Delaying Colostrum Intake by One Day Impairs Plasma Lipid, Essential Fatty Acid, Carotene, Retinol and α-Tocopherol Status in Neonatal Calves[1,2,3]

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ABSTRACT To study whether a delayed start of colostrum feeding in calves affects plasma lipids, fatty acids and fat-soluble vitamins, one group was fed colostrum (milkings 1–4) on d 1 and 2, then mature milk up to d 7, whereas two other groups were fed glucose or water on d 1, colostrum (milkings 1–4) on d 2 and 3 and then mature milk up to d 7. In calves fed colostrum on d 1, starting 5–7 h after birth, plasma concentrations of triglycerides, phospholipids, total cholesterol and of essential and nonessential fatty acids in triglyceride, phospholipid and cholesterol ester fractions as well as of carotene, retinol and α-tocopherol up to d 7 were significantly higher than in calves in which colostrum feeding started after >24 h of life. On the other hand, plasma concentrations of vitamin B-6, vitamin B-12 and folic acid were not influenced. Results indicated reduced efficiency of absorption of colostral fatty acids and of fat-soluble vitamins, but not of (selected) water-soluble vitamins, if colostrum is not fed on d 1 of life. In conclusion, colostrum intake within the first 24 h of life is required for an adequate plasma lipid, essential fatty acid, carotene, retinol and α-tocopherol status in the first week of life of calves. J. Nutr. 127: 2024–2029, 1997.

KEY WORDS: • *fatty acids* • *lipids* • *fat-soluble vitamins* • *colostrum* • *bovine* • *neonates*

Colostrum contains various substances that are important for newborns. Among these are essential and nonessential fatty acids as well as fat- and water-soluble vitamins. Intake through colostrum of essential and nonessential fatty acids and of vitamin A and vitamin E is vital in many species, including neonatal calves (Bondi 1987) and pigs (Hidiroglou et al. 1993). Plasma levels of vitamins A and E increase in neonatal calves after colostrum intake (Kumagai et al. 1994). A delayed colostrum intake may impair essential fatty acid and fat-soluble vitamin status as a consequence of decreasing concentrations in colostrum with increasing time after parturition and additionally as a result of a decreased absorptive capacity. This may contribute to enhanced incidence especially of infectious diseases because of involvement of various fatty acids, vitamin A and vitamin E in host defense (Eicher et al. 1994, Kabara 1980) and in association with antioxidative properties.

We have tested the hypothesis that feeding calves glucose or water instead of colostrum on d 1 of life leads to reduced plasma concentrations of lipids, essential fatty acids and fat-soluble vitamins (retinol and α-tocopherol). In addition, we have studied effects on selected water-soluble vitamins (B-6, B-12 and folic acid).

MATERIAL AND METHODS

Animal, feeding and experimental procedures. Husbandry, feeding, experimental protocols and procedures have been described in detail by Hadorn et al. (1997). In short, three groups were formed, each consisting of seven animals. Calves of the control group (group C)[5] were fed colostrum milkings 1 and 2 (1.5 L/meal) on d 1, colostrum milkings 3 and 4 (2.0 L/meal) on d 2 and then mature milk [5% of body weight (BW)] up to d 7 of life. On d 1, calves of the glucose (G) and and water (W) groups were fed glucose monohydrate twice (1.5 L/meal; 2g/kg BW, dissolved in tapwater) or water (1.5 L/meal), respectively, colostrum milkings 1 and 2 (1.5 L/meal) on d 2, colostrum milkings 3 and 4 (2.0 L/meal) on d 3 and then mature milk (5% of BW) up to d 7 of life.

Blood samples were obtained as described by Hadorn et al. (1997). Tubes containing dipotassium-EDTA (1.8 g/L blood) were used to collect blood for the determination of triglycerides, cholesterol, phospholipids, carotene, retinol, α-tocopherol, vitamin B-6, vitamin B-12 and folic acid. Samples were cooled on ice and centrifuged at

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[5] Abbreviations used: BW, body weight; group C, control group fed colostrum on d 1 and 2 and then mature milk up to d 7 of life; group G, fed glucose on d 1, colostrum on d 2 and 3 (milkings 1–4) and then mature milk up to d 7 of life; group W, fed water on d 1, colostrum on d 2 and 3 (milkings 1–4) and then mature milk up to d 7 of life.

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1000 × *g* for 20 min. Supernatants (plasma) were stored at −20°C for later analyses.

Cows were milked twice daily. The first four milkings were collected separately in plastic bottles for d 1 and 2, respectively. Colostrum was stored at 4°C and warmed to 40°C immediatly before being given to the calves. Aliquots of colostrum were taken from each cow before feeding and stored at −20°C until analyzed. Concentrations of individual essential and nonessential fatty acids, carotene, retinol and α-tocopherol did not change when colostrum (milking 1) was stored for 24 h at 4°C.

Laboratory methods. *Blood analyses.* Triglycerides and cholesterol were measured enzymatically using kits (# 07-3679−1 and # 07−3663−5, respectively) from Hoffmann-La-Roche (Basel, Switzerland). Phospholipids were measured enzymatically with a kit (# 61, 491) from Bio-Mérieux (Marcy l' Etoile, France). Concentrations of fatty acids in triglyceride, phospholipid and cholesterol ester fractions were determined by gas chromatography as described (Sallmann et al. 1992). Carotene, retinol and α- tocopherol were determined by HPLC (Vuillemier et al. 1983). Concentrations of vitamin B-6 were measured radioenzymatically using a kit (# RK-VB6) from Bühlmann Laboratories AG, Schönenbuch, Switzerland. Plasma concentrations of vitamin B-12 and of folic acid were simultaneously measured by solid-phase RIA using a kit (Dualcount) from Diagnostic Products, Los Angeles, CA, donated by Bühlmann Laboratories AG.

Triglycerides were measured in all blood samples on d 1, 2 and 7. Phospholipids, cholesterol, carotene, retinol and α-tocopherol were measured on d 1, 2, 3, 4 and 7 in the first (preprandial) daily blood sample. Vitamin B-6, vitamin B-12 and folic acid were determined in the first (preprandial) blood sample of d 1, 2 and 7 and fatty acids in the first blood sample on d 7.

Analyses in colostrum. Fatty acids were determined by gas chromatography as described by Sallmann et al. (1992). Carotene, retinol and α-tocopherol were measured in whole colostrum according to Farah et al. (1992).

Statistics. Values are expressed as means ± SEM, $n = 7$ per group. As described by Hadorn et al. (1997), data were analyzed by ANOVA using the GLM procedure of the SAS System for windows (SAS 1993). The model used was $Y_{ijk} = \mu + \text{treatment}_i + \text{time}_j + (\text{treatment}_i \times \text{time}_j) + e_{ijk}$, where Y_{ijk} = measured value, μ = general mean, treatment_i = feeding (water, glucose or colostrum), time_j = age at the time of blood sampling, $\text{treatment}_i \times \text{time}_j$ = interaction between time and treatment and e_{ijk} = residual error. Paired *t* test was used to evaluate differences of values within groups and Student's *t* test was used to localize differences ($P < 0.05$) between groups.

RESULTS

Plasma triglyceride concentrations (**Fig. 1**) in group C increased transiently ($P < 0.05$) 1 h after feedings on d 1 and increased ($P < 0.05$) after the first meal on d 2. Concentrations in group C before the first feeding on d 7 were not different from those before the first feeding on d 1 and 2. Concentrations in group G decreased ($P < 0.001$) on d 1 at 7 h after the first and 2 h after the second feeding and on d 2 at 7 h after the first feeding ($P < 0.05$), but not on d 7. Concentrations in group G before the first feeding on d 2 and 7 were lower ($P < 0.05$) than before feeding on d 1. Concentrations in group W decreased ($P < 0.01$) on d 1 after the first, but did not decrease after the second water intake, tended to increase ($P < 0.1$) within 1 h after each feeding on d 2, but did not significantly change postprandially on d 7. Concentrations before the first feeding on d 7 did not differ from concentrations before the first feeding on d 1 and 2. On d 1, concentrations at 7 and 15 h were lower ($P < 0.05$) in group G than in groups C and W. On d 2, basal concentration tended to be higher ($P < 0.1$) in groups C and W than in group G, and concentrations at 7 and 15 h were higher ($P < 0.01$) in group C than in groups G and W. On d 7, basal concentrations were higher ($P < 0.01$) in group C than in groups G and W. Mean levels after the second feeding on d 1, 2 and 7 were higher ($P < 0.05$) in group C than in the other groups. On d 1, mean levels after the second feeding were lower in group G than in group W ($P < 0.05$).

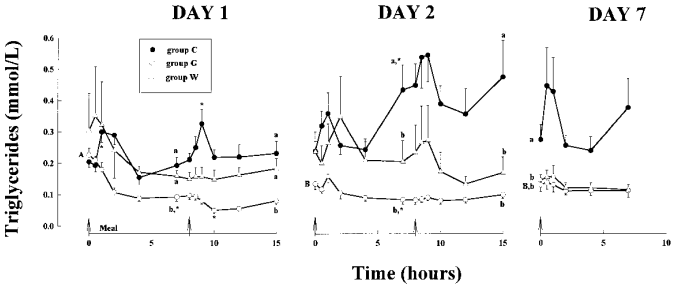

FIGURE 1 Plasma triglyceride concentrations in calves of groups C (control), G (glucose) and W (water) on d 1, 2 and 7 of life. Group C was fed colostrum twice daily on d 1 (milkings 1 and 2) and on d 2 (milkings 3 and 4), then milk up to d 7. Group G was provided glucose twice on d 1, whereas Group W was provided water twice on d 1; both groups were then fed colostrum twice daily on d 2 (milkings 1 and 2) and on d 3 (milkings 3 and 4) and milk twice daily up to d 7. The ↑ indicates time of feeding. Data are means ± SEM, $n = 7$ per group. Means without common uppercase letters (A, B) are significantly different ($P < 0.05$) within a group on different days (d 1, 2 and 7). Means without common lowercase letters (a, b) are significantly different ($P < 0.05$) among groups on d 1, 2 or 7 of life at different time points (before and 7 h after feed intake on d 1, 2 and 7). *Means (of peak or nadir values ≤7 h after meal intakes) are significantly different ($P < 0.05$) from prefeeding values.

Phospholipid plasma concentrations (**Fig. 2***A*) in group C increased ($P < 0.05$) from d 1 to 7. Concentrations in group G did not change from d 1 to 2; on d 3, they tended to be higher ($P < 0.1$) than on d 1, increased ($P < 0.001$) from d 3 to 4, and on d 7 tended to be higher ($P < 0.1$) than on d 1 and 2. Concentrations in group W increased ($P < 0.05$) from d 1 to 2; on d 4, but not on d 7, they were higher ($P < 0.05$) than on d 1. Phospholipid concentrations from d 2 to 7 in group C were higher ($P < 0.01$) than in groups G and W.

Cholesterol plasma concentrations (Fig. 2*B*) markedly increased from d 1 to 7 ($P < 0.01$ from d 1 to 2, $P < 0.05$ from d 2 to 3 and $P < 0.01$ from d 2 to 7). Concentrations in group G did not change significantly on d 1 and 2, but increased ($P < 0.01$) from d 2 to 3 and from d 3 to 4 ($P < 0.05$) and then did not change until d 7. Concentrations in group W increased ($P < 0.05$) from d 1 to 2, and from d 3 to 7 tended to be higher ($P < 0.1$) than on d 2. From d 2 to 7, concentrations in group C were higher ($P < 0.05$) than in groups G and W.

Saturated, total (n-3), total (n-6), total (n-7) and total (n-9) fatty acid concentrations in plasma triglycerides on d 7 in group C were higher ($P < 0.05$) than in groups G and W, but did not differ in groups G and W (**Table 1**). Relative amounts (mol/100 mol) of fatty acids in triglyerides in the three groups did not differ (not shown). Concentrations of saturated, total (n-3) and total (n-6) fatty acids in plasma phospholipids on d 7 were higher ($P < 0.05$) and those of total (n-7) and total (n-9) fatty acids tended to be higher ($P < 0.1$) in group C than in groups G and W, but did not differ in group G and W. Relative amounts (mol/100 mol) of total (n-9) fatty acids in phospholipids were lower ($P < 0.05$) in group C than in groups G and W, whereas relative amounts (mol/100 mol) of saturated, total (n-3) and total (n-7) fatty acids in the three groups were not different (not shown). Concentrations of saturated, total (n- 3) and total (n-6) fatty acids in plasma cholesterol esters on d 7 were significantly higher ($P < 0.05$), and those of (n-7) and (n-9) fatty acids tended to be higher ($P <$

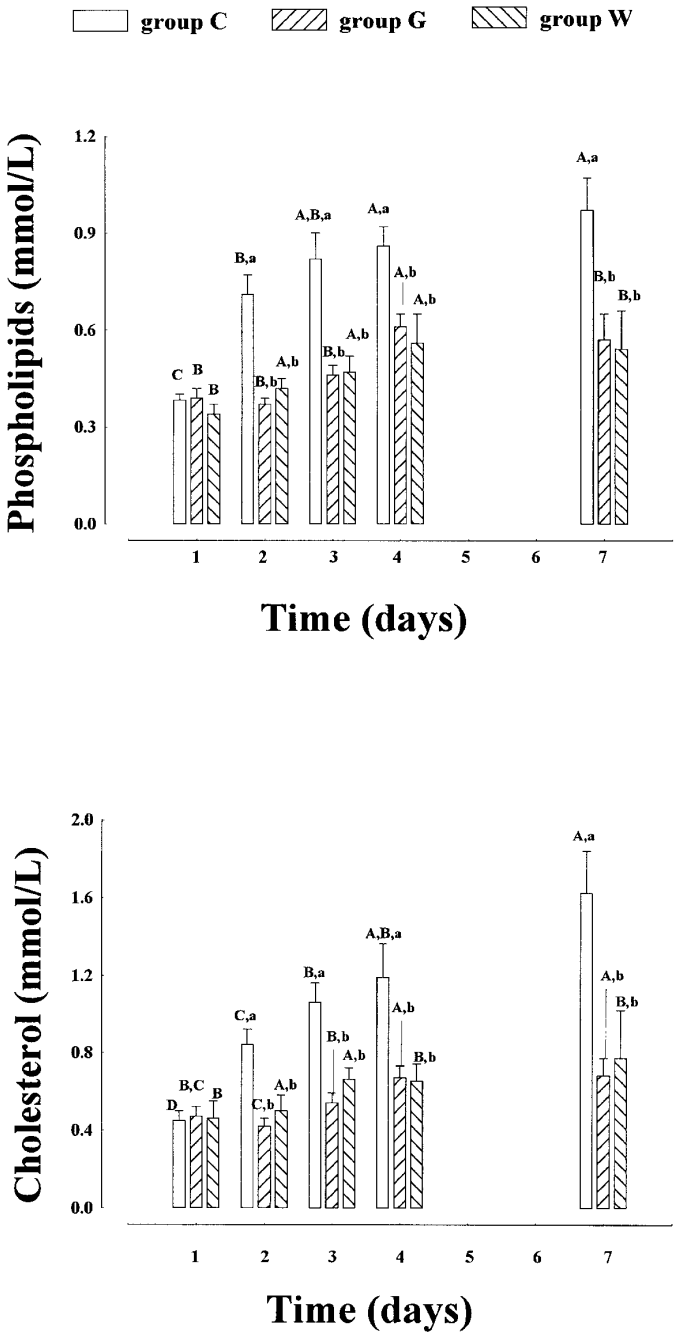

FIGURE 2 Plasma phospholipid and cholesterol concentrations in calves of groups C (control), G (glucose) and W (water) on d 1, 2, 3, 4 and 7 of life. Data are means ± SEM, $n = 7$ per group. Group C was fed colostrum twice daily on d 1 (milkings 1 and 2) and on d 2 (milkings 3 and 4), then milk up to d 7. Group G was fed glucose twice on d 1, whereas group W was fed water twice on d 1, then both groups were twice daily fed colostrum on d 2 (milkings 1 and 2) and on d 3 (milkings 3 and 4) and milk twice daily up to d 7. Means without common uppercase letters (A, B, C) are significantly different ($P < 0.05$) within a group on d 1, 2, 3, 4 and 7. Means without common lowercase letters (a, b) are significantly different ($P < 0.05$) between groups on d 1, 2, 3, 4 or 7.

0.1) in group C than in groups G and W, but were not different in groups G and W. Relative amounts (mol/100 mol) of saturated, (n-7) and (n-9) fatty acids in cholesterol esters were lower ($P < 0.05$), whereas relative amounts (mol/100 mol) of (n-3) and (n-6) fatty acids were higher ($P < 0.05$) in group C than in groups G and W (not shown). If triglycerides, phospholipids and cholesterol ester fractions were taken together, fatty acid concentrations of the (n-3), (n-6), (n-7) and (n-9) series and levels of saturated as well as of unsaturated fatty acids (including essential fatty acids, i.e., linoleic, linolenic and arachidonic acids) were higher ($P < 0.05$) in group C than in groups G and W, but did not differ in groups G and W.

Carotene plasma concentrations (**Fig. 3**A) markedly increased ($P < 0.01$) in group C on d 1 ($P < 0.05$ at 7 h after the first meal; not shown) up to d 2 and then remained elevated until d 7. Concentrations in group G did not change significantly on d 1, increased on d 2, were higher on d 3 and 4 ($P < 0.05$) than on d 1 and 2 and were not different than levels on other days on d 7. Concentrations in group W did not change significantly on d 1, increased ($P < 0.05$) on d 2, were higher on d 3 and 4 ($P < 0.05$) than on d 1 and were not different than levels on other days on d 7. Concentrations in group C were higher ($P < 0.05$) than in groups G and W on d 2, 3, 4 and d 7.

Retinol plasma concentrations (Fig. 3B) markedly increased ($P < 0.001$) in group C on d 1 ($P < 0.05$ at 7 h after the first meal; not shown) and then remained elevated until d 7. Concentrations in group G did not change significantly on d 1, increased ($P < 0.01$) on d 2, and from d 3 to d 7 were higher ($P < 0.05$) than on d 1 and 2. Concentrations in group W decreased ($P < 0.05$) on d 1 ($P < 0.05$ at 7 h after the first meal; not shown), increased on d 2 ($P < 0.05$ at 7 h after the first meal; not shown) up to d 3 ($P < 0.01$) and then remained elevated. Concentrations in group C were higher than in the other groups on d 2 ($P < 0.001$) and d 3 ($P < 0.01$) and were higher on d 7 ($P < 0.01$) than in group W and tended to be higher ($P < 0.1$) than in group G.

α-Tocopherol plasma concentrations (Fig. 3C) markedly increased ($P < 0.05$) in group C from d 1 to 2, remained elevated on d 3 and 4, but tended to be higher ($P < 0.1$) on d 7 than on d 1. Concentrations in group G did not change significantly during the study. Concentrations in group W increased ($P < 0.05$) from d 1 to 2 and then remained elevated. Concentrations in group C were higher ($P < 0.05$) than in groups G and W on d 2, 3, 4 and 7.

Vitamin B-6 plasma concentrations from immediately before the first feeding on d 1 (17 ± 5, 12 ± 3 and 9 ± 2 nmol/L in groups C, G and W, respectively) were slightly higher ($P < 0.05$) than on d 2 (9 ± 1, 9 ± 3 and 8 ± 1 nmol/L in groups C, G and W, respectively), but much higher ($P < 0.001$) on d 7 (36 ± 9, 35 ± 8 and 32 ± 9 nmol/L in groups C, G and W, respectively) than on d 1 and 2. There were no significant differences among groups.

Vitamin B-12 plasma concentrations from immediately before the first feeding on d 1 (0.94 ± 0.04, 0.94 ± 0.11 and 1.45 ± 0.47 nmol/L in groups C, G and W, respectively) and on d 2 (1.17 ± 0.16, 0.62 ± 0.15 and 0.70 ± 0.14 nmol/L in groups C, G and W, respectively) were not different, but were lower ($P < 0.02$) on d 7 (0.70 ± 0.11, 0.48 ± 0.08 and 0.69 ± 0.12 nmol/L, respectively) than on d 1 and 2. Concentrations were higher ($P < 0.05$) on d 2 in group C than in groups G and W.

Folic acid plasma concentrations from immediately before the first feeding on d 1 (27 ± 3, 21 ± 1 and 29 ± 5 nmol/L in groups C, G and W, respectively) and on d 2 (23 ± 3, 24 ± 3 and 26 ± 3 nmol/L in groups C, G and W, respectively) were not different, but were lower ($P < 0.05$) on d 7 (17 ± 1, 18 ± 3 and 15 ± 1 nmol/L in groups C, G and W, respectively) than on d 1 and 2. There were no significant differences among groups.

TABLE 1

Plasma fatty acid concentrations in blood plasma triglyceride, phospholipid and cholesterol ester fractions in 7-d old calves receiving three different diets[1]

	Fatty acids in triglycerides			Fatty acids in phospholipids			Fatty acids in cholesterol esters		
Group	C	G	W	C	G	W	C	G	W
				mmol/L					
Fatty acids									
14:0	64.8 ± 20.7^{A}	19.3 ± 3.5^{B}	20.7 ± 4.5^{B}	25.2 ± 4.0^{A}	16.1 ± 1.3^{B}	20.2 ± 2.2^{AB}	39.1 ± 13.0^{A}	15.7 ± 1.3^{B}	18.4 ± 5.4^{AB}
16:0	228.9 ± 69.0^{A}	76.4 ± 9.7^{B}	82.3 ± 12.9^{B}	470.4 ± 58.5^{A}	266.0 ± 30.8^{B}	279.2 ± 46.8^{B}	138.1 ± 26.1^{A}	75.6 ± 3.5^{B}	71.0 ± 14.4^{AB}
18:0	65.0 ± 15.1^{A}	27.1 ± 4.2^{B}	26.4 ± 3.5^{B}	525.8 ± 113.9^{A}	285.1 ± 26.4^{B}	291.0 ± 53.4^{B}	14.0 ± 2.1	10.2 ± 0.7	13.7 ± 2.5
Total saturated	366.1 ± 104.1^{A}	128.2 ± 15.4^{B}	136.8 ± 20.8^{B}	1067.2 ± 170.7^{A}	593.0 ± 61.6^{B}	631.6 ± 116.0^{B}	214.7 ± 46.6^{A}	112.1 ± 6.8^{B}	114.5 ± 24.3^{B}
18:3 (n-3)	24.8 ± 3.6^{A}	13.3 ± 1.1^{B}	15.4 ± 2.5^{B}	52.1 ± 11.5^{A}	20.5 ± 3.6^{B}	21.2 ± 5.0^{B}	219.4 ± 60.4^{A}	56.8 ± 10.1^{B}	71.2 ± 32.7^{B}
20:5 (n-3)	—	—	—	16.9 ± 2.0^{A}	9.6 ± 0.7^{B}	10.9 ± 1.6^{B}	—	—	—
22:6 (n-3)	—	—	—	13.1 ± 1.2	11.9 ± 0.9	11.6 ± 1.8	—	—	—
Total (n-3)	24.8 ± 3.6^{A}	13.3 ± 1.1^{B}	15.4 ± 2.5^{B}	106.9 ± 14.6^{A}	55.0 ± 5.9^{B}	57.3 ± 8.8^{B}	219.4 ± 60.4^{A}	56.8 ± 10.1^{B}	71.2 ± 32.7^{B}
18:2 (n-6)	21.4 ± 3.2^{A}	10.0 ± 1.8^{B}	12.1 ± 2.8^{B}	216.4 ± 41.4^{A}	93.2 ± 25.0^{B}	92.8 ± 32.1^{B}	467.1 ± 91.8^{A}	134.6 ± 28.9^{B}	147.1 ± 61.4^{B}
18:3 (n-6)	1.4 ± 0.3^{A}	0.7 ± 0.1^{B}	0.7 ± 0.1^{B}	6.1 ± 0.4	5.4 ± 0.1	6.8 ± 1.4	7.9 ± 2.9	5.0 ± 2.1	7.9 ± 6.1
20:3 (n-6)	—	—	—	31.0 ± 4.9^{A}	17.0 ± 2.0^{B}	16.0 ± 3.6^{B}	4.6 ± 1.0^{A}	2.3 ± 0.3^{B}	2.6 ± 0.3^{B}
20:4 (n-6)	—	—	—	46.0 ± 6.9^{A}	23.3 ± 4.3^{B}	21.7 ± 5.9^{B}	22.0 ± 4.3^{A}	10.5 ± 1.0^{B}	10.8 ± 3.3^{B}
Total (n-6)	28.8 ± 3.2^{A}	10.7 ± 2.8^{B}	12.8 ± 2.8^{B}	302.4 ± 51.6^{A}	140.8 ± 31.0^{B}	138.9 ± 45.0^{B}	501.6 ± 98.5^{A}	152.4 ± 29.5^{B}	168.4 ± 64.2^{B}
Total (n-7)	24.3 ± 6.6^{A}	10.8 ± 1.8^{B}	10.5 ± 1.1^{B}	64.9 ± 4.7	52.3 ± 7.6	45.5 ± 13.1	75.1 ± 21.6	38.5 ± 1.5	40.3 ± 9.5
C18:1 (n-9)	161.7 ± 33.7^{A}	70.9 ± 13.8^{B}	73.0 ± 10.6^{B}	456.0 ± 54.2^{A}	317.4 ± 41.4^{AB}	302.1 ± 47.2^{B}	143.3 ± 29.1^{A}	86.2 ± 4.6^{B}	94.0 ± 17.4^{AB}
Total (n-9)	184.6 ± 35.9^{A}	85.0 ± 14.3^{B}	89.4 ± 11.0^{B}	524.2 ± 57.5^{A}	362.6 ± 43.0^{B}	360.9 ± 50.4^{B}	147.2 ± 29.3^{A}	89.7 ± 4.6^{B}	98.1 ± 17.7^{AB}

[1] Data are means ± SEM, $n = 7$ per group. Group C was fed colostrum twice daily on d 1 (milkings 1 and 2) and on d 2 (milkings 3 and 4), then milk up to d 7. Group G was fed glucose twice on d 1, whereas group W was fed water twice on d 1, then both groups were fed colostrum twice daily on d 2 (milkings 1 and 2) and on d 3 (milkings 3 and 4) and milk twice daily up to d 7. Blood samples were taken preprandially (before first feedings on d 1, 2 and 7 of life).^{A,B} Means without common letters are significantly different within groups between ($P < 0.05$) within triglyceride, phospholipid and cholesterol ester fractions.

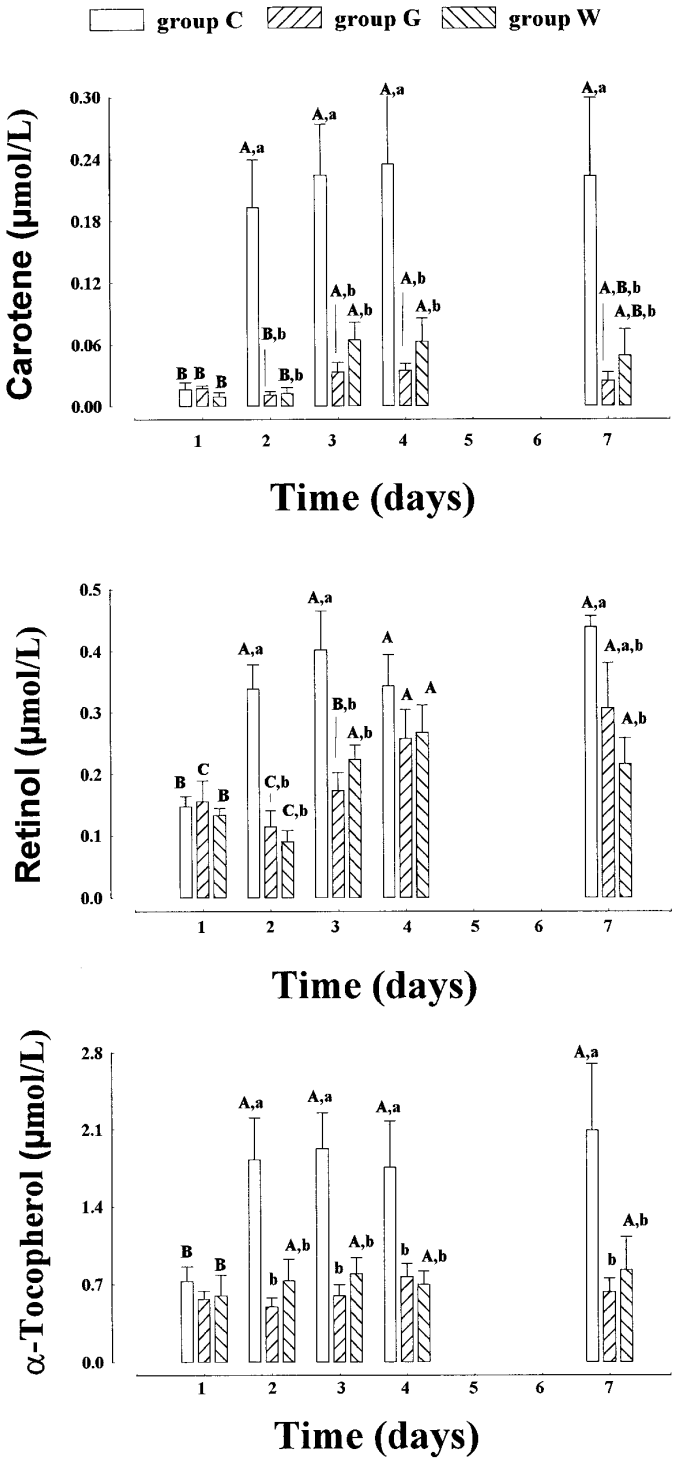

FIGURE 3 Carotene, retinol and α-tocopherol concentrations on d 1, 2, 3, 4 and 7 of life. Data are means ± SEM, $n = 7$ per group. For details, see legend to Figure 2.

DISCUSSION

As described by Hadorn et al. (1997), significantly higher plasma nonesterified fatty acid concentrations in calves of the same experiment, fed only water instead of colostrum on d 1, mirrored reduced energy intake, whereas levels transiently decreased after glucose feeding. These data indicated that fat metabolism in newborn calves is affected immediately after birth and basically as in mature cattle.

A rise of plasma triglycerides, phospholipids and cholesterol and of individual (saturated, unsaturated, essential and nonessential) fatty acids in triglyceride, phospholipid and cholesterol ester fractions in calves of group C was the result of the high fat intake by ingestion of colostrum (Leat 1967). In our study, changes of triglycerides, phospholipids and cholesterol and of fatty acids in these fractions were similar in groups G and W, but were greatly different in these groups from levels in group C, indicating marked effects on fat metabolism of feeding on d 1. Effects of feeding colostrum on d 1 were very different from those seen on d 2 and, most importantly, in calves not fed colostrum on d 1, there was a relative deficiency of essential fatty acids. There is evidence that diets differing in fat and cholesterol composition given in early life can have lasting effects on fat absorption and intermediary lipid metabolism (Coates et al. 1983, Kris-Etherton et al. 1979, Mott et al. 1990, Thomson et al. 1993).

Lipid absorption is complex and includes a luminal phase (digestion), a mucosal phase (uptake and lipoprotein formation, possibly involving biotransformation, catabolism and vesicular transport) and a secretory phase (delivery of fatty acids into blood and of lipoprotein vesicular particles into lymphatic vesicles) (Thomson and Ditschy 1981). If colostrum is not provided on d 1 of life, a defect in one or several of these steps may have been responsible for low lipid and fatty acid levels. Reduced lipase activity is a major cause of insufficient lipid absorption in neonates. This would involve pregastric (lingual) lipase because pancreatic lipase activity in neonatal calves is low (Widdowson 1984). Functional maturity of the liver, including bile acid availability, is essential for fatty acid absorption. On the basis of plasma bile acid concentration, measured in the same calves, a defect in liver function and an abnormal bile acid metabolism in calves of groups G and W was unlikely (Hadorn et al. 1997). However, the content of fatty acid binding protein, which is associated with fatty acid absorption, in the small gut of calves not fed colostrum on d 1 of life was possibly reduced, similar to the effect in colostrum-deprived pigs (Reinhart et al. 1992). Colostrum intake enhances the synthesis of specific proteins in the small intestine (Burrin et al. 1992), including possibly the fatty acid binding proteins as well. In addition, modified intermediary metabolism of fatty acids in calves not fed colostrum may contribute to low circulating fatty acids and lipid levels.

Newborn calves contain low levels of β-carotene, retinol and α-tocopherol in their tissues and blood plasma because of a very limited placental transfer from the dam to the fetus (Bondi 1987, Hidiroglou 1989, Kumagai et al. 1994). Mammary transfer and/or supplementation of neonatal calves with β-carotene, retinol and α-tocopherol is necessary for proper metabolic and immune functions (Eicher et al. 1994, Hidiroglou 1989). Because concentrations of β-carotene, retinol and α-tocopherol decrease from the first to the fourth milked colostrum sample to relatively low concentrations in mature milk in dairy cows (Ferrando and Fourlon 1979, Hidiroglou 1989), intake particularly of the first colostrum is very important to improve the status of these vitamins in neonatal calves (Kumagai et al. 1994). Our study shows that carotene, retinol and α-tocopherol levels increased much less and remained significantly lower up to d 7 in calves provided only water or glucose than in those fed colostrum on d 1. Thus there were marked differences between calves fed colostrum starting on d 1 or 2. To the best of our knowledge, these are the first results indicating that an optimal status dependent on colostrum-borne vitamins is dependent on time after birth and that colostrum should therefore be provided within the first 24 h of life. The data indicate that providing only glucose or water on d 1

reduced the calves' plasma concentration of carotene, retinol and α-tocopherol. Whether this can be compensated after the first week of life, i.e., is only a transient effect, has to be investigated. For β-carotene and various cartenoids, rapid absorption has been demonstrated in liquid-fed calves (Bierer et al. 1995, Poor et al. 1992;).

Fat-soluble vitamins are absorbed by mechanisms similar to those for fatty acids (Cohn et al. 1992). The hypothesis is advanced that colostrum intake on d 1 is very important for the establishment of absorptive mechanisms, allowing intestinal transport not only of proteins and peptides but also of fatty acids and fat-soluble vitamins. Intestinal effects may be directly mediated by a factor or by factors contained in colostrum or indirectly by endocrine changes induced by colostrum intake. β-Lactoglobulin, present in high concentrations in colostrum, may be particularly important for intestinal uptake of retinol in neonatal calves (Papiz et al. 1986). Effects on various aspects of intermediary vitamin metabolism, such as on transport proteins, cannot be excluded, however. To what extent carotenes are transformed into retinol is unknown as well but is of importance because the conversion in calves takes place only in the intestinal mucosa (Bondi 1987).

Concentrations of vitamin B-6, vitamin B-12 and of folic acid were selected as representatives of B-vitamins to compare their behavior with that of fat-soluble vitamins. Although some B-vitamins (thiamine, riboflavin, niacin) are in a higher concentration in colostrum than in mature milk (Bondi 1987), it is not known if this was the case for vitamin B-6, vitamin B-12 and folic acid and to what extent colostrum and milk intake contributed to changes in plasma concentrations in our study. On the basis of the close interrelationships between vitamin B-12 and folic acid metabolism, it is important to note that concentrations moved in similar directions in our calves. Because there were no significant differences in concentrations of the three B-vitamins among the three groups provided colostrum, glucose or water on d 1 of life, colostrum intake on d 1 of life did not modify the status of these three vitamins, in marked contrast to fat-soluble vitamins. Vitamin B-6 behaved similarly to fat-soluble vitamins, but very differently than vitamin B-12 and folic acid because its concentrations were higher on d 7 than on d 1. However, differences in feeding immediately after birth did not have an influence on vitamin B-6 levels, in contrast to fat-soluble vitamins.

In conclusion, intake of colostrum instead of glucose or water on d 1 of life had effects not only on nonesterified fatty acids (Hadorn and Blum 1994), but also on triglycerides, phospholipids and cholesterol. Furthermore, carotene, retinol and α-tocopherol were significantly affected if colostrum feeding was delayed by 1 d. Differences in plasma triglycerides, phospholipids, cholesterol, essential and nonessential fatty acids acids, carotene, retinol and α-tocopherol lasted up to d 7. Additional studies are necessary to test whether effects are permanent or of only a transient nature.

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