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Nutrient intake in the bovine during early and mid-gestation causes sex-specific changes in progeny plasma IGF-I, liveweight, height and carcass traits

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ABSTRACT

Fetal and postnatal growth are mediated by insulin-like growth factors (IGFs) and their binding proteins (IGFBPs). Maternal nutrient intake during gestation can program the postnatal IGF-axis. This may have significant economic implications for beef cattle production. We investigated the effect of high (H = 240%) and low (L = 70%) levels of recommended daily crude protein (CP) intake for heifers during the first and second trimesters of gestation in a two-by-two factorial design on progeny (n = 68) plasma IGF-I, IGF-II, total IGFBP (tIGFBP), postnatal growth and carcass traits. Calves were heavier at birth following high CP diets during the second trimester (P = 0.03) and this persisted to 29 d. Plasma IGF-I concentrations of males were greater for *HL* compared to *LL* (P < 0.01) and *HH* (P > 0.04) from 29 to 657 d, and for *LH* compared to *LL* from 29 until 379 d (P = 0.02). Exposure to low CP diets during the first trimester resulted in heavier males from 191 d onwards (P = 0.04) but a tendency for lighter females from 552 d onwards (P = 0.07) that had lighter carcass weights (P = 0.04). *Longissimus dorsi* cross-sectional area of all carcasses was greater following exposure to low CP diets during the second trimester (P = 0.04). Heifer nutrient intake during the first and second trimesters causes persistent and sex-specific programming of progeny plasma IGF-I, postnatal liveweight and carcass weight. Refining heifer nutritional programs during early gestation may optimize production objectives in progeny.

1. Introduction

Breeder cattle managed under extensive grazing conditions, and consequently their developing fetus, experience a large variation in nutrient availability throughout the year. Maternal nutrient intake during gestation affects progeny postnatal growth and carcass characteristics in cattle as in other species (Greenwood et al., 2006; Larson et al., 2009; Martin et al., 2007; Stalker et al., 2006). Insulin-like growth factors (IGFs) are associated with traits of economic importance to cattle production due to their role in cell growth, proliferation and metabolism (Hyatt et al., 2004). Specifically, calf plasma IGF-I concentration at birth is positively associated with calf birth weight (Breier et al., 1988) as is average postnatal serum IGF concentration with average daily gain and linear growth (Lund-Larsen et al., 1977). However, there is a negative association between average circulating IGF-I concentrations and improved feed efficiency (Moore et al., 2005). Six IGF-binding proteins regulate IGF clearance from circulation, IGF access to receptors (Gallaher et al., 1992) and some also act independently on cells (Firth and Baxter, 2002). Fetal nutrient supply regulates the fetal IGF axis (Brameld et al., 2000; Oliver et al.,

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1993; Osborn et al., 1992), and can program the IGF axis after birth in rodents (Olausson et al., 2006) and humans (Verkauskiene et al., 2005), but few studies have investigated the latter in cattle. Changes in the IGF axis may have long-term consequences for postnatal growth and performance. In sheep, maternal nutrient restriction during early gestation reduces hepatic expression of type 2 IGF receptor in offspring at 3-years of age (Hyatt et al., 2007b) whilst restriction during late gestation increases hepatic expression of IGF-I, but reduces hepatic expression of types 1 and 2 IGF receptor in offspring at 1-month of age (Hyatt et al., 2007a). Despite changes to hepatic IGF gene expression, plasma IGF-I concentration was not altered (Hyatt et al., 2007b). The aims of this study, therefore, were to determine the effect of varying heifer nutrient intake during the first and second trimesters of gestation, on plasma IGF-I, -II, total IGF binding proteins (tIGFBP), growth of progeny from birth until 657 days (d) and their carcass characteristics at 680 d.

2. Materials and methods

All procedures were performed with the prior approval of The University of Queensland Animal Ethics Committee, approval number SVS/716/06/MLA/AACO.

2.1. Animals and treatments

The study was a two-by-two factorial design. The study animals are the progeny of two-year-old heifers that have been previously described (Micke et al., 2010). Heifers ($n = 118$) were divided into four treatment groups on the first day of artificial insemination (AI) according to stratification by weight within each composite genotype and individually stall fed until parturition. The four treatment groups determined the level of crude protein (CP) fed to each heifer during the first (T1) and second (T2) trimesters of gestation (*HH*: T1 = 76.3 MJ ME/d and 1.4 kg CP/d; T2 = 82.4 MJ ME and 1.4 kg CP/d, *HL*: T1 = 76.3 MJ ME/d and 1.4 kg CP/d; T2 = 63.1 MJ ME/d and 0.4 kg CP/d, *LH*: T1 = 62.5 MJ ME/d and 0.4 kg CP/d; T2 = 82.4 MJ ME/d and 1.4 kg CP/d, *LL*: T1 = 62.5 MJ ME/d and 0.4 kg CP/d; T2 = 63.1 MJ ME/d and 0.4 kg CP/d). All heifers were fed 71.45 MJ ME and 1.06 kg CP/d in the third trimester (T3). Trimester one was defined as 0 to 93 d after AI, T2 from 94 to 180 d and T3 from 181 d to parturition. Transition feeding periods from 92 to 97 d and 179 to 184 d enabled heifers to adjust to the ration changes in a stepwise manner. All heifers consumed their daily feed allocation each day whilst under supervision. Detailed composition of the heifer rations is given in Table 1 and the rationale underlying ration formulation and their feeding management has been described previously (Micke et al., 2010).

Pregnancy was positively diagnosed in 77 heifers (*HH* = 19; *HL* = 20; *LH* = 19; *LL* = 19) at 39 d via transrectal palpation with the aid of a 5 MHz linear rectal probe attached to a real time ultrasound scanner (model Aloka-500®, Aloka Inc., Tokyo, Japan). During the study, six spontaneous abortions (*HH* = 3; *HL* = 1; *LH* = 2; *LL* = 0) (Sullivan et al., 2009a) occurred resulting in a total of 71 heifers (*HH* = 16; *HL* = 19; *LH* = 17; *LL* = 19) that completed the study and gave birth (mean gestation length = 286 ± 0.5 d; range = 278–298 d) (Sullivan et al., 2009b). Three progeny were removed from the study after birth: one due to mis-mothering; one pre-weaning from sudden death of unknown causes; and one post-weaning from death due to misadventure, leaving 68 progeny distributed across four treatment groups (*HH* = 15; *HL* = 18; *LH* = 16; *LL* = 19). Hereafter, all ages refer to the average age of progeny on the day of sampling.

Postnatally, progeny remained with their mothers on improved and native pastures until weaning at 191 d in accordance with standard beef herd management practice (Meat and Livestock Australia, 2004). They were supplemented daily with whole cotton seed (*Gossypium spp.*) allocated at 1 kg/animal whilst grazing native pastures until 401 d. From 401 d, they were managed as part of a larger group of yearling cattle at Surat, Queensland (27°16′S, 149°07′E) due to unforeseen drought conditions at their property of origin. Each animal was allocated 20 kg/d as fed of a silage-based ration. The ration was 40.7% dry matter and consisted of 85% corn silage (*Zea mays*), 12% whole cottonseed (*Gossypium spp.*) and 3% vitamin and mineral mix. Progeny commenced an intensive feedlot finishing program on 541 d at Dalby, Queensland (27°18′S, 151°26′E), where they remained as one group in their own feedlot pen and were fed commercial feedlot rations prior to commercial slaughter at 680 d. Male and female progeny remained together in the same management group at all times throughout the study.

Males were castrated at 153 d in accordance with standard beef herd management practice (Newman, 2007). All progeny were vaccinated against clostridial diseases and leptospriosis (Ultravac 7 in 1: Pfizer Animal Health, West Ryde, NSW) on 65 and 123 d with a third clostridial vaccine given on 544 d (Ultravac 5 in 1: Pfizer Animal Health, West Ryde, NSW). On 379 and 544 d all progeny were vaccinated against *Bovine herpesvirus 1* (Rhinogard Intranasal Vaccine (Live): Q-Vax Pty Ltd., Brookfield, QLD) and *Mannheimia haemolytica* (Bovilis MH: Intervet Australia Pty Limited, Bendigo East, Vic.).

2.2. Data and sample collection

Progeny were weighed at birth (Micke et al., 2010), 15 d, 29 d and then approximately monthly until 657 d. Height was defined as the distance between the ground and the cranial dorsal iliac spine and was measured on 15, 29, 65, 123, 191, 286, 379, 462, 552 and 657 d. Progeny blood samples were collected into tubes containing lithium-heparin (Vacutainer: Becton Dickinson, Franklin Lakes, NJ) within 5 min of birth and then immediately after progeny were brought in from grazing or their feedlot pen at 8:00 am on 29, 94, 191, 379 and 657 d. Samples were stored for 1–2 h on ice prior to being centrifuged at room temperature at 3000 × *g* for 10 min. Plasma was harvested and then stored at −20 °C until analyses.

At slaughter, each animal was killed by captive bolt stunning and exsanguination. Standard carcasses (AUSMEAT, 1998) were halved and each side weighed prior to entering the chiller. Carcass weight (HCW) was calculated