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Effects of nutrient restriction followed by realimentation on growth, visceral organ mass, cellularity, and jejunal morphology in lambs

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ABSTRACT

Effects of nutrient restriction and realimentation on growth, cellularity of visceral organs and jejunal morphology in lambs were investigated. Forty Wu Zhu Mu Qin lambs were divided into control group (CG), moderately protein-restricted group (PR), moderately energy-restricted group (ER) or severely protein- and energy-restricted group (PER). The experiment included an adaptation period (0–30 days), nutritional restriction period (31–90 days), and realimentation period (91–180 days). Weight of lambs was measured weekly. Four lambs of each group were slaughtered at 90 days and 180 days. After slaughter, visceral organs were weighed, and subsamples were obtained to evaluate visceral DNA and protein contents, and jejunal morphology. Final body weight (BW), dry matter intake (DMI) and average daily gain (ADG) of lambs in PR, ER and PER were significantly less ($P<0.01$) than those of CG lambs during the restriction period. On d 180, no significant difference was observed for BW among PR, ER and CG, however, BW of lambs in PER was still less ($P<0.01$) than that of CG, PR and ER; ADG of nutrition restricted lambs was significantly greater than ($P<0.01$) that of CG. Visceral organ weight, on wet tissue basis, decreased with nutrition restriction ($P<0.05$); there was no difference ($P>0.05$) of visceral organ weights among treatments on d 180. As compared with CG, PR had decreased DNA concentration of the liver ($P<0.05$), DNA and protein concentration of the pancreas ($P<0.05$), protein concentration and protein:DNA of kidney and omasum ($P<0.05$) on d 90; ER had decreased DNA concentration of the heart ($P<0.05$); and PER had decreased DNA concentration of the liver ($P<0.01$). Intestinal cellularity was not affected by treatment on d 90. Except for DNA concentration of the duodenum of lambs in ER, and DNA concentration of the jejunum of lambs in PR and ER, no significant differences were observed among treatments in cellularity of visceral organs on d 180. Compared with CG, crypt depth and muscle thickness of the jejunum were decreased ($P<0.01$) in lambs of PR, ER and PER on d 90. Villus height, crypt depth, muscle thickness and mucosa thickness of lambs in PR and ER were similar to CG lambs on d 180. Results indicate that nutritional restriction of 60 days can retard the growth, cellularity of visceral organs and jejunal morphological development of lambs, and retarded cellularity achieves complete compensatory growth after realimentation of 90 days.

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1. Introduction

Animals that undergo a period of nutritional restriction and are then refed typically exhibit compensatory growth, which is faster and more efficient than normal growth (Hogg, 1991). Most domesticated ruminants are subjected to periods of feed restriction. This can be owed to economic, husbandry, or physiological reasons or to unfavorable climatic conditions that limit forage growth and feed availability (Chilliard et al., 1998). In Northern China, nutrient digestibility and the digestible energy of pastures drop markedly during the winter to spring, leading to periods of restriction in feed quality and quantity for livestock (Lu, 1997). However, spring exactly coincides with the rapid growing phase for newborn lambs, which results in a sharp conflict between the high nutritional requirements of lambs and restricted feed quality and quantity of grassland.

Variations in nutrient intake alters the mass (Long et al., 2010) and cellularity (Caton et al., 2009) of visceral tissues which are among the most metabolically active in the body of ruminants (Ortigues and Doreau, 1995). Visceral tissues can account for up to 50% of total energy expenditure (Burrin et al., 1989), divided almost equally between the digestive tract and the liver. As a consequence, variations in the weight of visceral tissues contribute to the adaptations in maintenance requirements of the animal according to its feeding level (Nozière et al., 1999). The impacts of undernutrition during gestation on maternal and fetal growth have been extensively studied (Ford et al., 2007; Micke et al., 2010). However, the influence of restriction of protein or energy or both on visceral organ growth and cellularity of growing lambs is less defined. Therefore, our objectives were to investigate whether restriction of protein or energy or both affects growth, mass and cellularity of visceral organs, and jejunal morphology in lambs and to determine whether the effects are reversed after realimentation.

2. Materials and methods

Animals used for all experiments were cared for in accordance with guidelines of the Animal Nutrition Research Institute of Inner Mongolia Agricultural University and the Ministry of Agriculture of China for the care and use of laboratory animals.

2.1. Animals and experimental design

Forty native wether lambs (3 months old; 16.91 ± 0.71 kg body weight) were selected from flocks in the Xilinhaote pasture. Before implementation of the experimental protocol, lambs were dewormed with ivermectin injection (Huarui Animal's Pharmaceutical Co., LTD) at the dosage of 0.02 ml/kg body weight, and fed grass hay and a commercial starter (crude protein: 185.2 g/kg, metabolizable energy: 11.32 MJ/kg; Zhengda Co., LTD) diet for a 30 days pre-experimental period. Lambs were then allocated randomly to one of the four groups (10 per group), including control group (CG), moderately protein-restricted group (PR), moderately energy-restricted group (ER), and severely protein- and energy-restricted group (PER).

The nutrition level of the CG during the restriction stage and the diet offered to all lambs in the realimentation stage were designed according to Inner Mongolia fine-wool sheep feeding standards (Zhang and Zhang, 1998). Nutrient restricted lambs were provided 61% of CG requirement for crude protein (CP) in PR, 79% of CG requirement for metabolizable energy (ME) in ER, and 42% and 76% CG requirements for CP and ME in PER. The nutrition restriction stage lasted for 60 days and then all groups were fed the same diet for 90 days of realimentation. The diets of each group were processed into pellet and the ingredients and chemical composition of diets are given in Table 1. Lambs were fed *ad libitum* in individual pens, and feed was provided at 08:00 and 18:00 daily. Feed that was not consumed was collected and weighed daily before the morning feeding. Diets were sampled daily, composited weekly, and analyzed for dry matter (DM) content (AOAC, 1995). A portion of each weekly sample was retained and subsequently composited by diet at the end of each experimental period. Composited dietary samples were ground (ginder SF-130C, Jishou Zhongcheng Machinery Factory) through a 1-mm screen and analyzed for CP, Ca, and P according to the procedures of AOAC (1995). Content of dietary neutral detergent fiber (NDF) was analyzed according to the procedures of Van Soest et al. (1991). Animals were weighed weekly and the amount of feed was adjusted as body weight increased. Water and salt licking blocks were freely available.

Table 1
Chemical composition and nutritive value of diets (DM basis).

Items	Restriction period[a]				Realimentation period
	CG	PR	ER	PER	
Ingredients (%)					
Mixed pasture	38.0	38.0	14.0	25.0	61.1
Corn stalks	–	–	44.0	53.0	–
Corn	36.0	57.8	3.0	15.70	21.0
Soybean meal	22.0	–	17.7	2.0	14.0
Sunflower meal	–	–	17.4	–	–
Limestone	1.10	0.90	1.00	0.58	1.00
$CaHPO_4$	–	0.40	–	0.82	–
NaCl	0.40	0.40	0.40	0.40	0.40
Premix[b]	0.50	0.50	0.50	0.50	0.50
Bentonite	2.00	2.00	2.00	2.00	2.00
Composition[c]					
ME, MJ/kg	10.6	10.5	8.4	8.1	9.8
CP, g/kg	151	92	150	63	125
Ca, g/kg	4.30	4.22	4.41	4.70	3.96
P, g/kg	2.92	2.75	2.84	3.41	2.65
NDF, g/kg	333	326	480	540	461

[a] CG = control group; PR = moderately protein-restricted group; ER = moderately energy-restricted group; PER = severely protein- and energy-restricted group.

[b] Provided per kilogram of basal diet: Fe 25 mg; Zn 35 mg; Cu 9 mg; Co 0.1 mg; I 0.9 mg; Se 0.25 mg; Mn 19.5 mg; vitamin A 3000 IU; vitaminD_3 1000 IU; vitamin E 15 IU; niacin 60 mg (Zhengda, Inner Mongolia, China).

[c] Crude protein (CP), Ca, P and neutral detergent fiber (NDF) were determined values, and metabolizable energy (ME) was calculated according to Zhang and Zhang (1998).