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Effects of calf early nutrition on muscle fiber characteristics and gene expression

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ABSTRACT

The aim of this study was to evaluate the effect of herbage allowance treatment of native pastures from calf conception to weaning on muscle fiber density and diameter and gene expression (insulin-like growth factor (IGF) system and adipogenesis) during the first year of age of purebred (Hereford and Angus) and crossbred (F1) dams offspring. Forty crossbred calves, offspring of purebred or crossbred dams, were used in a randomized block design with a factorial arrangement of herbage allowance (HA) of native pastures (high and low; 4 vs. 2.5 kg dry matter/kg body weight (BW)) and dam genotype resulting in 4 calf groups (high-purebred, high-crossbred, low-purebred, low-crossbred offspring). Calf BW were registered while blood and *Semitendinosus* muscle samples were collected at birth, weaning (142 days) and at 380 days old to measure plasma IGF-I concentrations and muscle expression of genes related with the IGF system and adipogenesis by quantitative real time PCR. Calf BW at birth did not differ between calf groups but during the postnatal period, low purebred offspring were lighter ($P < 0.05$) than the other three calf groups. Lean to fat tissue ratio tended to be greater ($P = 0.08$) in high than in low HA offspring. Muscle fiber density did not differ among calf groups, but fiber diameter was greater in low than high and in crossbred than purebred offspring. Plasma IGF-I concentrations were lower ($P < 0.05$) in low purebred offspring than in the other three calf groups. The *IGFBP5* mRNA expression was greater in low crossbred offspring when compared to the other three groups and *PPARG* mRNA expression was greater in high than in low and in purebred than crossbred offspring at birth whereas *SREBF1* mRNA expression was greater in high crossbred compared to the other three groups at birth and at weaning. At 380 days, after winter restriction, *IGF receptor type 1 (IGF1R)* and *IGFBP5* mRNA expression were greater in high purebred than in high crossbred offspring. The environment provided by the dams during gestation and lactation is probably influenced by the nutritional plane and genotype of the cow. As a consequence, changes appeared between calf groups in calf BW, body composition, *Semitendinosus* muscle fiber diameter and expression of genes related with the IGF-I system and adipogenesis.

1. Introduction

Beef cows in rangeland extensive conditions experience poor nutritional environments for variable periods of time

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during pregnancy and lactation, as their intake depends on quantity and quality of herbage produced by native pastures, which is subjected to large intra and inter-annual climate variations. These periods of nutrient restriction (during gestation and/or lactation) can affect calf muscle growth and development as well as intramuscular fat (marbling) and compromise beef meat production (Du et al., 2013; Rehfeldt et al., 2011).

Muscle growth and its intrinsic properties determine, at least in part, the quantity and quality of the meat produced. Muscle mass is mainly determined by fiber number and size (Rehfeldt et al., 2011). In livestock, new muscle fibers are formed during the prenatal stage (early and mid-gestation) with primary fibers forming first, followed by secondary fibers that develop around these primaries. The number of muscle fibers (muscular hyperplasia) is thought to be completed at birth (Rehfeldt et al., 2011; Du et al., 2013). The postnatal skeletal muscle development is mainly due to the increase in muscle fiber size (hypertrophy) as satellite cells, a population of committed myogenic cells, proliferate and fuse with existing fibers increasing DNA content and protein synthetic capacity resulting in muscle fiber hypertrophy (Rehfeldt et al., 2011). In ruminants, undernutrition during early and mid fetal periods reduced fiber number whereas undernutrition during the end of fetal and during postnatal periods may reduce calf body weight (BW) at birth and decrease myonuclei number, muscle fiber diameter or cross sectional area and muscle fiber type (Greenwood et al., 2000; Zhu et al., 2006; Du et al., 2010; Rehfeldt et al., 2011).

The somatotropic axis (growth hormone—insulin-like growth factor; GH-IGF) is one of the main mechanisms for both environmental and genetic effects on growth, development and differentiation of skeletal muscle, via both mitogenic and myogenic processes and metabolic and anabolic actions (Clemmons, 1998; Philippou et al., 2007; Duan et al., 2010; Rehfeldt et al., 2011). This axis involves peptide hormones (GH, IGF-I and IGF-II), their receptors (GHR and IGF1R) and IGF binding proteins (IGFBP1 to 6), which can either potentiate or inhibit IGF action by modulation of their bioavailability to receptors (Clemmons, 1998). Recent studies have shown that many genes of the somatotropic axis were differentially expressed in animals selected for greater muscle growth and differentiation potential (Keady et al., 2011). In addition, muscle expression of several components of ST axis modulated by pre- and postnatal nutrition in mice (Bayol et al., 2004) and cattle (Oksbjerg et al., 2004; Rehfeldt et al., 2011).

Similar to myogenesis, adipogenesis can be divided into preadipocyte hyperplasia and adipocyte hypertrophy, which occurs by accumulation of triacylglyceride (Du et al., 2013). In ruminants adipogenesis is initiated before mid gestation in beef cattle (Bonnet et al., 2010), with the first detection of adipocytes in visceral fat depots followed by subcutaneous, intermuscular, and intramuscular fat depots (Taga et al., 2011). Although adipocyte hyperplasia may occur during postnatal growth, the fetal period is a major stage for generation of intramuscular adipocytes and thereby for intramuscular fat accumulation potential later on life (Tong et al., 2008). *Peroxisome proliferator activated-receptor-γ* (*PPARG*) is an indispensable transcription factor for adipocyte differentiation inducing specific adipocyte gene expression which results in lipid accumulation and adipocyte maduration (Du et al., 2013). In addition, *sterol regulatory element-binding transcription factor 1* (*SREBF1*) regulates lipid metabolism through the induction of genes which are important for triglyceride uptake, synthesis and storage (Shao and Espenshade, 2012). Nutrition in early life affected muscle expression of *PPARG* and *SREBF1* mRNA in cattle (Du et al., 2010b; Graugnard et al., 2009), which is correlated with different potential of intramuscular adipogenesis.

Our hypothesis was that control of grazing intensity of native pastures through changes in herbage allowance would impact on dam nutrition during gestation and lactation, thus, altering calf muscle fiber characteristics and gene expression during the growing period (pre and post-weaning). Therefore, our objective was to evaluate the effects of herbage allowance treatment of native pastures from calf conception to weaning on muscle fiber density and diameter and gene expression (IGF system and adipogenesis) of purebred (Hereford and Angus) and crossbred (F1 Hereford and Angus) dam offspring at the one year of age.

2. Materials and methods

2.1. Location, animals and experimental design

The experiment was conducted on 90 ha of native grasslands (Campos biome) located at the Prof. Bernardo Rosengurtt Experimental Station (School of Agronomy, Universidad de la República, Uruguay; 32°S, 54°W) from December 2008 to November 2010. Animal procedures were approved by the Animal Experimentation Committee of Universidad de la República (CHEA, Uruguay).

Forty calves and their dams were used in a randomized block design with two replications (block 1: sandy loam soil, 60 ha and block 2: clay loam soil, 30 ha) and four plots in each block to which a 2×2 factorial arrangement of herbage allowance and dam genotype was allocated. Herbage allowance treatments were estimated according to Sollenberger et al. (2005) and represented 4 and 2.5 kg dry matter (DM)/kg BW (Hi-HA and Lo-HA, respectively) on an annual mean basis that varied among seasons (Table 1). Herbage allowance treatments determined changes of herbage mass and height but did not affect chemical composition of offered herbage (Table 1). Experimental dams were purebred (Hereford, $n=12$ and Angus, $n=10$) or crossbred (F1-H × A, $n=8$ and F1-A × H, $n=10$) multiparous cows (5 to 6 year-old) that belonged to a group of experimental animals generated as part of a diallel crossbreeding experiment between Angus and Hereford breeds conducted for 10 years at the Experimental Station. Calf sires were Hereford or Angus, determining that calves from purebred dams were crossbred (H × A and A × H offspring) while calves from crossbred dams were backcross (H-H × A, H-A × H, A-H × A and A-AH) progeny (Table 2).

Dams were maintained in the same plot (same herbage allowance treatment) since May 2007 and gestated and lactated one calf every year from 2007 to 2009. The