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# Different milk feeding intensities during the first 4 weeks of rearing dairy calves: Part 2: Effects on the metabolic and endocrine status during calfhood and around the first lactation

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## ABSTRACT

Feeding dairy calves at high intensity has been demonstrated to increase milk yield in later life. We investigated the effect of 3 different feeding regimens in the preweaning period on the metabolic and endocrine status during calfhood and in heifers at the onset of the first lactation. In trial 1, 57 German Holstein calves were allocated to 3 different feeding groups: milk replacer restricted to 6.78 kg/calf per day, 11.5% solids (MR-res, n = 20), milk replacer 13.8% solids, ad libitum (MR-ad lib, n = 17), and whole milk ad libitum (WM-ad lib, n = 20). All calves received ad libitum colostrum for 3 d postnatal (p.n.). From d 4 to 27, all calves were fed according to their respective feeding regimen, resulting in average intakes of 6.38, 9.25, and 9.47 kg/d in MR-res, MR-ad lib, and WM-ad lib, respectively. Thereafter, all calves were fed according to the MR-res regimen until weaning at d 55 (gradually until d 69 p.n.). Blood samples were collected on d 0 before colostrum intake and on d 1, 3, 11, 22, 34, 43, 52, 70, 90, and 108 p.n. Liver biopsies were taken on d 19 and 100, and on d 22, 52, and 108 p.n. intravenous glucose tolerance tests were performed. The male calves (n = 8 to 10 per group) underwent also an insulin tolerance test on d 24, 54, and 110 p.n. The females (n = 28) from trial 1 were further reared and bred as common practice, and were enrolled in trial 2 when beginning the last trimester of pregnancy. Blood samples were collected monthly antepartum starting 91 d before calving and weekly (0–70 d) postpartum. Trial 1 was subdivided into 4 phases (P): P0 (d 0–1), P1 (d 2–27), P2 (d 28–69), and P3 (d 70–110 p.n.). In trial 1, the leptin and adiponectin concentrations increased with colostrum intake. Differences in fatty acids, insulin, adiponectin, revised quantitative insulin sensitivity check index (RQUICKI), and variables from the glucose tolerance tests were largely limited to P1. The MR-res group had greater RQUICKI and fatty acid values, and lower insulin and, as a trend, adiponectin concentrations than in 1 or both ad lib groups. These differences were partly sustained in P2 (fatty acids, adiponectin, and RQUICKI) and in P3 (adiponectin). The hepatic mRNA abundance of the gluconeogenic enzymes phosphoenolpyruvate carboxykinase and pyruvatcarboxylase increased from d 19 to 100. None of the blood variables were different between the groups when tested in pregnancy and lactation. Our results do not support a sustained deflection of metabolic regulation by rearing at different feeding intensities; nevertheless, the differences observed during rearing might influence nutrient utilization in later life or the cellular development of organs, such as the mammary gland, and thereby affect milk yield. Further studies involving greater animal numbers and, thus, improved power will help to sort out the mechanisms of programming body function in later life via nutrition in early life.
**Key words:** dairy calf, metabolic programming, insulin sensitivity, adiponectin, RQUICKI

## INTRODUCTION

Metabolic programming is defined as a permanent or long-lasting change in the structure or function of an organism arising from a stimulus or insult that acts during a sensitive or critical period in early life (Lucas, 1991). In dairy cows, nutrition during fetal or neonatal life can influence health and performance in later life (Bach, 2012). Feeding increased amounts of whole milk or milk replacer in the first weeks of rearing

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was reported to increase milk yield in the first lactation as compared with the common practice of feeding calves restrictively (Shamay et al., 2005; Moallem et al., 2010). In addition, increased growth rates due to increased intakes of concentrate in the first months of life were positively correlated with later milk yields (Bach and Ahedo, 2008; Heinrichs and Heinrichs, 2011). A meta-analysis of 12 studies on the topic demonstrated that long-term productivity benefitted from increased nutrient intake from milk or milk replacer during the preweaning period; those authors also stated that many studies were underpowered to appropriately test such effects (Soberon and van Amburgh, 2013).

The current concepts regarding the mechanisms underlying increased milk yield in intensively reared dairy calves mainly comprise 3 different aspects: (1) improved gastrointestinal function and liver metabolism resulting in greater feed digestibility and better nutrient utilization (Baldwin et al., 2004; Khan et al., 2011); (2) stimulated development of the mammary parenchyma, which may in turn give rise to a greater capacity for milk production (Brown et al., 2005; Geiger et al., 2016); and (3) tuning of the endocrine regulation of metabolism in favor of milk synthesis in later life. In the latter context, insulin and insulin sensitivity are of central importance; the reduced insulin sensitivity of peripheral tissues observed in late pregnancy and early lactation facilitates the partitioning of nutrients, in particular glucose, toward the mammary gland, in which glucose uptake is largely independent of insulin (Bell and Bauman, 1997). Evidence from both animal models and epidemiological studies in humans shows that early nutrition may affect insulin action in later life (Martin-Gronert and Ozanne, 2012; Duque-Guimarães and Ozanne, 2013). Results from rat studies suggest that the early environment can also affect β-cell mass and function and, hence, insulin secretion (Tarry-Adkins and Ozanne, 2011). Intensive feeding of male Holstein calves during the first 3 wk of life has been demonstrated to increase the numbers of islets of Langerhans and the circulating concentrations of insulin at 8 mo of age (Prokop et al., 2015). In the current study, we focused on the endocrine and metabolic alterations potentially induced by the feeding regimen in early life. We hypothesized that intensive feeding during the first 4 wk of life will elicit sustained changes of metabolic hormones that will continue until lactation and promote milk production. In addition, we hypothesized that ad libitum feeding of whole milk will be more effective to yield a metabolic profile in favor of milk production as compared with milk replacer. To test these hypotheses and to elucidate the mode of action of the beneficial effects reported for intensive feeding of dairy calves during the first weeks of life on their later lactational performance, we aimed (1) to characterize their metabolic and endocrine status during differential feeding (d 4–27 of life), and (2) to evaluate whether potential differences might be sustained until d 110 of life and also during late pregnancy (last trimester) and the first 70 d of lactation.

## MATERIALS AND METHODS

The animal experiments were performed in strict accordance with the German Law for the Protection of Animals and were approved by the relevant authority (Landesuntersuchungsamt Rheinland-Pfalz, Koblenz, Germany; G 11–20–026). Two trials were conducted. Trial 1 was focused on the effects of different preweaning feeding regimens in calves. In trial 2, the female calves from trial 1 were studied as heifers during late pregnancy and the first 70 d of lactation. Both trials were performed at the Educational and Research Centre for Animal Husbandry, Hofgut Neumuehle, Muenchweiler a.d. Alsenz, Germany. The experimental design and the gross outcomes in terms of performance are presented in the companion paper by Korst et al. (2017). The experimental designs are described in brief in the following sections.

### *Trial 1*

German Holstein calves (29 females and 28 males) were studied from April 2012 to January 2013 during their first 110 d of life. All calves were born spontaneously at term and received colostrum milked from their dam within 2 h after birth via a teat bucket in the calving pen next to their dam. The calves were then transferred to individual straw-bedded hutches (Flixbox, Mayer Maschinenbaugesellschaft mbH, Tittmoning, Germany) and fed twice daily by a teat bucket with colostrum from their dam for the first 3 d of life. The amounts offered per meal were sized to exceed the actual intake; the latter was quantified by subtracting the residual milk from the total amount offered per meal. The mean colostrum intake in the subsequently formed feeding groups was not different; the average daily intake during the 3-d colostrum phase was 5,982 ± 176 g (mean ± SEM). The differential feeding was started on d 4 postnatal (**p.n.**). The calves were randomly allocated to 3 different feeding groups balanced for sex and BW: one received milk replacer (**MR**; Neumühle sauer, Trouw Nutrition Deutschland GmbH, Burgheim, Germany) restricted to a maximum of 6.78 kg/d (**MR-res**; 11.5% solids; n = 20, each 10 males and females); the second group had ad libitum access to MR (**MR-ad lib**; 13.8% solids; n = 17, 8 males and 9 females); and the last group had ad libitum access to