ORIGINAL ARTICLE

Impact of energy and protein restriction on energy expenditure of gestation in twin-bearing ewes

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ABSTRACT

This study aimed to investigate the impact of energy and protein restriction on energy expenditure of gestation (EEgest) in twin-bearing ewes. Multiparous twin-bearing ewes were fed either adequate (A: n = 10) or restricted to 60% of energy and protein requirements (R: n = 10) during the last 6 weeks of gestation. Whole-body energy expenditure (EE) and retained energy (RE) were calculated from respiratory gaseous exchange combined with nitrogen balance at 7, 5 and 2 weeks prepartum. Twin lamb birth weight was lower in the R group compared to those in the A group (7.9 ± 0.19 kg, P < 0.01). The EEgest was lower in the R group than the A group (4.6 vs 5.9 MJ/day, SE = 0.30, P < 0.01). Between 5 and 2 weeks prepartum, EEgest contribution to the whole-body EE significantly (P < 0.01) increased from 39% to 45% and from 34% to 40% in the A and R groups, respectively. Based on kg conceptus weight, both EEhomeorhetic (from 292 to 270 kJ/kg/day, SE = 6.2, P < 0.001) and EEconceptus (from 259 to 177 kJ/kg/day, SE = 23.8, P = 0.02) decreased between weeks 5 and 2 prepartum. The EEconceptus tended to be lower (P = 0.06) in the R group than the A group both at 5 weeks (219 vs 298 kJ/kg/day, SE = 32.8) and 2 weeks (from 138 to 217 kJ/kg/day, SE = 30.1) prepartum. In conclusion, energy and protein restriction reduced energy expenditure of gestation calculated per kg conceptus weight. The decrease may be associated with energy expenditure of conceptus growth and maintenance.

Key words: heat production, maternal feed restriction, ovine, pregnancy.

INTRODUCTION

In general, the marked increase in total energy expenditure during late gestation in sheep (Brody 1945; Graham 1964; Russel et al. 1967; Lodge & Heaney 1970) indicates that gestation (fetal growth) is energetically very inefficient in comparison with other physiological process. Approximately 87% of the metabolizable energy (ME) requirement for fetal growth and development is dissipated as heat (Bell et al. 2005) while this value is approximately 35–50% in growing animals. However, the low efficiency of energy utilization for conceptus growth (in animals) varies with nutrient intake (Robinson et al. 1980). The efficiency of utilization of energy (from diet and mobilized body reserve) for fetal growth seems to be higher in undernourished dams than in well-nourished dams (Lodge & Heaney 1970; Sykes & Field 1972; Robinson et al. 1980). This might be caused by contribution of body reserves in undernourished dams rather than dietary ME (Robinson et al. 1980). Another explanation may be that maternal-fetal metabolism is compromised. The latter is supported by the well-documented occurrence of nutritional intrauterine-growth retardation in fetuses in ruminants (Anthony et al. 2003). In the present study, we hypothesized that higher energy efficiency for conceptus growth and development in undernourished dams is associated with alteration in energy expenditure of conceptus development regardless of the source of available energy.

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The objective of the present study was therefore to investigate the impact of energy and protein restriction on energy expenditure of gestation during the last trimester of gestation in twin-bearing ewes.

**MATERIALS AND METHODS**

**Experimental animals and feeding**

Twenty multiparous Shropshire twin-bearing ewes were moved indoors at 10 weeks prepartum. The ewes were fed adequate hay silage for 2 weeks and then around maintenance level for the following 2 weeks in order to adapt to the rations and feed intake. During the last 6 weeks of gestation, half of the ewes (A group) were fed an adequate diet of hay silage plus 200 g/day barley, and a protein supplement (Table 1) according to the NRC (1985). The rest of the ewes (R group) were fed a restricted diet of hay silage equivalent to 60% of their energy and protein requirements. The rations for both groups were adjusted weekly based on the individual ewe’s bodyweight. Feed was offered at 10.00 hour and 15.00 hour. Bodyweight was recorded weekly. Animals had free access to water and mineral-vitamin supplement. Ewes were kept in the same stable except when placed in metabolic cages (59 cm wide, 160 cm long and 80 cm high) for balance trials. All experimental procedures complied with the guidelines of and were approved by the National Committee on Animal Experimentation, Denmark.

**Balance trials and indirect calorimetry**

Energy and nitrogen (N) balance trials were conducted at weeks 7, 5 and 2 prepartum. Each balance trial lasted for 7 days: 2 days as adaptation period without any collection, followed by 5 days of daily feces, urine and feed residue collection. Each day, 10% of the total amount collected was stored at -18°C for later chemical analyses. An open-air circuit system (temperature, 15–18°C; humidity, 65–75%; 12-h light–dark cycle) consisting of two respiration chambers was used to measure 22-h respiratory gaseous exchange in the middle of each balance trial (Chwalibog et al. 2004). The gross energy content of feed and feces was measured using an adiabatic bomb calorimeter (System C700; IKA Analyzentechnic, Heitersheim, Germany). The nitrogen content in feed, feces and urine was determined by means of the Kjeldahl method using the Tecator-Kjeltec system 1026 (Tecator AB, Höganas, Sweden) distilling unit.

**Calculations**

Whole-body energy expenditure (EE; kJ/day) were calculated from 24-h O2 consumption, CO2 and CH4 production and urinary nitrogen excretion (UN) in accordance with Brouwer (1965), as follows:

\[
EE (kJ) = (16.18 \times O_2 (l)) + 5.02 \times CO_2 (l) - 0.2 (kJ/l) \times CH_4 (l) - 5.99 (kJ/g) \times UN (g)
\]

Metabolizable energy (ME) intake was obtained by subtracting energy voided with feces, urine, and methane from gross energy intake. Retained energy (RE) was the difference between ME intake and whole-body EE. Conceptus weight (CW) at different times (t) was estimated using the following equation (Robinson et al. 1977):

\[
CW(t) = BrW \times 2.42 - 17.564e^{-0.0198} - 0.00079 \times N + 0.0046 \times Bwewe
\]

where BrW was total litter birthweight [kg], N the number of fetus(es), and Bwewe the weight [kg] of the ewe at mating time. Non-conceptus tissue weight at different times in gestation was calculated by deducting the estimated conceptus weight (2) from the weight of the pregnant ewe. The difference between non-conceptus tissue weights at two different times was assumed to be the weight change in non-conceptus tissues.

Energy cost of basal metabolism of non-conceptus tissues (EEbasal-metabolism-non-conceptus) was calculated using the value of 298 kJ/kgW-0.75/d (Kiani et al. 2007) where the W-0.75 is metabolic body size. In order to calculate energy expenditure associated with non-conceptus weight change (EEnon-conceptus-tissues-weight-change), the ME values of 23.85 MJ/kg and 20.0 MJ/kg weight gain and loss were used, respectively. Moreover, the efficiencies of the energy utilization for maternal gain

**Table 1** Chemical composition of the rations ingredients

<table>
<thead>
<tr>
<th></th>
<th>Hay silage</th>
<th>Barley</th>
<th>Protein supplement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter (%)</td>
<td>58.0</td>
<td>88.7</td>
<td>89.5</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>10.0</td>
<td>2.2</td>
<td>5.1</td>
</tr>
<tr>
<td>Crude protein (%)</td>
<td>8.2</td>
<td>10.4</td>
<td>45.4</td>
</tr>
<tr>
<td>Crude fat (%)</td>
<td>1.6</td>
<td>2.3</td>
<td>5.7</td>
</tr>
<tr>
<td>Gross energy (MJ/kg DM)</td>
<td>18.4</td>
<td>18.3</td>
<td>20.9</td>
</tr>
</tbody>
</table>

DM, dry matter.