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Effect of Maternal Under-nutrition during Late Pregnancy on Lamb Birth Weight*

F. Gao, X. Z. Hou, Y. C. Liu[1], S. Q. Wu and C. J. Ao**

College of Animal Science and Medicine, Inner Mongolia Agricultural University, Huhhot, China

ABSTRACT : This study investigated the effects of maternal undernutrition during late pregnancy on lamb birth weight. 45 Mongolian ewes, synchronized for oestrus and then mated, were divided into four groups and offered 0.86 MJME/kgw$^{-0.75}$d^{-1} (control group; CG : *ad libitum* access to feed), 0.44 MJME/kgw$^{-0.75}$d^{-1} (Restricted Group 3; R3), 0.33 MJME/kgw$^{-0.75}$d^{-1} (Restricted Group 2; R2) and 0.20 MJME/kgw$^{-0.75}$ d^{-1} (Restricted Group 1; R1) respectively during late pregnancy (90-150 days). During restriction, maternal net body weight loss, insulin and NEFA concentrations and lamb birth weight were measured. The results indicated that loss of maternal body weight in R3, R2 and R1 was 4.42, 7.23, 11.13 kg respectively, which was significantly ($p<0.01$) higher than that in CG (0.93 kg). Insulin concentrations of the ewes in R1, R2 and R3 were lower and were significantly different ($p<0.05$) between restricted groups and CG at 124 d of pregnancy. NEFA concentrations in all groups tended to decrease from 90d of gestation to parturition and in R1 were significantly ($p<0.05$) lower than in CG at 124 d of gestation. Lamb birth weight in R1 was significantly lower than in R2, R3 and CG ($p<0.05$). In conclusion, with decreasing supply of maternal nutrition, the retardation of fetal growth became worse. When the plane of nutrition was below 0.33 MJME/kgw$^{-0.75}$d^{-1}, significant effects of maternal undernutrition on lamb birth weight were observed. (**Key Words :** Late Pregnancy, Ewe, Undernutrition, Lamb Birth Weight)

INTRODUCTION

Sheep production is affected by genetic and non-genetic factors, such as sex (Assan and Makuza, 2005), shearing ewes during pregnancy (Cam and Kuran, 2004) and the plane of maternal nutrition (Robinson et al., 1999), etc. In north China, livestock production systems mainly depend on natural grassland vegetation. Especially during the winter-spring grazing season, nutrient digestibilities and digestible energy of pastures drop markedly (Lu, 1997) which causes a periodical restriction in feed quality and quantity for animals. However, the winter-spring season coincides with the reproduction period of sheep and energy requirements of pregnant ewes increase by 50 to 120% above maintenance in late pregnancy (NRC, 1985). The increase in energy demand during pregnancy is required to support conceptus growth and maintenance requirements of the ewe (Freetly and Ferrell, 1997), which results in sharp conflict between the high nutrition requirements of ewes and shortage of feed supply from farmland. It has been reported that two million mongolian sheep were starved each year and the remaining ones may lose 20%-35% of their body weight during pregnancy and lactation (Ma et al., 1988). Maternal undernutrition not only restricts production performance of ewes but also affects lamb birth weight and postnatal growth. Structural and physiological modifications in fetal development caused by maternal undernutrition during pregnancy may have an adverse effect on lamb health (Baker, 1999; McMillen et al., 2001) and could result in lack of compensatory growth and increased risk of perinatal morbidity and mortality, including reduced neonatal viability and an increased predisposition to cardiovascular, metabolic and endocrine disease in adult life (Barker, 1999), which are all correlated with birth weight (Gluckman and Hanson, 2004). However, the situation is always complex and within the uterus fetal development tends to be buffered by maternal regulation against unpredictable environmental effects. Only when the plane of nutrition falls below a crucial stage is fetal growth and development inhibited resulting in low birth weight.

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** Corresponding Author: X. Z. Hou. Tel: +86-471-431-7654, Fax: +86-471-430-1530, E-mail: Houxz05@sina.com.cn

[1] College of Biotechnology and Bioengineering, Inner Mongolia Agricultural University, Huhhot, 010-018, China.

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Table 1. Average live weights of the ewes in each treatment at initiation of the experiment

Treatment [a]	R1 (12 [b])	R2 (11)	R3 (11)	CG (11)
Nutrition regimes (MJME/kgw$^{-0.75}$d^{-1})	0.20	0.33	0.43	0.86
Feeding regimens	23% *ad libitum*	38% *ad libitum*	50% *ad libitum*	*ad libitum*
Average live weight (kg)	40.78±1.29 [c]	40.78±0.90[c]	42.02±1.26 [c]	41.95±1.13 [c]

[a] refers to restricted group1, restricted group2,restricted group3 and control group.

[b] No. of ewes per group.

[c] Means within row with same superscripts are not significantly different (p>0.05).

Table 2. Chemical composition and nutritive value of grass fed and grass left during restriction period

Nutrient composition	ME (MJ/kg)	DM (%)	CP (%)	EE (%)	NDF (%)	ADF (%)	ASH (%)	Ca (%)	P (%)
Fed grass	8.59	95.38	8.36	1.40	76.52	45.01	5.57	0.31	0.24
Left grass	-	95.00	6.73	1.52	75.06	47.43	4.42	0.31	0.24

Table 3. The weight of constituents of conceptus of the ewes at 90 d of pregnancy (kg)

Live weight of ewe	Fetus	Amniotic fluid	Placentome	w.c.c [a]
39.36±2.57	0.46±0.060	0.84±0.037	0.30±0.00	1.60±0.037

[a] Refers to the weight of constituents of conceptus.

Therefore, the objective of this study was to study the effects of maternal undernutrition during late pregnancy on lamb birth weight.

MATERIAL AND METHODS

Experimental period

Since the most rapid phase of ovine fetal development is during the last two months of pregnancy (Robinson, 1977; 1999), maternal undernutrition was carried out from 90 d of gestation until delivery.

Animals

45 mongolian ewes, in their second or third parity, were mated at a synchronized oestrus by injecting PG2α (1 ml) twice at intervals of seven days. The 45 animals, with average live weight of approximately 41.45±0.58 kg at 90 d of pregnancy, were then randomly allocated to four groups during late pregnancy (Table 1): Control group (CG:*ad libitum* access to feed, 0.86 MJME/kgw$^{-0.75}$d^{-1}), Restricted Group3 (R3:0.43 MJME/kgw$^{-0.75}$d^{-1}, 50% *ad libitum*), Restricted Group2 (R2:0.33 MJME/kgw$^{-0.75}$d^{-1}, 38% *ad libitum*) and Restricted Group 1 (R1:0.20 MJME/kgw$^{-0.75}$d^{-1}, 23% *ad libitum*).

Management

All animals were housed in individual pens and fed chopped natural hay (Table 2). Following a one-week acclimatization, CG ewes were fed at 08:30, 11:00 and 16:00 h daily (the feed refusals were approximately 10% of the total amount offered). Restricted ewes were fed at 08:30 and 16:00 h each day, and the amount of feed offered was constant throughout the restricted period. The animals had free access to water and a mineral mixture block. The feed refusals were collected daily and recorded before feeding at 08:30 h and sub-sampled for chemical analysis.

Slaughtering procedures

At the onset of the restriction period (at 90 d of gestation), four ewes were selected from each group and weighed prior to slaughter to serve as an initial comparison group. Blood was collected and weighed. After dressing, gravid uterine tissue and fetuses were removed, followed by weighing of each placentome and amniotic fluid. The weight of conceptus constituents of the ewes (including the weight of fetal, placentome and amniotic fluid) subtracted from maternal body weight gave maternal net body weight. The final net body weight (FNBW) subtracted from maternal initial net body weight (INBW) gave maternal net body weight loss during restriction (NBWL). After parturition, the weights of ewes and lambs were recorded.

Blood sampling and plasma collection

Jugular blood samples (10 ml) were obtained before the animals were fed in the morning at 90, 124 and 144 d of gestation and at lambing. The blood was collected into heparinized tubes and centrifuged at 3,000 g within 2 h of collection for the analysis of insulin (INS) and non-esterified fatty acid (NEFA).

Statistical analysis

All data were assessed according to the general linear model (GLM) procedure of Statistical Analysis Systems (SAS8.01). Duncans test was used to identify significant differences between mean values. Data was presented as the mean±standard error.

RESULTS

Maternal net body weight

Table 3 shows the mean weight of conceptus of ewes at 90 d of pregnancy. There were no significant differences (p>0.05) in initial maternal net body weight between each

Table 4. Maternal net body weight change of ewes in each group during feed restriction period

Treatment[c]	R1	R2	R3	CG
Initial net body weight ((NBW) (kg)	39.89±1.02 [a]	40.28±1.02 [a]	39.18±1.04 [a]	39.18±1.40 [a]
Final net body weight (FNBW) (kg)	28.76±0.82[c]	33.05±1.19 [b]	34.76±1.16 [b]	38.25±1.46
Net body weight loss (NBWL) (kg)	11.13±0.49 [a]	7.23±0.45 [b]	4.42±0.60 [c]	0.93±0.69 [d]
NBWL/INBW ×100 (%)	27.9[a]	17.9[b]	11.3[c]	2.4 [d]

[a b c d] Means within row with different superscripts are significantly different (p<0.05)
[c] Refers to restricted group1, restricted group2, restricted group3 and control group.

Table 5. Insulin concentration of ewes in each group during restricted period (mIU/L)

Treatment[c]	R1	R2	R3	CG
d90 [d]	3.18±1.02 [a]	4.26±1.15 [a]	3.10±1.61[a]	2.99±1.26[a]
d124	1.63±0.29[b]	1.68±0.80 [b]	1.33±0.50[b]	3.63±0.68 [a]
d144	2.16±0.59 [a]	1.96±0.66[a]	3.66±1.25 [a]	3.22±2.00 [a]
Postpartum	3.85±0.84 [a]	4.87±1.25 [a]	4.09±0.63 [a]	5.95±1.46 [a]

[a b] Means within row with different superscripts are significantly different (p<0.05).
[c] Refers to restricted group1, restricted group2, restricted group3 and control group. [d] Days of gestation.

Table 6. Effect of maternal undernutrition at late pregnancy on lamb birth weight (kg)

Treatment[c]	R1	R2	R3	CG
Average lamb birth weight	2.80±0.087 [b]	3.38±0.12 [a]	3.70±0.077 [a]	3.67±0.16 [a]

[a b] Means within row with different superscripts are significantly different (p<0.05).
[c] Refers to restricted group1, restricted group2, restricted group3 and control group.

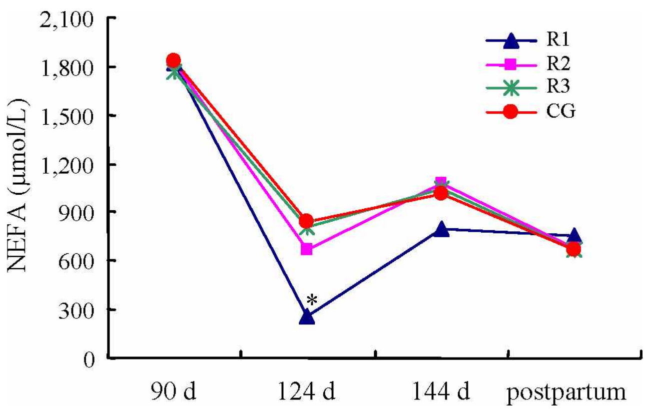

Figure 1. NEFA concentration of the ewes in each group during restricted period. * Means significantly different (p<0.05) between restricted group 1 and restricted group 2, restricted group 3 and control group.

group (Table 4). However, after parturition maternal net body weight in R1, R2 and R3 were significantly reduced when compared with CG (p<0.05), and the reductions of maternal net body weight of ewes in CG, R3, R2 and R1 were 0.93, 4.42, 7.23, 11.13 kg (p<0.01), respectively. When the changes were expressed as a percentage of maternal body weight , tissues of the ewes in group R3, R2 and R1 were mobilized 11.3%, 17.9%, 27.9%, which were all significantly (p<0.01) higher than in CG (2.4%).

Insulin and NEFA

During the restricted period, insulin concentrations in R1, R2 and R3 were lower, (Table 5), and were significantly different (p<0.05) between restricted groups and CG at 124 d of pregnancy.

NEFA concentrations (see Figure 1) in all groups were decreasing from 90d to 144d of gestation and in R1 were significantly (p<0.05) lower than in CG at 124 d of gestation. From 144 d of gestation to parturition, NEFA concentration in R1 was maintained at a constant lower level, but the concentrations in R2, R3 and CG still tended to decrease.

Lamb birth weight

Lamb birth weights are presented in Table 6 and in R1 were significantly lower than those of R2, R3 and CG (p<0.05).

DISCUSSION

The developing mammalian fetus depends completely on the maternal organism to meet its metabolic needs for growth and development (Khan and Ludri, 2002). The final trimester of pregnancy is the period when most of the increase in size of the fetus takes place. When exogenous energy is inadequate, maternal body tissues mobilize endogenous energy (Sibanda et al., 1997) and make adaptations instinctively (McMillen et al., 2001), which are associated with a reduction in body weight. Maternal adaptive regulations ensure uterine nutritional partitioning to maximize maintenance of fetal growth. In this experiment, maternal net weight in R1, R2 and R3 was reduced by 27.9%, 17.9% and 11.3%, respectively, during restricted feeding periods. These reductions could be explained by the fact that tissues are differentially mobilized and greater losses occur in the carcass (Aziz et al., 1992) and the metabolically active tissues such as the liver and the digestive tract (Ryan et al., 1993) during nutritional restriction. These tissue losses enable the animal to reduce its maintenance requirement and increase its chance of survival during undernutrition (Ryan et al., 1993). On the other hand, more importantly, these results indicated that the maternal system was mobilizing stores to meet requirements of the growing fetus, developing mammary glands and the ewe itself in late gestation. The lower the plane of nutrition the more reserves were mobilized to maintain pregnancy and fetal growth, which may also be one reason that maternal undernutrition in R2 and R3 did not significantly ($p>0.05$) influence lamb birth weight.

During feed restriction, there is a shift in the energy balance due to reduced levels of blood glucose, and at this point the utilization of fatty acids becomes the major source of energy (Brockman and Laarveld, 1986). Yambayamba et al. (1996) suggested that the most immediate response to feed restriction was a reduced insulin concentration, reflecting the lower energy and protein supply. In this study, insulin concentrations in R1, R2 and R3 were lower ($p<0.05$) than in CG which is in agreement with the results of Hayden et al. (1993) and Yambayamba et al. (1996). These results indicated that the reduction of insulin concentration would have improved greater mobilization of adipose tissue, and plasma NEFA concentrations often are increased in nutritionally restricted animals (Hornick et al., 1998; Ponter et al., 2000). However, some researchers have reported that there were no effects of low nutrition on NEFA concentrations. Differences in physiological states or plane of nutrition were possible reasons for conflict with previously reported NEFA concentrations in ewes on restricted levels of feed. In this study, NEFA concentrations in restricted groups were lower than in CG from 90 d to 124 d of gestation. The lower NEFA concentration indicated not only a greater fat mobilization but also a greater utilization of fatty acids. The rate of fat mobilization may have been lower than that of utilization of fatty acids, which resulted in decreasing NEFA concentrations. During prolonged underfeeding plasma NEFA level tends to reach a plateau or to decrease, perhaps as part of a general mechanism to spare body lipids and so prolong survival (Chilliard et al., 1998). One important observation in the present study was that NEFA concentration decreased as feed restriction progressed, implying a more negative energy balance and therefore more fat would need to be mobilized and utilized during late gestation in order to maintain normal lamb birth weight. Maternal glucose and amino acids are spared by mobilizing more adipose tissues and utilizing NEFA throughout the maternal body (Shu, 2003), which would more effectively satisfy the fetal nutritional requirements.

However, with the supply of nutrients continuously decreasing, the protective buffer system of the maternal body would be challenged. The growth of the fetus would be impaired when the plane of nutrition was below a threshold and the requirements of pregnancy could not be maintained by mobilizing tissue stores, which may lead to a significant reduction in lamb birth weight. In this experiment, though the maternal net body weight loss in R1 was 27.9% during restricted periods, the average lamb birth weight was significantly lower than in other groups. From 144 d of gestation to delivery, the NEFA concentration in R1 was maintained at a constant lower level, but NEFA concentrations in R2, R3 and CG still tended to decrease. These results indicated that the utilization of NEFA in R1 ewes had reached its utmost level, which resulted in a significant reduction of average lamb birth weight in these ewes.

In conclusion, during late pregnancy, the lower the plane of nutrition the more reserves were mobilized to maintain pregnancy and conceptus growth. However, with the decreasing supply of maternal nutrition, the retardation of fetal growth became worse. When the plane of nutrition was below 0.33 $MJME/kgw^{-0.75}d^{-1}$, significant effects of maternal undernutrition on lamb birth weight were observed. However, it is necessary to clarify whether the threshold varies among species.

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