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Effect of feeding level of pregnant dairy heifers sired by one bull on maternal metabolism, placental parameters and birth weight of their female calves

Sonja Spiegler[a], Martin Kaske[a,1], Ursula Köhler[a], Heinrich H.D. Meyer[a], Frieder J. Schwarz[b], Steffi Wiedemann[a,*]

[a] Physiology Weihenstephan, ZIEL, Technische Universitaet Muenchen, Weihenstephaner Berg 3, 85350 Freising-Weihenstephan, Germany

[b] Department of Animal Sciences, Animal Nutrition, Technische Universitaet Muenchen, Hochfeldweg 6, 85350 Freising-Weihenstephan, Germany

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ABSTRACT

This study aimed to evaluate the effect of different phases of feed restriction on the metabolism and placental indices of growing heifers inseminated with sexed semen of one bull and on the birth weights of their calves. Red-Holstein heifers were randomly divided into three groups. C-group animals ($N=17$) daily received recommended energy and crude protein (standard diet). ER-Group animals ($N=14$) were fed 60% of recommended energy and crude protein for the first two pregnancy months followed by the standard diet. LR-group animals ($N=13$) were provided with the standard diet throughout the first seven months and with 60% energy and crude protein for the last two months of pregnancy. Blood metabolites and weights of dams were assessed regularly during pregnancy. Placenta weight, area of placentomes and calves' birth weights were examined directly after birth. The physiological levels of blood metabolites varied in C-group animals during the different pregnancy stages. Both restriction periods resulted in reduced weight gain of the dams. ER-group animals showed a marked compensatory growth during mid-pregnancy. Serum glucose, cholesterol and beta-hydroxybutyrate were lower in ER-group animals compared with C-group animals during early restriction. During late restriction, only non-esterified fatty acids increased in LR-group animals. Placental parameter and calves' birth weights did not differ between groups. Results indicate only minor effects of a 40% energy and protein restriction during early or late pregnancy in growing heifers on maternal metabolic and placental indices as well as on foetal development, but further studies might show long-term consequences of offspring.

1. Introduction

Optimum intrauterine development is essential to the success of pregnancy and the survival of the species as it affects the post-natal mortality rate, growth and body composition as well as the long-term health and productivity of the offspring. The complex processes of organogenesis and growth of the conceptus are recognised to be dependent

* Corresponding author. Present address: Institute of Animal Breeding and Husbandry, Christian-Albrechts-University, Olshausenstr. 40, 24098 Kiel, Germany. Tel.: +49 431 880 4533; fax: +49 431 880 5265.
E-mail address: swiedemann@tierzucht.uni-kiel.de (S. Wiedemann).

1 Present address: AGRIDEA, Eschikon 28, 8315 Lindau, Switzerland.

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on the individual interplay of genetic and environmental influences, and maternal dietary intake has been demonstrated to be one of the key factors (Chmurzynska, 2010; Bach, 2012). During bovine pregnancy, available nutrients are partitioned between maternal and foetal tissues in a hierarchy determined by the tissues' metabolic activity (Hammond, 1947). In this context, intrauterine requirements of the conceptus and postnatal supply of growing tissues in the offspring have a high priority status in nutrient partitioning (Bauman and Currie, 1980; Redmer et al., 2004). However, in the dairy industry, young animals are often used for breeding before their body growth is complete, which results in competition for nutrients between the growing animal and the developing foetus and can require compromises in nutrient partitioning from one side or both. In fact, the birth weights of calves born by still growing heifers are reduced depending on the dam's age and weight in comparison with non-growing and heavier older cows (summarised in Holland and Odde, 1992). In addition, pregnant heifers are regularly held on pasture until shortly before parturition resulting in possible periods of suboptimal nutrition (Endecott et al., 2013). A restriction in maternal dietary feed intake leads to a decreased blood concentration of nutrients which, in turn, triggers their reduced distribution to less metabolically active tissues and leads to reduced maternal tissue growth and fat deposition (summarised in Redmer et al., 2004). Particularly at sensitive time frames, alterations in maternal nutrition are regarded as key factors which induce abnormal foetal growth and development and influence subsequent postnatal health (McMillen and Robinson, 2005). At the beginning of pregnancy, when requirements of the conceptus are still insignificant, maternal nutrient restriction can lead to intrauterine growth retardation (Robinson et al., 1999). Intrauterine growth retardation on the one side alters placental function, further foetal growth and development and on the other side predisposes offspring to cardiovascular, metabolic and endocrine diseases in later life in humans, rodents and pigs (Simmons et al., 2001; Bee, 2004; Gluckman and Hanson, 2004). A feed restriction during the late stages of pregnancy coincides with the stage of maximum foetal growth and has an effect on glucose insulin homeostasis in humans, indicating a nutritional regulation of the foetal somatotropic axis in late pregnancy (Plagemann, 2006).

Results in ruminants also suggest that the intrauterine programming of the foetal metabolism due to early or late maternal nutrient restriction can alter foetal development and result in lasting effects on body composition in later life, growth efficiency and the health of the offspring (Gardner et al., 2005; Ford et al., 2007; Long et al., 2010). However, in still-growing heifers, the metabolism during pregnancy and effects of feed restriction during early and late stages have not been well documented. It was therefore the aim of this experiment in primiparous cows inseminated with semen from the same bull to (a) monitor diet-dependent changes in various maternal key blood metabolites during early and late pregnancy, and (b) test the hypothesis that energy deficiency during early or late restriction leads to altered dams' placental indices and/or birth weights of half-siblings as a potential trigger for changes in later-life metabolism in the bovine offspring.

2. Material and methods

This study was approved by the Bavarian Animal Welfare Committee (AZ 55.2-1-54-2531-5-08).

2.1. Animals and experimental design

The experiments were performed with Red-Holstein heifers at the Hirschau research farm of the Technische Universitaet Muenchen (Marzling, Germany). Heifers were born at the farm and raised after weaning in an open stable. At the age of approximately twelve months, they were moved into groups of up to five animals to a barn and kept in one pen with a slatted floor. The pens were equipped with transponder-controlled Calan doors® (Holma van Melle, Brussels, Belgium) to ensure daily assessment of individual feed intake. Animals were trained to become accustomed with this feeding system for several weeks. As of the age of 14 months, the heifers were monitored twice a day during their resting phase for signs of estrus based on the onset and cessation of standing or mounting. Estrus was induced (2 ml Dalmazin®, 1.5 μg Cloprostenol, Selectavet Dr. Otto Fischer GmbH, Weyarn-Holzolling, Germany) in those animals which did not show visual signs of estrus for several weeks and ultrasound assessment indicated an intact corpus luteum.

All the heifers were inseminated using semen from one bull ("Optimal"; Rinderproduktion Niedersachsen, Germany). The semen was sexed via flow cytometry and checked for quality at the Department of Biotechnology of the Institute of Animal Breeding, (FAL, Neustadt, Germany; Rath and Johnson, 2008). Each heifer received 2 million spermatozoa per insemination.

A total of 69 animals were available for first insemination. However, 25 animals had to be excluded for various reasons. Thus, a total of 44 heifers were analysed. After insemination, the heifers were randomly assigned to three feeding groups: control (C-group, $N = 17$), early restriction (ER-group, $N = 14$) and late restriction (LR-group, $N = 13$; Fig. 1).

Pregnancy stages of the heifers were divided into three experimental periods (Fig. 1). Period 1 was defined from the day of successful insemination up to the end of the 2nd month of pregnancy. Period 2 lasted from the 3rd month up to the end of the 7th month of pregnancy. Period 3 was intended to include the 8th and 9th month of pregnancy.

The heifers in the C-group were fed a standard total mixed ration (TMR; Table 2) formulated to cover maintenance requirements and an average daily gain (ADG) of 650–750 g throughout pregnancy according to the recommendations of the German Society of Nutrition Physiology (GfE, 2004). The crude protein content of the TMR was above the requirements due to the high amount of grass silage. The amount of TMR offered each day was calculated on the basis of body weight and the expected growth rate. During the last four weeks of pregnancy, each heifer received 2.5 kg concentrates per day as a top dressing with the TMR (Table 2).