaning at 15 weeks. From six weeks of age, the lambs were also fed sheep pellets (60% lucerne, 30% barley, 5% linseed, 5% molasses; Country Harvest Stockfeed, Hamilton, NZ). Lambs on H received a ration of pellets that increased daily by 200 grams whenever all the feed was consumed, while those on L received sufficient pellets to gain weight slowly.

At 2, 4 and 8 months of age, groups of lambs receiving the L diet were subsequently placed on the H intake (L-H) of 200 gram increments whenever feed was entirely consumed. After a period of compensatory growth, the L-H groups were slaughtered together with groups of H and L animals at 4, 8 and 15 months. At each slaughter, L-H lambs had spent approximately half their postnatal life in an undernourished state. Live weight was recorded each week and feed intake of the L treatment was adjusted to ensure that animals did not lose weight.

At slaughter, carcasses were weighed and the length of M. *semitendinosus* measured *in situ*. M. *semitendinosus* was then dissected from the left hind limb and weighed. Carcasses were chilled overnight and the right hind limb removed and frozen for later dissection of muscle, fat and bone. Data were compared by ANOVA, using co-variate adjustment on final live weight or hot carcass weight to allow comparisons to be drawn between H and L-H animals at similar carcass and live weights.

RESULTS

Average live weights of the treatment groups throughout the experiment are presented in Figure 1. Overall, H animals gained weight at 186 g/d while those on the L treatment gained 50 g/d. The L-H treatment groups had average daily gains in weight which were similar to or greater than those in age- or weight-matched H animals (Table 1).

FIGURE 1: Average live weight of groups of lambs on High, Low or Low-High nutrition treatments. Points are at 10 day intervals. (mean ± SED)

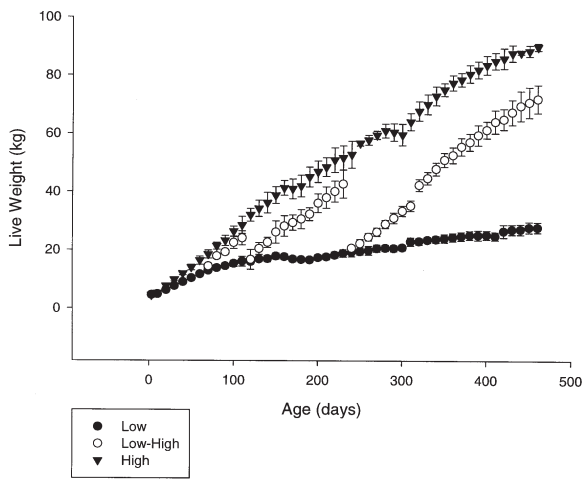

TABLE 1: Average daily gains in live weight of lambs on high nutrition (H) and low-high nutrition (L-H) treatments.

	Average daily gains in live weight (g/d) Mean (SEM)			Significance (Students t-Test)			
	H	H*	L-H	H vs L-H	H *vs L-H	%L-H /H	%L-H /H*
2-4 month	246 (9.8)	219 (6.7)	242 (8.6)	NS	p = 0.053	102	110
4-8 month	206 (7.2)	259 (10.1)	234 (11.4)	p = 0.054	NS	114	90
8-15 month	153 (3.8)	173 (4.8)	224 (6.4)	p < 0.001	p < 0.001	146	129

* Gains for the same period of time calculated for younger H lambs which were at the same initial weight as L-H lambs.

Table 2 shows that each period of compensatory growth was insufficient to completely restore body weight. At all ages, final live weight of the L-H groups was less than that of H ($p < 0.001$). Hot carcass weights, when adjusted using live weight as a co-variate, showed little difference between H and L-H treatments. At a common live weight, H animals at 8 months had relatively larger carcasses than L-H animals of the same age ($p < 0.05$), but this was not the situation in older and younger animals. After adjustment of data using hot carcass weight as a co-variate, muscle measurements showed little difference between the L-H and H treatments. At 8 months, length of M. *semitendinosus* in the H treatment was greater than in the L-H treatment ($p < 0.05$) but weight was not different.

TABLE 2: Live weight, carcass weight and muscle measurements at slaughter of lambs on high nutrition (H) and low-high nutrition (L-H) treatments.

	H	L-H	S.E.D	Significance (ANOVA)
Final Live weight (kg)				
4 month	27.3	23.6	0.88	p < 0.001
8 month	49.1	42.7	1.90	p < 0.001
15 month	86.2	68.6	1.96	p < 0.001
Hot carcass weight (kg)*				
4 month	14.0	11.7	0.52	NS
8 month	27.2	22.6	0.74	p < 0.05
15 month	49.9	37.6	2.83	NS
M. *semitendinosus*, Length (cm)#				
4 month	14.3	13.7	0.63	NS
8 month	18.3	16.8	0.90	p < 0.05
15 month	16.7	16.5	1.50	NS
M. *semitendinous*, Weight (g)#				
4 month	77.6	73.1	5.68	NS
8 month	109.6	102.0	11.59	NS
15 month	170.5	147.8	14.98	NS

* Final live weight used as a co-variate for analysis.
# Hot carcass weight used as a co-variate for analysis.

Data for muscle, fat and bone content of hind limbs were also adjusted using hot carcass weight as a co-variate. Comparisons were made between H and L-H, disregarding the age at slaughter, and no difference was found between treatments (Table 3). These data suggest that normal proportions of muscle, fat and bone were maintained in the L-H treatment, despite a markedly differing path of growth.

TABLE 3: Overall comparison of hind limb composition in lambs on high nutrition (H) and low-high nutrition (L-H) treatments, using hot carcass weight as a co-variate.

	Treatment		SED	Significance
	H	L-H		(ANOVA)
Muscle (kg)	1.95	1.98	0.047	NS
Fat (kg)	1.18	1.13	0.065	NS
Bone (g)	339	334	11.0	NS

DISCUSSION

In terms of the definitions provided by Ryan (1997), each group of L-H, animals in this trial achieved partial compensation of live weight, 80-87%, after variable periods of nutritional restriction. That is, although the gain in live weight was generally greater in LH animals than of age- or weight-matched lambs on H, weight differences between the groups were reduced but not eliminated. This may have arisen through insufficient time being allowed for LH groups to recover completely.

The overall rate of gain in each L-H group was relatively constant. This was surprising given that the duration of each period of poor nutrition was increased e.g. 2, 4 and 7 months (Graham & Searle, 1975), although it could be interpreted that the severity of the L treatment increased concurrently with the duration as L animals advanced in age. Others have noted that there is little difference in the rate of growth between low- and high-birth weight lambs fed on a high plane of nutrition during the first few weeks of life (Greenwood *et al*., 1998). Our data fit with the suggestion that more severe nutritional stress gives rise to a constant growth rate during compensatory growth, together with a variable period of recovery (Scales & Lewis, 1971).

Once differences in hot carcass weight were accounted for, none of the muscle and carcass measurements differed consistently between L and L-H treatments. The results of the hind limb dissection, in particular, reinforce that the period of compensatory growth in this experiment was sufficient to allow restoration of 'normal' levels of carcass tissues. Surprisingly, the 15 month L-H animals, which were unlikely to have undergone puberty before or during their compensatory growth period, showed skeletal dimensions which were similar to the H lambs which would have undergone puberty some 8 months earlier. This indicates that ultimate skeletal size may not be as tightly regulated by steroid-induced epiphysis closure as is often suggested (Hogg, 1991).

Our results indicate that potential live weight gain and carcass composition are not compromised by periods of under-nutrition at any age when this is followed by improved nutrition and the opportunity for compensatory growth. This differs from Ryan (1997) who suggested that young ruminants do not show compensatory growth, but supports other studies (Krausgrill *et al.,* 1997) in that young sheep retain the capacity to fully recover from prolonged/severe under-nutrition if given sufficient time to do so.

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