Animal Feed Science and Technology 165 (2011) 31–37

Contents lists available at ScienceDirect

Animal Feed Science and Technology

journal homepage: www.elsevier.com/locate/anifeedsci

The influence of a supplement of β-carotene given during the dry period to dairy cows on colostrum quality, and β-carotene status, metabolites and hormones in newborn calves

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ARTICLE INFO

Article history:
Received 20 July 2010
Received in revised form 8 February 2011
Accepted 18 February 2011

Keywords:
Dietary β-carotene
Dry period
Dairy cows
Calf
Colostrum

ABSTRACT

The objectives of the present study were to investigate whether a dietary supplement of β-carotene given to dairy cows during the dry period was able to: (1) increase their β-carotene status, (2) increase the amount of β-carotene in colostrum, (3) increase the concentrations of immunoglobulin G in colostrum and (4) modify metabolic hormone, enzyme and metabolite status in their calves at birth. Forty Holstein cows were allocated to one of two dietary treatments: a control diet (C, $n=20$) or the same diet plus 1 g β-carotene/cow/day (BC, $n=20$) starting on the day of drying-off. The β-carotene supplement was given individually to the cows throughout the dry period. From week 2 after the start of supplementation, blood concentrations of β-carotene were higher in BC compared to C cows ($P<0.0001$). The β-carotene concentrations of colostrum were higher in BC than in C cows (3.10 ± 0.23 mg/l vs.1.44 ± 0.24 mg/l, $P<0.001$). Colostrum production was not different between groups (BC, 11.11 ± 1.21 kg vs. C, 10.05 ± 2.25 kg). The content of IgG in colostrum was not affected by treatment (BC, 82.65 ± 8.79 mg/ml vs. C, 79.32 ± 9.02 mg/ml). Blood concentrations of β-carotene in calves at birth were unaffected by treatment (BC, 1.16 ± 0.21 mg/l vs. C, 1.27 ± 0.24 mg/l). A supplement of β-carotene given during the dry period to dairy cows did not affect metabolite and metabolic hormone concentrations and enzyme activities in newborn calves. The results of this study indicate that a dietary supplement of β-carotene given in late-gestation was able to increase β-carotene concentrations in dam blood and in colostrum but was unable to increase colostral IgG. In addition, hormone and metabolite status and enzyme activities in the neonatal calf were also unaffected.

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doi:10.1016/j.anifeedsci.2011.02.013

1. Introduction

β-Carotene is the natural precursor for vitamin A (retinol) in ruminants. Several studies have shown the importance of β-carotene, in its own right, on reproduction, immune function and health in the cow and calf (Michal et al., 1994; Kume and Toharmat, 2001). However, the majority of raw materials used to feed dairy cows are very poor sources of β-carotene (Nozière et al., 2006) and plasma concentrations of β-carotene have been shown to decrease in dairy cows during the pre-partum period (Kawashima et al., 2009a). This may be due to the transfer of β-carotene from blood to colostrum or to the foetus. However, in many species neonatal liver stores of vitamin A are very low. Therefore, the transfer of vitamin A and β-carotene to colostrum and its intake shortly after birth are fundamental in providing adequate vitamin A and β-carotene to the neonate. The importance of immunoglobulin G (IgG) levels in colostrum for calf health is recognized (Kume and Toharmat, 2001). However, little information on the possible effect of β-carotene supplementation to dairy cows on colostral IgG concentration is available. Various studies have been conducted to study the effect of supplements of various antioxidants, including β-carotene, on cow health during the peripartum period (Chawla and Kaur, 2004; Spears and Weiss, 2008). To date there has been little research into the possible effects of a supplement of β-carotene during late pregnancy on calf health at birth. In newborn calves there are great morphological and functional changes (Blum and Hammon, 2000) and there are several hormones and metabolites involved in these processes including insulin, cortisol, insulin-like growth factor-1 (IGF-1), glucose, non-esterified fatty acids (NEFA), β-hydroxybutyrate (BHB), urea, albumin and protein. The changes in these parameters reflect the health status of newborn calves. Determination of enzyme activity is a useful tool to monitor health status. In cattle, changes in the enzyme activities of: γ-glutamyl transferase (γ-GT), aspartate aminotransferase (ASAT), alkaline phosphatase (ALP) and creatinine kinase (CK) are associated with liver, heart and skeletal function (Zanker et al., 2001; Hussein and Abd Ellah, 2008).

The objectives of the present study were to investigate whether a dietary supplement of β-carotene given during the dry period to dairy cows was able to (1) increase their β-carotene status, (2) increase the amount of β-carotene in colostrum, (3) increase the concentration of IgG in colostrum and (4) modify metabolic hormones, (cortisol, insulin and IGF-1), enzyme activities (ALP, ASAT, γ-GT and CK), and metabolites (glucose, NEFA, urea, BHB, creatinine, albumin, and protein) in their calves at birth.

2. Materials and methods

The present study was carried out according to French legislation on animal experimentation in line with the European Convention for the Protection of Vertebrates used for Experimental and other Scientific Purposes (European Directive 86/609).

2.1. Animals and management

This experiment was conducted at the experimental farm of AgroParisTech, Thiverval-Grignon, France. Forty, primiparous and multiparous, Holstein cows, calving between November 2008 and July 2009, were used in the experiment. On the day of drying-off cows were allocated to one of two dietary treatments: maize silage based control diet (C, $n = 20$) or control diet plus 1 g β-carotene/cow/day (BC, $n = 20$, 10 g Rovimix® β-carotene containing 100 g/kg β-carotene; DSM Nutritional Products). The supplementation level was defined based on the fact that maize silage diets are very poor in β-carotene compared to grass silage, hay or lucerne diets. We wanted to obtain blood values well above 3 mg/l, the concentration generally considered to cover requirements (Frye et al., 1991). The criteria used to form the experimental groups were: live weight, body condition score, age, previous 305-day milk production, expected calving date, and blood β-carotene concentration. The age composition of the control and β-carotene groups of cows were respectively; 1st lactation cows, 10 and 11 animals; 2nd lactation cows, 4 and 4 animals; 3rd lactation cows, 4 and 2 animals; 4th lactation cows, 1 and 3 animals and 5th lactation cows, 1 and 0 animals. The β-carotene supplement was given individually to the cows in the morning with a small part of the control diet concentrate (500 g rapeseed meal). The dry period lasted 8 weeks. Cows were group housed in a barn on straw and received total mixed rations (TMR), formulated to meet average requirements for maintenance and gestation (INRA, 1989). Two different diets were formulated (Table 1) and fed to the cows depending on their requirements (1st and 2nd month of the dry-period). The diets contained a vitamin and mineral mix which covered vitamin A requirements. Cows had free access to water and salt licks. The concentration of β-carotene in the 1st and 2nd month dry cow TMR and rapeseed meal were 4.32, 3.72 and 0.63 mg/kg dry matter respectively. This resulted in the 1st month diet providing 43.3 mg/cow/day and the 2nd month diet providing 42.0 mg/cow/day.

2.2. Sampling and data collection

Blood samples were obtained at −8, −6, −4, −2 weeks before and on the day of calving by caudal venipuncture before the morning feed. Cows were moved to the calving pen one month before the expected calving date. Ease of calving was noted on a 0–2 scale (where 0, no assistance to 2, requiring heavy traction, Jacobsen et al., 2000). The cows were filmed during calving by four cameras. The time required for the calves to move from the lying position to a sterno-abdominal position was noted and used as an indicator of calf vitality at birth. Calf rectal temperature was measured at birth. Immediately