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The effect of ewe size and nutritional regimen beginning in early pregnancy on development of singleton foetuses in late pregnancy

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ABSTRACT

This study set out to investigate the effects of ewe size and pregnancy nutritional level on the development of singleton-foetuses in late pregnancy and was part of a large study investigating life-time effects of maternal nutrition on the offspring. Heavy (H) and light (L) Romney ewes were allocated to ad libitum (A) or maintenance (M) nutritional regimens from day 21–day 140 of pregnancy (P21–P140). At P140, 39 singleton-bearing ewes (HA: $n = 9$, HM: $n = 10$, LA: $n = 10$, LM: $n = 10$) were euthanized and ewe and foetal organs were collected and weighed. L-ewes were lighter ($P<0.05$) and gained ($P<0.05$) more live weight during pregnancy than H-ewes. M-ewes were lighter ($P<0.05$) and gained ($P<0.05$) less live weight during pregnancy than A-ewes. Foetuses from M-ewes had lighter ($P<0.05$) thyroid glands and spleens than did foetuses from A-ewes. However, no ewe-size or nutritional effects were found ($P>0.05$) on foetal weight or dimensions, weight of kidney, perirenal fat, heart, thymus, adrenal glands or gastrointestinal tract, mammary gland, ovaries or scrotum. In conclusion, these findings indicate that singleton-bearing ewes are able to buffer their foetus against maintenance nutrition to protect foetal growth and development in late pregnancy. In addition, singleton-bearing ewes fed ad libitum, partition the excess nutrients to itself rather than further enhancing foetal development. Ewe size had no effect on size or development of singleton-foetuses at P140, indicating that maternal size is of less importance when the ewe is carrying a singleton.

1. Introduction

Nutritional levels of pregnant ewes are often a compromise between herbage availability and nutritional demand, which could affect foetal growth. It is known that under-nutrition of singleton-bearing ewes in mid- and late-pregnancy can reduce foetal growth (Harding and Johnston, 1995; Heasman et al., 1999) and lamb birth weight (Oliver et al., 2002) and alter the relative size of many organs (Heasman et al., 1999; Oliver et al., 2001), including foetal mammary glands (Blair et al., 2010). While the effects of maternal under-nutrition during mid- and late-pregnancy have been studied on numerous occasions, comparisons between studies can be difficult due to differences in ewe live weight and/or body condition (Kenyon, 2008; Mellor, 1983; Robinson et al., 1999; Symonds et al., 2007; Wu et al., 2006).

Size of the dam could play an important role in foetal development, through its effect on size of the placenta, which influences the nutrient supply to the developing foetus and its growth (Mellor, 1983). Embryo transfer and cross-breeding experiments in large and small breeds of sheep (Dickinson et al., 1962; Gootwine et al., 1993), horses (Allen et al., 2002; Walton and Hammond, 1938), cattle (Joubert and Hammond,

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1958) and pigs (Wilson et al., 1998) have shown that foetal growth can be altered from the normal genetic potential by varying dam size. In addition, within a population, the heritability of adult live weight in sheep is ~0.40 and the genetic correlation between birth weight and adult live weight is ~0.22 (Safari et al., 2005).

In summary, the literature indicates that both maternal nutrition and size have the potential to alter foetal growth and birth weight. However, there are very few studies which specifically examine the effects of maternal nutrition during pregnancy of dams of different sizes. There is a potential that nutritional effects during pregnancy are less apparent in offspring from dams of larger size.

The current study described here, is part of a large study investigating the life-time effects of ewe size (heavy vs. light) and nutritional regimen (maintenance vs. ad libitum) during pregnancy on the performance of the female singleton- and twin-born offspring. To date we have shown that maintenance nutrition compared to ad libitum nutrition of the ewe during pregnancy had a negative effect on birth weight of twins and not singletons (Kenyon et al., 2009). In addition, maintenance nutrition of the ewe during pregnancy negatively affected weaning weight of twins and not singletons (Kenyon et al., 2009) and liveweight gain of the lambs, irrespective of birth rank (van der Linden et al., 2007) and altered the metabolism of twin-born offspring at 16 months of age (van der Linden et al., 2010a, b). Moreover, twin foetuses carried by ewes fed maintenance during pregnancy had heavier mammary glands than twin foetuses carried by ewes fed ad libitum (van der Linden et al., 2009). Furthermore, compared to ad libitum nutrition of the ewe, maintenance nutrition positively affected milk production and milk composition of female twin-born offspring at two years of age (van der Linden et al., 2009) and positively affected birth weight and weaning weight of the second generation (van der Linden et al., 2010c).

Therefore, to determine if alterations in foetal size and/or weight of organ systems observed in twin foetuses (Blair et al., unpublished data) also extend to singletons, the effects of ewe size and nutrition from day 21–140 of pregnancy on the size and mass of various organs and systems of singleton-foetuses and their ewes were investigated. We hypothesise that ewe nutrition would negatively affect foetal development but that dam size would have no effect.

2. Materials and methods

All animal manipulations were approved by the Massey University Animal Ethics Committee. The original source of the ewes and where the study commenced was the Massey University Riverside Farm, 10 km north of Masterton, New Zealand. At day 53 of pregnancy, the ewes were moved to Massy University Keeble Sheep and Beef Cattle Farm, 5 km south of Palmerston North, where the study continued.

2.1. Experimental design

The heaviest 450 (heavy (H) 60.8 ± SE 0.18 kg, condition score (CS) 3.02 ± SE 0.03) and 450 lightest (light (L), 42.5 ± 0.17 kg, CS 1.97 ± 0.03) Romney ewes from a commercial flock of 2900 ewes were synchronised via a progesterone controlled internal drug release devices (CIDR, 0.3 g progesterone, Pharmacia & UpJohn, Auckland, New Zealand) and artificially inseminated, using intra-uterine laparoscopy with semen from one of four Suffolk rams over a two-day period, as previously described by Kenyon et al. (2009). Twenty one days (P21) after artificial insemination, ewes which had not returned to oestrus ($n = 612$), were randomly allocated to either maintenance (M) or ad libitum (A) nutrition until P140 with each nutritional regimen included both H- and L-ewes (Kenyon et al., 2009). The aim of the maintenance nutritional regimen was to ensure that the total ewe live weight increased in pregnancy at a rate similar to that of the expected conceptus mass (Rattray et al., 1974a). The aim of the ad libitum nutritional regimen was to provide unrestricted herbage intake under grazing conditions. Within each feeding regimen, singleton- and twin-bearing ewes were not separated. Therefore, the study included four groups; HA- ($n = 151$), HM- ($n = 153$), LA- ($n = 155$) and LM-ewes ($n = 153$) all of which contained singleton- and twin-bearing ewes. To achieve the feeding regimens, ewes were rotationally grazed according to the protocol previously described by Kenyon et al. (2009). The average pre- and post-grazing herbage masses were 1330 ± 140 kg DM/ha and 804 ± 133 kg DM/ha for the maintenance regimen and 2304 ± 157 kg DM/ha and 1723 ± 150 kg DM/ha for the ad libitum regimen (Kenyon et al., 2009). Ewes were weighed and body condition scored at P1, P53 and P140 of pregnancy, as previously described by Kenyon et al. (2009). During P140–142, 39 randomly selected singleton-bearing ewes (HA: $n = 9$, HM: $n = 10$, LA: $n = 10$, LM: $n = 10$) were weighed. The selected ewes were randomly allocated to one of three days for euthanasia. The ewes were euthanized by captive bolt pistol, followed immediately by exsanguination.

Ewes that were not euthanized were allowed to give birth naturally and their female offspring have been studied for life-time performance effects (Kenyon et al., 2009; van der Linden et al., 2007; 2009; 2010a; 2010b; 2010c).

2.2. Ewe tissue dissection

Following euthanasia, the abdominal cavity was opened and the gravid uterus was removed and weighed. Then the liver, spleen, kidneys, heart, lungs, thyroid and adrenal glands, and mammary gland were collected and weighed on digital scales (Mettler Toledo GmbH, Greifensee, Switzerland). The carcass was weighed and dressing-out percentage was calculated.

2.3. Foetal tissue dissections

The foetus was removed from the uterus and the umbilical cord was ligated at the abdomen before being severed. Foetuses were euthanized by intra-cardiac injection of sodium pentobarbitone (Pentobarb 500, Chemstock Animal Health, Christchurch, New Zealand). Each foetus was gently squeezed to remove amniotic fluid from the wool and foetal weight, crown-rump length, thoracic girth circumference, fore-leg and hind-leg length were recorded, as well as sex of the foetus.

The myo-endometrium (excluding caruncles) and foetal membranes (excluding cotyledons) from each ewe were weighed. Placentomes were manually separated into their maternal (caruncle) and foetal (cotyledon) components and