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Note

Concentrations of vitamin C in plasma and milk of dairy cattle

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Summary — Colostrum or milk samples from 6 cows and blood plasma samples from the cows and their calves were taken between 0 and 28 d after calving and analyzed for vitamin C (ascorbic acid). At birth, the blood plasma concentration of ascorbic acid in calves ranged between 6.1 and 10.8 µg/ml, and declined within 5 d to between 2.7 and 4.5 µg/ml. Correspondingly, the concentration was twice as high in colostrum (16 µg/ml) than in milk at 2 d after calving (8 µg/ml). The plasma ascorbic acid concentration was initially lower in cows than in their calves, and reached the same level approximately 28 d after calving.

dairy cattle / vitamin C / blood plasma /milk

Résumé — Concentration en vitamine C du plasma sanguin et du lait chez la vache laitière. *Des échantillons de colostrum ou de lait de 6 vaches de race Holstein et des échantillons de plasma des 6 vaches et de leurs veaux ont été prélevés entre 0 et 28 j après le vêlage et analysés pour déterminer leur teneur en vitamine C (acide ascorbique). À la naissance, la teneur en acide ascorbique du plasma sanguin des veaux est comprise entre 6,1 et 10,8 µg/ml et diminue après 5 j entre 2,7 et 4,5 µg/ml. Les teneurs correspondantes dans le colostrum (16 µg/ml) sont 2 fois plus élevées que dans le lait, 2 j après le vêlage. La teneur en acide ascorbique du plasma est, au vêlage, plus faible chez les vaches que chez leurs veaux, mais est identique 28 j environ après le vêlage.*

vaches laitières / vitamine C / plasma sanguin / lait

INTRODUCTION

Ascorbic acid (ascorbate, vitamin C) is synthesized in the liver of most mammals (Chatterjee, 1978). Calves do not synthesize endogenous vitamin C until approximately 3 wk of age, making them dependent on dietary vitamin C during this period (Palludan and Wegger, 1984). Without the availability of a functional biochemical procedure that relates to vitamin C status, information concerning inadequacies in this nutrient has been derived mainly from measuring ascorbic acid levels in plasma, leucocytes, blood and urine. The measurement of plasma levels of ascorbic acid is the most commonly used and practical procedure for determining vitamin C nutritional status in individuals or population groups (Sauberlich, 1975). Calves are born with a high plasma ascorbic acid content, which drops significantly in the postnatal period (Bouda *et al*, 1980). Low blood plasma levels of vitamin C have been found in young calves suffering from respiratory infection (Jagoš *et al*, 1977) and skin lesions (Scott, 1991). Cummins and Brunner (1991) reported the association of housing type with decreased plasma ascorbic acid and to a reduced immune response to a specific antigen. Bendich (1993) reported that supplementation of vitamin C provides a safe and effective means to enhance clinically relevant immune functions. Calf plasma ascorbate in the early postpartum period is correlated with maternal plasma ascorbate and is dependent on maternal nutrition (Smirnov, 1962). Itzeova (1984) reported an r^2 of 0.73 between plasma ascorbate in dam and calf plasma. There is, however, very little information on the variation of ascorbic acid in the milk and blood plasma of cows after parturition, and its effect on the progeny. The objective of this study was to measure milk and plasma vitamin C levels in cows as well as vitamin C in the plasma of their progeny.

MATERIALS AND METHODS

Six Holstein cows and their newborn calves were studied in the present experiment. Dry cows were fed 8.5 kg dry matter (DM) per day of a diet composed of corn silage (15%), hay (35%) and haylage (50%) on a DM basis. After birth, the calves remained for 3 d with their mothers and nursed their colostrum. The calves received the milk of their dams up to a maximum of 10% of body weight per day up to 4 wk of age, 50% in the morning (08.00) and 50% in the evening (16.00). In addition, calves had access to a starter ration (table I). Lactating cows received a mixed diet consisting of 88% forage (corn silage 70%, haylage 20%, hay 10%) and 12% concentrate (DM basis). Cows producing more than 7 kg of milk per day received concentrate in the form of pellets at the rate of 1 kg for each 3 kg of milk over 7 kg (Batra *et al*, 1992). Animals studied in this experiment were cared for under guidelines comparable to those developed by the Canadian Council of Animal Care.

Colostrum or milk and blood samples of cows were taken at calving and at 2, 7, 14, 21 and 28 d thereafter. Blood samples from calves were taken on the first day approximately 6 h after birth and following 3 h after ingestion of colostrum and then on 2, 7, 14, 21 and 28 d of age 1 h after morning feeding (09.00). Blood samples were centrifuged and plasma separated. Each sample of colostrum, milk or plasma was immediately mixed with 2.55% metaphosphoric acid in the ratio of 1:2. The sample mixtures were frozen at –70°C until analyzed less than 1 wk later. The ascorbic acid concentrations in samples were measured by high performance liquid chromatography using an electrochemical detector (Behrens and Madère, 1987). Data on vitamin C in plasma and milk of cows and plasma of calves were analyzed according to the following model:

$$Y = M + C + S + E$$

where Y = vitamin C in plasma or milk, M = overall mean, C = cow effect, S = sampling time effect and E = error term. The data were analyzed as a

Table I. Composition of starter diet.

Ingredient	*Percentage*
Soybean meal (48% CP)	20.00
Dehydrated alfalfa (15% CP)	5.00
Corn	24.65
Barley	38.50
Wheat bran	5.00
Wet molasses	3.75
Limestone	0.70
Monodicalcium phosphate	0.50
Mineral mix [a]	0.90
Vitamin mix [b]	1.00

[a] Contained (percentage): cobalt iodized salt, 76.67; sulphate of potash magnesia, 21.11; zinc oxide, 0.739; manganous oxide, 0.739; cupric oxide, 0.739. [b] Contained (percentage): wheat middling, 89.39; Bovatec™ (Mutual, Morrisburg, ON, USA), 2.66; vitamin E (50 IU/g), 6.84; vitamin A (30 000 IU/g), 0.95; vitamin D_3 (25 000 IU/g), 0.16.

repeated measures analysis of variance using the General Linear Model procedure of the SAS Institute (1982) and designating time as a repeated measure. Simple regression procedure was used to study the association of calf plasma vitamin C with dam plasma vitamin C concentration. The model used was as follows:

$$Y = A + B1 + E$$

where Y = calf plasma vitamin C, A = intercept, $B1$ = regression coefficient for dam plasma vitamin C and E = error term.

RESULTS AND DISCUSSION

At birth, the ascorbic acid concentration in blood plasma of calves (fig 1) was quite high (6.1 to 10.8 µg/ml) and declined rapidly during the first 2 d after birth (to 2.7 to 4.5 µg/ml). There was a further gradual decline between d 2 (2.7 to 4.5 µg/ml) and d 21 (0.8 to 2.6 µg/ml) after birth. The concentration of ascorbic acid in colostrum (16 µg/ml) was approximately twice as high (fig 1) as in milk samples (approximately 8 µg/ml) between d 2 and d 28 after calving.

In cows, the plasma ascorbic acid concentration was very low the first day after calving (1.9 µg/ml), then fluctuated between 2.2 and 2.6 µg/ml from 2 to 14 d and returned to the initial concentration at 21–28 d after calving (fig 2). These values for ascorbic acid concentration in plasma of cows are similar to those reported by Haag and Hoffman (1987). The analysis of variance results in the present experiment showed that the day of sampling effects was significant (P < 0.05) for both plasma and milk ascorbic acid concentration. Cow effects were not significant (P > 0.05) for plasma and milk ascorbic acid concentration.

The variation between calves in the plasma ascorbic acid concentration was quite high. It was, however, lower (P < 0.01) than the variation within days, which is in agreement with the study reported by Bouda

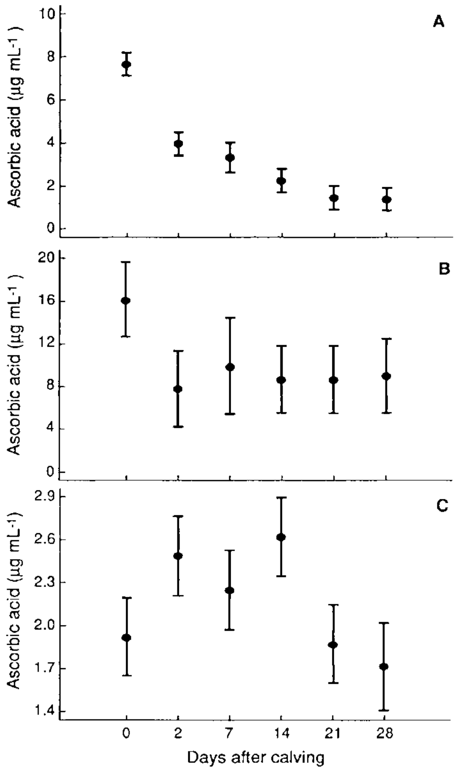

Fig 1. Mean concentration of ascorbic acid in (**A**) blood plasma of 6 Holstein calves after calving; (**B**) in colostrum or milk of 6 Holstein cows after calving; (**C**) in blood plasma of 6 Holstein cows after calving. Vertical bar represents 1 standard deviation.

et al (1980). It is suggested that in the calf, ascorbic acid concentration is an indication of its current metabolic situation and, therefore, subject to greater fluctuation. The present study was performed during the first 28 d of life, and it is well known that during this period the physiology of newborn animals undergoes radical change (Itzeova, 1984). Our results and those of Wegger and Moustgaard (1982) show that, at birth, calves have a high plasma ascorbic acid content which declines rapidly in the first 5 d after birth. Generally, the ascorbic acid values reported in the milk of cows in the present experiment were low and were only about one-tenth of the ascorbic acid found in milk of the sow (Wegger and Palludan, 1982). The values for ascorbic acid concentration in cow milk obtained in the present experiment were similar to those reported by Scott and Bishop (1986).

During the first weeks of life, the calf requirement for ascorbic acid is supplied by colostrum and milk and by the fetal storage of vitamin C. The higher content of vitamin C in colostrum than in milk may explain the higher level of ascorbic acid found in plasma of calves during the first day of life. It would appear that the ascorbic acid content in the plasma of calves declines in the first 3 wk of life, while the capacity to synthesize vitamin C develops only gradually. Calves are unlikely to synthesize sufficient quantities of vitamin C in their first weeks of life. It is probable that the ascorbic acid synthesizing ability is missing or is insufficient during the early postnatal period (Palludan and Wegger, 1984). This assumption is supported by Smirnov (1962) and Bouda *et al* (1980). Therefore, some form of vitamin C supplementation may be beneficial to newborn calves to enhance resistance to infectious diseases.

The overall regression coefficients of calf plasma vitamin C on dam plasma vitamin C concentration was 0.14 and this regression coefficient was not significant ($P > 0.05$). Smirnov (1962) reported that calf plasma ascorbate in the early postpartum period was correlated with maternal plasma ascorbate. Data from our study did not indicate any association of calf plasma vitamin C level with maternal vitamin C concentration. The correlation between plasma and milk vitamin C concentration of the cows was –0.43. This negative correlation was due to the fact that colostrum is very high in vitamin C and the level of vitamin C in the milk decreased with increase in the days after calving. On the other hand, cow plasma vitamin C content was lower at the time of parturition, and slowly increased with increase in the days after calving.

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