Effect of colostral β-carotene and vitamin A on vitamin and health status of newborn calves

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Abstract

The present study was conducted to clarify the relationship between colostral and plasma vitamin A and β-carotene, and to evaluate the effect of vitamin status on diarrhea and anemia of 46 Holstein newborn calves at 6 days of age. Colostral β-carotene and vitamin A concentrations at parturition ranged from 17.8 to 342.9 and from 32.9 to 450.0 µg/dl, respectively. Plasma β-carotene and vitamin A of calves increased at 6 days of age. Colostral β-carotene at parturition was positively correlated with plasma β-carotene of calves at 6 days of age, but there was no significant correlation between colostral and plasma vitamin A. Fecal DM concentration of calves decreased at 6 days of age, and fecal DM of calves at birth and 6 days of age ranged from 21.2 to 44.2 and from 11.7 to 40.6%, respectively. Plasma β-carotene and plasma vitamin A were positively correlated with fecal DM, but no correlations were observed between plasma vitamins and erythropoiesis components. These results suggest that β-carotene status of calves at 6 days of age is dependent on colostrum concentrations of β-carotene and affects the occurrence of diarrhea, and vitamin A status depends on colostral vitamin A and placental vitamin A transfer during gestation. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: β-carotene; Vitamin A; Calves; Colostrum

1. Introduction

Mortality and morbidity of newborn calves continue to be major problems on dairy farms, and their most common disease is diarrhea. Successful calf health depends on many factors related to management and nutrition, and the importance of consumption of an adequate amount of high quality colostrum on acquisition of passive immunity is widely recognized (Quigley and Drewry, 1998). However, the disease resistance acquired from colostrum Ig is only temporary, and the newborn calves must become immunocompetent before passive maternal immunity wanes (Rajala and Castren, 1995). Scours of calves are common at 5 days to 3 weeks of age and then the incidence declines (Nocek et al., 1984; Quigley et al., 1995; Quigley and Drewry, 1998). Additionally, the anemia in newborn calves and calf mortality at birth is more common for multiple calves than for single calves, for calves born from primiparous cows.
than for calves born from multiparous cows, and for male calves than for female calves (Kume and Tanabe, 1993a, 1994, 1996).

Colostrum is a source of immune components and nutrients for the neonates and contains greater concentrations of protein, fat, vitamins and minerals than does milk. Because some vitamins do not cross the placental barrier, colostrum is the primary source of these nutrients for the calf after birth (Kume and Tanabe, 1993b; Quigley and Drewry, 1998). Vitamin A and β-carotene provide a protective effect against various diseases and enhance many facets of the immune system (Chew, 1987). Lothhammer (1979) reported that calves of carotene-deficient cows had a higher incidence of diarrhea and mortality in the first week of life. Chronic deprivation of vitamin A results in anemia with some accompanying Fe deficiency (Mejia et al., 1979). Although colostral vitamin A and β-carotene varied with a number of factors (Foley and Otterby, 1978; Kume and Tanabe, 1993b), the effect of colostral vitamin A and β-carotene on health status of newborn calves has not been well clarified.

The present study was conducted to clarify the relationship between colostral and plasma vitamin A and β-carotene, and to evaluate the effect of vitamin status on diarrhea and anemia of newborn calves at 6 days of age.

2. Materials and methods

2.1. Calf

Data from 26 Holstein female and 20 male calves were collected at the National Institute of Animal Industry (Tsukuba, Japan) from March 1995 to December 1996. Calves consisted of five pairs of twins and 36 single calves. The birth weight of calves was 41.5±6.7 kg (mean±S.D.). The dams were given 3–4 kg/day of concentrate and appropriate amounts of silage and hay from Italian ryegrass in individual tie stalls to meet recommendations (Agriculture, Forestry, and Fisheries Research Council Secretariat, 1994) for TDN, protein and minerals. Calves were separated from the dams at birth and housed in individual pens. Each calf received ~1 kg of colostrum at parturition and, thereafter, 2.5 kg of colostrum at 09:00 and 16:00 h daily from its dam’s colostrum for 1 week postpartum.

2.2. Sampling and analytical method

Blood samples from calves were collected at birth and at 08:30 h on day 6 of age. At birth, blood samples were taken within 12 h after birth. Blood was sampled via jugular vein puncture into heparinized vacuum tubes. Fecal grab samples of calves were taken from the rectum within 12 h after birth and at 6 days of age. Rectal temperature of the calves was measured by a clinical thermometer at birth and at 08:30 h on day 6 of age. Colostrum samples from 40 dams were collected at parturition.

Blood hematocrit (Hct) and hemoglobin (Hb), plasma Fe and colostrum composition were determined as previously described (Kume and Tanabe, 1993a,b). Fecal samples were dried, ground in a stainless steel mill, and analyzed as previously described (Kume et al., 1998) after digestion in nitric and perchloric acid. Vitamin A and β-carotene of plasma and colostrum were determined by the method of Chew et al. (1982). However, only 25 plasma samples, which were obtained immediately after birth, were used for vitamin analyses at birth because of the evaluation of no vitamin transfer from colostrum.

2.3. Statistical analyses

The general linear models procedure of SAS (1988) was used to analyze the effect of age on fecal and plasma composition of calves. Relationships between colostral and plasma β-carotene and vitamin A were determined by regression analysis with averaged data of plasma in twins. Relationships between plasma and other components in feces and plasma were determined by regression analysis. Significance was declared at $P < 0.05$.

3. Results and discussion

3.1. Relationship between colostral and plasma vitamin concentrations

Colostral β-carotene and vitamin A concentrations (mean±S.D.) at parturition ranged from 17.8 to
Table 1
Least squares means and S.D. of fecal and blood samples of 46 calves at birth and 6 days of age

<table>
<thead>
<tr>
<th>Age (days)</th>
<th>Age effect</th>
</tr>
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<tbody>
<tr>
<td>X</td>
<td>S.D.</td>
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<tr>
<td>0</td>
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</tr>
<tr>
<td>6</td>
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Rectal temperature, °C
Feces
<table>
<thead>
<tr>
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<th>S.D.</th>
<th>X</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM, g/100 g</td>
<td>35.3</td>
<td>4.7</td>
<td>24.1</td>
<td>6.3</td>
</tr>
<tr>
<td>CP, g/100 g</td>
<td>43.4</td>
<td>9.3</td>
<td>62.5</td>
<td>13.9</td>
</tr>
<tr>
<td>Fe, mg/kg</td>
<td>14</td>
<td>14</td>
<td>296</td>
<td>175</td>
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</tbody>
</table>

Blood
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</tr>
</thead>
<tbody>
<tr>
<td>Hct, %</td>
<td>39.3</td>
<td>7.0</td>
</tr>
<tr>
<td>Hb, g/dl</td>
<td>11.6</td>
<td>2.2</td>
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</table>

Plasma
<table>
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<th>S.D.</th>
<th>X</th>
<th>S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin A, μg/dl</td>
<td>5.9</td>
<td>3.0</td>
<td>17.2</td>
<td>5.2</td>
</tr>
<tr>
<td>β-carotene, μg/dl</td>
<td>0.9</td>
<td>1.2</td>
<td>18.5</td>
<td>9.7</td>
</tr>
<tr>
<td>Fe, mg/l</td>
<td>1.61</td>
<td>0.62</td>
<td>0.87</td>
<td>0.84</td>
</tr>
</tbody>
</table>

* DM basis.
* At birth, 25 samples were analyzed.
*** P<0.001.

Table 1

Colostrum concentrations of β-carotene and vitamin A varied with a number of factors including individuality, breed, parity, prepartum diet, occurrence of mastitis etc., and colostral β-carotene and vitamin A decreased drastically with time postpartum (Foley and Otterby, 1978; Kume and Tanabe, 1993b). Parrish et al. (1953) reported that apparent vitamin A absorption of newborn calves was 81 to 95% during 1 week postpartum, whereas apparent absorption of carotenoids was only 38 to 65%. Although the wide range of colostrum β-carotene and vitamin A in the present study may be affected by some factors, colostral β-carotene directly affects plasma β-carotene of calves at 6 days of age.

The rapid increase of plasma vitamin A and β-carotene in the present study agreed with the previous data (Kume and Tanabe, 1993b), which showed that serum vitamin A and β-carotene of calves increased dramatically as the time postpartum increased. Colostrum is the main source of β-carotene and vitamin A for newborn calves after birth, as shown by the rapid increase of these vitamins in calf plasma, but vitamin status of calves depends not only on vitamin intake from colostrum but also on placental vitamin transfer from the dams during late gestation (Kume and Tanabe, 1993b). Because plasma β-carotene of calves at birth was extremely low, colostral β-carotene was a primary source for calves. However, compared to β-carotene, placental vitamin A transfer was important for newborn calves. These results suggest that β-carotene status

342.9 (169±85) and from 32.9 to 450.0 (122±77) μg/dl, respectively. Plasma β-carotene and vitamin A increased (P<0.001) at 6 days of age (Table 1). Colostral β-carotene at parturition was positively correlated (r=0.57; P<0.001) with plasma β-carotene of calves at 6 days of age, but there was no significant correlation between colostral and plasma vitamin A (Fig. 1). The relationship between plasma β-carotene of calves at birth and 6 days of age was not clear owing to the low concentrations at birth, but plasma vitamin A of calves at birth was positively correlated (r=0.48; P<0.05) with plasma vitamin A at 6 days of age.

Fig. 1. Relationships between colostral and plasma β-carotene and vitamin A of calves at 6 days of age. Regression equation and S.E. of plasma β-carotene (Y) on colostral β-carotene (X) was as follows: Y = 0.070(±0.016)***X + 10.38(±2.34)*** (r² = 0.32; ***P<0.001).
of calves at 6 days of age is dependent on colostrum concentrations of β-carotene, but vitamin A status depends on colostral vitamin A and placental vitamin A transfer during gestation.

3.2. Plasma vitamin and health status of calves

Fecal DM of calves decreased \((P < 0.001)\) at 6 days of age (Table 1), and fecal DM content of calves at birth and 6 days of age ranged from 21.2 to 44.2 and from 11.7 to 40.6%, respectively.

Rectal temperatures and fecal CP of calves increased \((P < 0.001)\) at 6 days of age. Plasma β-carotene \((r = 0.45; \ P < 0.01)\) and plasma vitamin A \((r = 0.29; \ P < 0.05)\) were positively correlated with fecal DM (Fig. 2), although no correlations were observed between plasma vitamins and rectal temperature.

Severe diarrhetic feces of calves contained more than 85% moisture, and feces that contained less than 80% moisture appeared normal (Abe et al., 1999). In the present study, diarrhetic calves were detected at 6 days of age, but calves at birth had normal range of fecal DM. Colostrum provides not only vital Ig but also significant amounts of immune proteins and nutrients that support the calf during the first few days of life, and the transfer of passive immunity reduces the incidence and severity of scours (Quigley and Drewry, 1998; Quigley et al., 1995). However, the incidence of scours and elevated body temperature of calves commonly occur during the first 1 to 3 weeks of life after absorption of Ig in the calf intestine ceases (Quigley et al., 1995).

In the present experiment, the diarrhetic calves had lower plasma β-carotene and vitamin A, but plasma β-carotene was more linearly related to the occurrence of diarrhea. Lotthammer (1979) reported that calves offered low colostral β-carotene and vitamin A showed a higher incidence of diarrhea and mortality in the first week of life. Thus, the low plasma β-carotene of calves at 6 days of age, which is dependent on colostrum concentrations of β-carotene, may affect the occurrence of diarrhea in the present study, although vitamin A is important for the prevention of diarrhea.

High quality roughage or supplemental vitamin for the dams during late gestation may be useful for newborn calves, because dietary levels of β-carotene and vitamin A for the dams affected not only colostral vitamin concentrations but also vitamin status of newborn calves (Lotthammer, 1979; Kaki-mura et al., 1991). However, colostral and plasma β-carotene and vitamin A concentrations varied drastically in the present study, although colostrum was given to the calves for 1 week. Supplemental vitamins are necessary for calves offered low colostral β-carotene and vitamin A to maintain their health status immediately after birth.

Blood Hct, Hb and plasma Fe of calves decreased \((P < 0.001)\) at 6 days of age, but fecal Fe increased \((P < 0.001)\) (Table 1). There were no significant correlations between plasma vitamins and the erythropoiesis components such as blood Hct, Hb,


References


plasma Fe and fecal Fe. Kume and Tanabe (1996) reported that Fe-deficiency anemia often developed in calves at birth and normal development of erythropoiesis was needed to prevent high mortality in anemic newborn calves. Mejia et al. (1979) suggested that anemia in rats may be a component of vitamin A deficiency, but might be masked by the dehydration that accompanies severe depletion of vitamin A. In the present study, the extremely low values of meconium Fe at birth may be due to the efficient shift in the Fe storage of dams to blood Hb of newborn calves, but plasma vitamin A and β-carotene had no effect on low erythropoiesis of calves at 6 days of age.

Increased supplementation of vitamin A improved fecal consistency of calves at 3 and 4 weeks of age (Eicher et al., 1994), but additional vitamin A provided by some scour treatments could be detrimental to calves that are already receiving vitamin A supplementation (Franklin et al., 1998). Further study is needed to evaluate the role of vitamin A and β-carotene for proper calf nutrition and health, because vitamin A and β-carotene enhance many facets of the immune system (Chew, 1987).

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