Growth performance, metabolic and endocrine traits, and absorptive capacity in neonatal calves fed either colostrum or milk replacer at two levels

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ABSTRACT: Colostrum (CO) contains high amounts, whereas whole milk and milk replacer (MR) contain small amounts, of bioactive and growth-promoting substances, such as IGF-I. An experiment was designed to study the effects of feeding CO or MR on the first 3 d to neonatal calves, followed by whole milk up to d 7, at low and high density. Intestinal absorptive capacity, plasma metabolite and hormone concentrations, and growth performance were measured during the 1st wk of life. Body weight increased (P < .05) similarly in calves fed low or high amounts of CO but did not rise in MR-fed calves. Loose feces were more frequent (P < .05) and absorption of xylose on d 5 was lower (P < .01) in MR- than in CO-fed calves, but there were no effects of feeding density within CO-fed or within MR-fed groups. However, high feeding density within CO-fed groups enhanced (P < .05) total protein, globulin, triglyceride, cholesterol, and insulin concentrations, whereas in the initially high and low MR-fed groups only plasma glucose and insulin after the first meal and plasma NEFA on d 2 were modified (P < .05) by different feeding density. Thus, feeding different amounts of CO partly influenced protein and fat metabolism in calves during the 1st wk of life, but it did not measurably affect intestinal function. However, feeding different amounts of MR, in the absence of CO, barely affected metabolic and endocrine traits and absorptive capacity. Thus, high density CO feeding, and therefore a high supply of nutrients, together with greater amounts of bioactive and growth-promoting substances influenced neonatal metabolism and growth more than a high density of MR feeding containing only small amounts of bioactive and growth-promoting substances. Factors in addition to nutrient density seem to be important for the development of neonatal calves.

Key Words: Newborn Animals, Colostrum, Milk Substitutes

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Introduction

Newborns must adapt to a new environment, including nutrition. Except for casein and lactose, colostrum (CO) contains nutrients as well as bioactive and growth-promoting substances in higher amounts than does milk replacer (MR) and whole milk (Koldovsky, 1989; Campana and Baumrucker, 1995). Bovine CO is especially rich in IGF-I, IGF-II, insulin, and prolactin (Ronge and Blum, 1988; Campana and Baumrucker, 1995). Components of CO enhance gastrointestinal (GI) tract proliferation, differentiation, digestive and absorptive capacity, and influence immune status, metabolism, and endocrine systems in newborn animals (Koldovsky, 1989; Simmen et al., 1990; Burrin et al., 1995; Xu, 1996; Le Dividich et al., 1997), as recently reviewed for calves (Guilloteau et al., 1997; Hammon and Blum, 1998a). Our aim for this study was to test the hypothesis that metabolic and endocrine traits and intestinal absorptive capacity of calves during their 1st wk of life are affected by two levels of CO feeding and two levels of MR feeding in the same way.

Materials and Methods

Animals and Husbandry

Newborn male calves (16 Simmental × Red Holstein, 3 Holstein Friesian, 1 Holstein Friesian × Limousine, and 4 Braunvieh × Brown Swiss) born between January and May 1997 were studied. They originated from the Swiss Federal Research Station of Animal Production, Posieux, and in part from farmers in the neighborhood of the experimental station. Calves were born as singles from cows with pregnancies of normal length. They were separated from their dams at birth and housed individually in pens for 7 d. Their BW were recorded immediately after birth and on d 7. Calves were randomly assigned to four groups, each consisting of six...
animals with initial BW of 43.8 ± 1.8, 46.2 ± .6, 46.5 ± 1.1 and 48.0 ± 2.6 kg, respectively.

Experimental Procedures

Experimental procedures were approved by the committee for animal experiments of the Canton of Freiburg, Granges-Paccot, Switzerland.

Feeding. During the first 3 d of life, CO (milking 1 to 6, respectively) was fed twice/24 h (at 12-h intervals) at a high level (group HF_C) and at a low level (group LF_C), and a commercial MR was fed twice/24 h (at 12-h intervals) at a high level (group HF_MR) and at a low level (group LF_MR). Starting with the seventh feeding (d 4 of life), all calves were fed whole milk at 0730 and 1630 daily. Calves of intensively fed groups (groups HF_C and HF_MR) received 2 × 1.75 L on d 1, 2 × 2.3 L on d 2, and 2 × 2.6 L on d 3 of CO or MR (100 g/L), respectively, and groups LF_C and LF_MR received 2 × 1.25 L on d 1, 2 × 1.7 L on d 2, and 2 × 1.9 L on d 3 of CO or MR (100 g/L), respectively. These volumes were provided to calves with an average BW of 45 kg. For calves with a BW different from 45 kg, volumes were adjusted (± 50, 65, or 75 mL of CO or MR/kg BW difference on d 1, 2, and 3, respectively). Whole milk was fed in amounts of 55 mL/kg BW to groups HF_C and HF_MR and in amounts of 43 mL/kg BW to groups LF_C and LF_MR twice daily. Water was added to CO, MR, and whole milk to reduce nutrient densities in calves fed at low levels (groups LF_C and LF_MR). Thus, low and high intensively fed calves were provided the same liquid volumes. For the first six meals feeding was by bottle, then by bucket using a nipple. Milk intake was recorded daily. From d 4 on, calves had free access to water. On d 5 of life, each calf was administered .5 g D-xylose/kg BW with the morning milk.

Cows were milked twice/24 h. The CO was from separate pools for milkings 1 to 6 (first 3 d of lactation) that were prepared before the study was started and stored in plastic bottles at −20°C. Before feeding, the CO was warmed to 40°C. The MR (UFA-100 without antibiotics) was from UFA AG, Sursee, Switzerland. Whole milk was from the milk pool derived from the 60 to 70 cows of the research station. Contents of DM, GE, crude protein (CP), crude fat or lipids (CL), inorganic matter, nitrogen-free extracts (NFE) and IgF-I of CO, milk, and MR are shown in Table 1.

All calves were injected s.c. with immunoglobulins (20 mL of Gammaserin, containing 100 g immunoglobulin G/L, purchased from Dr. E. Gräub AG, Berne, Switzerland) after the first blood sample. The CO-deprived calves were prophylactically treated against bacterial infections with Baytril (Bayer AG, Leverkusen, Germany) for the first 4 d (2 mL/40 kg BW s.c. once daily) and they were fed immunoglobulins (100 mL Serimun, containing 100 g bovine immunoglobulins of colostral origin/L, donated by Lohmann Animal Health GmbH & Co., Cuxhaven, Germany) with the first meal. From the third meal on, CO-deprived calves were fed Globigen 88 (containing 20 g chicken egg-derived immunoglobulins/kg, with high antibody titers against Escherichia coli type ETTEC, K99, and rota virus; kindly provided by Lohmann Animal Health GmbH & Co. KG) together with MR or milk (2 × 10 g on d 2, 2 × 8 g on d 3, 2 × 6 g on d 4, 2 × 4 g on d 5, 2 × 2 g on d 6, and 2 × 2 g on d 7).

Health Status. The health status of the calves was evaluated daily. Clinical examinations were scored. They included behavior (scores 0, 1, and 2 for attentive, exhausted, and apathic, respectively), rectal temperature (scores 0, 1, and 2 for 38.5 to 39.5, 39.6 to 39.9, and >40°C, respectively), heart rate (scores 0 and 1 for 90 to 110 and >110 beats/min, respectively), respiratory rate (scores 0 and 1 for 30 to 45 and >45 respirations/min, respectively), pulmonary sounds (scores 0, 1, and 2 for none, light, and distinct, respectively), coughing (scores 0, 1, and 2 for none, superficial, and deep or frequent, respectively), nasal discharge (scores 0, 1, and 2 for none, serous, and mucopurulent, respectively), eye discharge (scores 0 and 1 for none and present, respectively), fecal consistency (scores 0, 1, and 2 for normal, thin, and watery, respectively), appetite (scores 0, 1, and 2 for <10%, 10 to 80% and >80% rests of CO, MR, or milk, respectively), and navel infection (scores 0 and 1 for normal and inflamed, respectively). The sum of all scores was defined as disease index and was a measure of the health status (maximal score = 18).

Blood Samples. The first blood samples in groups HF_C, LF_C, HF_MR, and LF_MR were taken at 3.0, 3.25, 3.75, and 4.7 h after birth. Samples were obtained on d 1 before the first meal and at 2 h, 4 h, and 7 h after the first meal and before the second meal (12 h after first feed meal), on d 2, 3, 4, and 5 before feedings (i.e., at 24, 48, 72, and 96 h after the first meal, respectively), and on d 7 (i.e., at 144 h after the first meal) before the morning meal and 2 h after that meal. On d 5, samples were taken before and 4 h after xylose feeding.

Blood samples were taken from the jugular vein using evacuated tubes containing anticoagulants (1.8 g potassium-EDTA/L blood) and were cooled on ice before they were centrifuged at 1,000 × g for 20 min at 4°C. After centrifugation, the supernatants were partitioned into aliquots and stored at −20°C until they were analyzed. For the determination of hemoglobin (Hb), a small quantity of blood from the samples was used before the rest was centrifuged. Plasma was used for the determination of albumin, total protein, urea, triglycerides, cholesterol, glucose, NEFA, IgF-I, GH, insulin, glucagon, cortisol, 3,3′,5-triiodothyronine (T3), thyroxine (T4), and xylose. Samples of the pools of the first six milkings were stored at −20°C until they were analyzed.

Laboratory Analyses

Blood Analyses. Hemoglobin was determined as described by Hadorn et al. (1997). Protein, urea, triglycer-
Statistical Analyses

On d 1, after subtraction of prefeeding values, areas under the concentration curves from 0 to 7 h postprandially were calculated as measures of incremental or decremental changes (Δ0 to 7 h) after the first feed intake. Incremental or decremental changes within 2 h after feed intake (Δ2 h) were calculated after the first feed intake and after the morning meal on d 7. Incremental or decremental changes were also computed for changes at 12 h after the first feed intake (Δ12 h). Prefeeding values before the first, third, and fifth meal, as well as values before morning feedings on d 4, 5, and 7, are defined as basal values. Values are presented as means ± SEM.

For statistical evaluations, the SAS program package release 6.11 (SAS, 1993) was used. Group (treatment) and time effects on basal values were calculated using the repeated measurements analysis of variance (GLM procedure). Differences between treatments were localized with Bonferroni’s t-tests. If time effects were significant (P < .05) in the repeated measurement model within groups, changes of basal values were tested for significance by the GLM procedure, in which effects of the individual calf and time were considered.

All Δ0 to 7 h, Δ2 h, and Δ12 h values were also compared between groups with the GLM procedure, in which effects of treatment (group) and of the individual calf were considered. Differences between treatments were localized with Bonferroni’s t-tests. Within groups Δ0 to 7 h, Δ2 h, and Δ12 h values on d 1 as well as Δ2 h values on d 7 were tested for significance (P < .05) with paired t-tests. The significance of difference of Δ2 h responses on d 1 and 7 was furthermore evaluated with paired t-tests.

Results

Growth Performance and Feeding

Intakes of DM per kilogram BW for feedings 1 to 6 and for the average of feedings 7 to 13 are shown in

Table 1. Composition of colostrum, milk, and milk replacer

<table>
<thead>
<tr>
<th>Item</th>
<th>Colostrum</th>
<th>Milk replacer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter (DM), g/kg</td>
<td>Milking 1</td>
<td>122 ± 50</td>
</tr>
<tr>
<td></td>
<td>Milking 2</td>
<td>155 ± 50</td>
</tr>
<tr>
<td></td>
<td>Milking 3</td>
<td>154 ± 50</td>
</tr>
<tr>
<td></td>
<td>Milking 4</td>
<td>153 ± 50</td>
</tr>
<tr>
<td></td>
<td>Milking 5</td>
<td>153 ± 50</td>
</tr>
<tr>
<td></td>
<td>Milking 6</td>
<td>153 ± 50</td>
</tr>
<tr>
<td>Gross energy, MJ/kg DM</td>
<td>25.16</td>
<td>23.4 ± 18.3</td>
</tr>
<tr>
<td>Crude protein, g/kg DM</td>
<td>550</td>
<td>274 ± 220</td>
</tr>
<tr>
<td>Crude fat, g/kg DM</td>
<td>256</td>
<td>273 ± 210</td>
</tr>
<tr>
<td>Inorganic matter, g/kg DM</td>
<td>48</td>
<td>56 ± 188</td>
</tr>
<tr>
<td>Nitrogen-free extract, g/kg DM</td>
<td>146</td>
<td>397 ± 450</td>
</tr>
<tr>
<td>IGF-I, µg/kg DM</td>
<td>1275</td>
<td>≤20 ± 20</td>
</tr>
</tbody>
</table>

*Milking 1 to 6 were individual pools, respectively, prepared before the study was started.

*Milk was from a pool of 70 cows.

*Composition of milk replacer was as follows: 55% skim milk powder, 4% whey, 17.2% corn products (dextrose, glucose, oat cream, starch), 14.5% bovine fat, 4.4% swine fat, 1.9% lecithin/emulgator, 2% minerals, 1% tracer elements and vitamins.

*Nitrogen free extract contains 71% lactose.
Respiratory rates did not change significantly during the 7-d study, and there were no significant differences in rectal temperature, heart rate, respiratory rate, and health status. On d 4, fecal scores in groups HF MR were higher (P < .05) than in groups HFC and LFC, and was greater (P < .05) in group LF C than in group LF MR. The BW gain/GE intakes and BW gain/DM intake were higher (P < .05) in group HFC than in MR-fed groups. The d-7 glucocorticoid concentrations were highest (P < .05) in group HFC from d 4 to d 7, higher (P < .05) in group LF C than in MR-fed groups from d 4 to d 6, and higher (P < .05) in group LF C than HF MR on d 7. Globulin concentrations from d 2 to d 6 were higher in all groups within 12 h after the first meal and then remained elevated, but they did not change in the MR-fed calves during 1st wk of life (Table 2). Total protein concentrations on d 2 and 3 were higher (P < .05) in group HFC than in MR-fed groups and were higher (P < .05) in group LF C than in group HF MR. Protein concentrations were highest (P < .05) in group HFC from d 4 to d 7, higher (P < .05) in group LF C than in MR-fed groups from d 4 to d 6, and higher (P < .05) in group LF C than HF MR on d 7. Globulin concentrations from d 2 to d 6 were higher in all groups within 12 h after the first feeding and then decreased more slowly until d 7 (means for all groups 114 ± 10 beats/min), intermediate (mean for all groups: 112 ± 4 beats/min), whereas heart rates were similar at birth in all groups, values on d 7 were highest in group HFC (131 ± 10 beats/min), intermediate in groups LF C and HF MR (115 ± 8 and 105 ± 9 beats/min, respectively), and lowest in group LF MR (98 ± 2 beats/min). Respiratory rates did not change significantly during the 7-d study, and there were no significant group differences (means for all groups: 59 ± 5 and 55 ± 3 respirations/min on d 1 and 7, respectively).

Table 2. Growth performance, weight gain, and feed utilization in calves fed high (HFC) or low (LF C) amounts of colostrum and high (HF MR) or low (LF MR) amounts of milk replacer on the first 3 d.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Group HFC</th>
<th>Group LF C</th>
<th>Group HF MR</th>
<th>Group LF MR</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW at birth, kg</td>
<td>43.8 ± 1.83</td>
<td>46.2 ± 6</td>
<td>46.5 ± 1.1</td>
<td>48.0 ± 2.6</td>
</tr>
<tr>
<td>BW gain d 0–d 7, kg</td>
<td>3.47 ± .61ab</td>
<td>1.78 ± .46ab</td>
<td>.72 ± .64bc</td>
<td>−.67 ± .56c</td>
</tr>
<tr>
<td>BW gain/DM intake, kg/kg</td>
<td>.83 ± .13a</td>
<td>.55 ± .14a</td>
<td>.19 ± .20ab</td>
<td>−.23 ± .21b</td>
</tr>
<tr>
<td>BW gain/GE intake, g/MJ</td>
<td>34.4 ± 5.4</td>
<td>22.8 ± 6.0a</td>
<td>8.9 ± 9.5ab</td>
<td>−10.7 ± 9.9b</td>
</tr>
</tbody>
</table>

Values with different letters within a row are different (P < .05) between groups.
Values are different (P < .05) from d 0.
Table 4. Means ± SEM (n = 6) for blood plasma concentrations of total protein, globulins, albumin, urea, glucose, nonesterified fatty acids (NEFA), growth hormone (GH), and insulin-like growth factor I (IGF-I) in calves fed high (HF C) or low (LF C) amounts of colostrum and high (HF MR) or low (LF MR) amounts of milk replacer on the first d (n.m. = not measured)

<table>
<thead>
<tr>
<th>Trait and group</th>
<th>Basal level</th>
<th>Δc-7 h after feed intake</th>
<th>Day 2, basal level</th>
<th>Day 3, basal level</th>
<th>Day 4, basal level</th>
<th>Day 5, basal level</th>
<th>Day 7, basal level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total protein, g/L</td>
<td>40.6 ± 1.1b</td>
<td>n.m.</td>
<td>49.6 ± 1.3a</td>
<td>52.5 ± 1.2a</td>
<td>53.5 ± 1.2a</td>
<td>54.9 ± 1.3a</td>
<td>54.6 ± 1.3a</td>
</tr>
<tr>
<td>Albumin, g/L</td>
<td>3.6 ± .7a</td>
<td>.8 ± .8</td>
<td>4.2 ± .4a</td>
<td>3.0 ± .2a</td>
<td>2.8 ± .2a</td>
<td>2.7 ± .2b</td>
<td>2.7 ± .3b</td>
</tr>
<tr>
<td>Urea, mmol/L</td>
<td>3.4 ± .5a</td>
<td>.4 ± .5</td>
<td>3.9 ± .5a</td>
<td>2.8 ± .4a</td>
<td>2.5 ± .3a</td>
<td>2.4 ± .3c</td>
<td>2.9 ± .4a</td>
</tr>
<tr>
<td>Glucose, mmol/L</td>
<td>3.5 ± .4a</td>
<td>.1 ± .7</td>
<td>2.2 ± .2b</td>
<td>2.1 ± .5b</td>
<td>3.0 ± .6b</td>
<td>4.1 ± .6b</td>
<td></td>
</tr>
<tr>
<td>NEFA, mmol/L</td>
<td>4.6 ± .5a</td>
<td>7.10 ± 2.71b</td>
<td>6.02 ± 0.3</td>
<td>5.54 ± 0.25</td>
<td>5.39 ± 0.45</td>
<td>5.24 ± 0.76</td>
<td>4.47 ± 0.25</td>
</tr>
<tr>
<td>NH, μg/L</td>
<td>10.5 ± 3.8</td>
<td>81.56 ± 22.4a</td>
<td>12.7 ± 2.7</td>
<td>13.9 ± 3.6B</td>
<td>18.1 ± 3.7BC</td>
<td>10.1 ± 2.4B</td>
<td>14.7 ± 2.9</td>
</tr>
<tr>
<td>IGF-I, μg/L</td>
<td>134.5 ± 15</td>
<td>-21.9 ± 46.6</td>
<td>139.9 ± 13A</td>
<td>103.8 ± 8</td>
<td>137.4 ± 16A</td>
<td>138.0 ± 13A</td>
<td>121.2 ± 14A</td>
</tr>
</tbody>
</table>

*Within metabolic traits or hormones, means with different lowercase letters are different (P < .05) from values before the first meal within groups.

*Within metabolic traits or hormones, means with uncommon uppercase letters within a column are different (P < .05) between groups.

*Mean incremental or decremental changes after feed intake on d 1 are significant (P < .05).
Figure 1. Plasma concentrations of triglycerides in calves fed high (HF\textsubscript{C}, ●) or low (LF\textsubscript{C}, ○) amounts of colostrum and high (HF\textsubscript{MR}, ▲) or low (LF\textsubscript{MR}, △) amounts of milk replacer on the first 3 d of life. Means without common uppercase letters (A, B, C) are different (\(P < .05\)) between groups. For simplicity, only means with significant differences (\(P < .05\)) relative to time 0 (based on variance analysis) are marked with uncommon lowercase letters (a, b).

on d 2 in groups were higher (\(P < .05\)) in CO- than in MR-fed calves.

Plasma glucose concentrations (Table 4) increased (\(P < .05\)) after the first feed intake in MR-fed calves but not in CO-fed calves. From d 1 to 4, basal glucose concentrations increased in CO-fed groups (\(P < .001\)) and then remained elevated, but they did not change significantly in MR-fed groups. The Δ0 to 7 h response was greater (\(P < .05\)) in group HF\textsubscript{MR} than in all other groups. There were no group differences within CO-fed or within the MR-fed groups from d 2 to 7.

Plasma NEFA concentrations (Table 4) decreased (\(P < .05\)) after the first meal in all groups, and the decrease was greater (\(P < .05\)) in group HF\textsubscript{MR} than in group LF\textsubscript{C}. Basal NEFA concentrations decreased during the 1st wk of life in all groups. The d-2 basal concentrations were lower (\(P < .05\)) in group HF\textsubscript{MR} than in group LF\textsubscript{MR} and in group LF\textsubscript{C}. The d-4 basal NEFA concentrations were higher (\(P < .05\)) in group LF\textsubscript{C} than in group HF\textsubscript{MR}. On d 7, NEFA concentrations decreased (\(P < .05\)) within 2 h after the morning meal in MR-fed groups, but they did not change significantly in CO-fed groups. The Δ2 h responses in MR-fed groups were greater (\(P < .01\)) on d 1 than on d 7 but were similar in CO-fed groups.

Plasma triglyceride concentrations (Figure 1) did not change significantly or consistently on d 1 after the first meal and on d 7 after the morning meal. Basal triglyceride concentrations increased (\(P < .1\) for group LF\textsubscript{C} and \(P < .001\) for group HF\textsubscript{C}) from d 1 to 4 in CO-fed groups and then remained elevated in group HF\textsubscript{C} until d 7 but decreased (\(P < .001\)) up to d 7 in group LF\textsubscript{C}. Concentrations in groups HF\textsubscript{MR} and LF\textsubscript{MR} at 12 h after the first meal were lower (\(P < .05\)) than before the first meal. Whereas concentrations in group HF\textsubscript{MR} did not significantly change up to 7 d, concentration in group LF\textsubscript{MR} decreased (\(P < .05\)) from d 1 to 4 and then remained at this concentration up to d 7. Plasma triglyceride concentrations on d 3 were higher (\(P < .05\)) in group HF\textsubscript{C} than in groups HF\textsubscript{MR} and LF\textsubscript{MR} and higher (\(P < .05\)) in group LF\textsubscript{C} than in group LF\textsubscript{MR}. On d 4 were higher (\(P < .05\)) in CO-fed than in MR-fed groups, and on d 5 and 7 were higher (\(P < .01\)) in group HF\textsubscript{C} than in group LF\textsubscript{C} and the MR-fed groups.

Plasma cholesterol concentrations (Figure 2) in CO-fed groups remained stable from d 1 to 2 and then increased (\(P < .001\)) up to d 7 and 5, respectively. In the MR-fed groups, cholesterol concentrations increased (\(P < .01\)) transiently from d 1 to 3 and then decreased (\(P < .05\)) from d 3 to 5. On d 3, concentrations were higher (\(P < .05\)) in group HF\textsubscript{C} than in group LF\textsubscript{MR}, and from d 4 to 7 values in the CO-fed groups were higher (\(P < .01\)) than in the MR-fed groups. On d 7 cholesterol concentrations were higher (\(P < .01\)) in group HF\textsubscript{C} than in group LF\textsubscript{C}.

Plasma insulin concentrations (Figure 3) transiently increased (\(P < .05\)) in groups LF\textsubscript{C}, HF\textsubscript{MR}, and LF\textsubscript{MR}...
within 2 h after intake of the first meal and total incremental changes (Δ0 to 7 h) were significant (P < .05) in all groups. The Δ2 h responses and total incremental changes (Δ0 to 7 h) after the first meal were greater (P < .05) in group HF_MR than in groups HF_C, LF_C, and LF_MR. Preprandial concentrations at 12 h after the first meal were elevated (P < .05) in CO-fed groups, and this increase was greater (P < .05) in group HF_C than in the MR-fed groups and was greater (P < .05) in group LF_C than in group HF_MR. In group HF_C concentrations were still higher (P < .05) on d 2 than on d 1. Concentrations on d 2 were higher (P < .05) in group HF_C than in group HF_MR and on d 4 were higher (P < .05) in group HF_C than in all other groups. On d 7, concentrations 2 h after the morning feeding increased (P < .05) in group LF_C and tended to rise (P < .1) in group LF_MR. The incremental changes within 2 h after feed intake in groups HF_MR and LF_MR were markedly greater (P < .01) on d 1 than on d 7.

Plasma glucagon concentrations (Figure 4) during the 7-h period after the first meal increased (P < .05) in groups HFC, LFC, and HF_MR and tended to rise (P < .1) in group LF_C. Concentrations were still elevated (P < .05) at 12 h after the first feeding in groups HFC, LF_C, and LF_MR. The rise of glucagon within 12 h after the first meal was greater (P < .05 for group HFC, and P < .01 for group LF_C) in CO-fed groups than in MR-fed groups. Concentrations then returned to values on d 1 in CO-fed groups, did not further change in group HFC, but irregularly increased (P < .05) in group LF_C up to d 7. In MR-fed groups concentrations increased (P < .05) from d 2 to 5 to levels that were higher than those before the first feeding on d 1 (P < .05 for group HF_MR and P < .1 for group LF_MR). On d 2, concentrations were higher (P < .05) in CO-fed groups than in MR-fed groups. Conversely, concentrations on d 5 were lower (P < .05) in group LF_C than in MR-fed groups and were lower (P < .05) in group HFC than in group LF_MR. There were no group differences within CO- or MR-fed groups.

Plasma GH concentrations (Table 4) increased within the 7-h period after the first meal in groups HFC and LF_MR and tended to rise (P < .1) within the 7-h period after the first meal in group HF_MR, but Δ0 to 7 h responses were not significantly different between groups. Concentrations of GH increased (P < .05) within 12 h after the first feed intake in all groups and then returned to preprandial values of d 1 in CO-fed groups, whereas concentrations in the MR-fed groups increased irregularly (P < .01) from d 1 to 4, followed by a decrease (P < .05) up to d 7. Plasma GH concentrations on d 3 were higher (P < .05) in group LF_MR than in group HFC, on d 4 were higher (P < .05) in group HF_MR than in CO-fed groups and higher (P < .05) in group LF_MR than in group LF_C, and on d 5 were higher (P < .05) in the MR-fed groups than in the CO-fed groups. There were no group differences within CO- or MR-fed groups.

Plasma IGF-I concentrations (Table 4) decreased (P < .05) after the first feed intake within the 7-h period.

Figure 2. Plasma concentrations of cholesterol in calves fed high (HFC, ●) or low (LFC, ○) amounts of colostrum and high (HF_MR, ▲) or low (LF_MR, △) amounts of milk replacer on the first 3 d of life. Means without common uppercase letters (A, B, C) are different (P < .05) between groups. For simplicity, only means with significant differences (P < .05) relative to time 0 (based on variance analysis) are marked with uncommon lowercase letters (a, b).
in MR-fed groups and continued to decrease in MR-fed groups up to d 7 and were lower (P < .05) on d 3, 5, and 7 than concentrations before the first meal in group LF_C, but they did not change significantly in group HF_C. On d 2 concentrations were higher (P < .05) in CO-fed groups than in group HF_MR. Concentrations on d 4 and 5 were higher (P < .05) in CO-fed groups than in MR-fed groups and on d 7 were higher (P < .05) in group HF_C than in groups HF_MR and LF_MR and higher (P < .05) in group LF_C than in group HF_MR. There were no group differences within CO- or MR-fed groups.

Plasma cortisol concentrations decreased (P < .01) in all groups from d 1 to 7. Concentrations on d 3 were higher (P < .05 and P < .1, respectively) in group LF_MR than in groups LF_C and HF_C (156 ± 25 mmol/L for LF_MR, 75 ± 14 mmol/L for LF_C, and 84 ± 17 mmol/L for HF_C). There were no group differences within CO- or MR-fed groups.

Plasma concentrations of T_3 decreased (P < .001) in all groups from d 1 to 7. Concentrations on d 2 were lower (P < .01) in group HF_MR than in group LF_MR (3.7 ± .6 mmol/L for HF_C and 10.7 ± 1.1 mmol/L for LF_MR). There were no group differences within CO- or MR-fed groups.

Plasma concentrations of T_4 decreased (P < .001) up to d 7 in all groups. There were no significant group differences.

**Xylose Absorption Test**

Plasma xylose concentrations on d 5 before xylose feeding were .65 ± .08, .77 ± .03, .47 ± .06, and .50 ± .05 mmol/L for groups HF_C, LF_C, HF_MR, and LF_MR, respectively, and xylose concentrations were higher (P < .05) in group LF_C than in the MR-fed groups. At 4 h after xylose intake, concentrations increased (P < .05) to 3.36 ± .18, 3.10 ± .23, 1.60 ± .28, and 1.50 ± .23 mmol/L in groups HF_C, LF_C, HF_MR and LF_MR, respectively, and were higher, as well as incremental changes, in the CO-fed than in the MR-fed groups (P < .001 for group HF_C and P < .01 for group LF_C). There were no group differences within high and low level CO-fed groups as well as within high and low level MR-fed groups.

**Discussion**

An approximately 30% difference in DM intake in LF and HF calves had surprisingly no significant effects on growth rate within CO-fed or MR-fed groups. However, BW increased in CO-fed calves. The rise of BW gain in CO-fed groups was probably due to high intake of energy and protein. The lack of BW gain in MR-fed calves may have been the result of a reduced intake of energy and protein as well as non-nutritional growth-promot-
ing substances that stimulate development of the GI tract and (directly or indirectly) of other organs (Burrin et al., 1992, 1996).

Calves in this study were generally healthy, and cardiorespiratory and rectal temperatures were in the normal range (Vermorel et al., 1989; Hadorn et al., 1997). The higher incidence of loose feces in MR- than in CO-fed groups indicated slightly impaired GI tract function in MR-fed calves, in accordance with Hadorn et al. (1997) and Zanker (1997). The impaired GI tract function was supported by reduced absorptive capacity for xylose in MR- compared to CO-fed calves, a finding that was in accordance with recent studies (Hammon and Blum, 1997a; Bühler et al., 1998). Reduced xylose absorption was also seen in neonatal calves fed a milk-based formula containing the same nutrient contents as CO, but barely any growth-promoting substances (such as IGF-I; Rauprich, Hammon, and Blum, unpublished data), suggesting that the feeding level as such seemed not to change the absorptive function, as also seen in this study. Biologically active substances in CO may have contributed to differences of xylose absorption between CO- and MR-fed calves (Burrin et al., 1995).

Total protein and globulin concentrations increased rapidly in CO-fed calves as a consequence of immunoglobulin absorption but barely increased in MR-fed calves, as expected (Hadorn and Blum, 1997; Hadorn et al., 1997; Hammon and Blum, 1998b). In calves fed increased amounts of CO, higher concentrations of total protein and globulins on d 7 demonstrated prolonged effects of high CO intake on globulin status (and especially on IgG), as also seen in other studies (Morin et al., 1997; Hammon and Blum, 1998b). Albumin concentration behaved as recently described (Hadorn et al., 1997). Its rise in CO-fed calves was probably the result of enhanced hepatic synthesis. The decrease of hemoglobin concentration was already previously described (Kurz and Willett, 1991; Steinhardt et al., 1995; Hadorn et al., 1997) and was probably the result of hemodilution after CO and MR intake. Under conditions without hepatic and kidney dysfunctions, plasma urea concentrations are dependent on protein intake, synthesis, and degradation. The relatively high urea concentrations in CO-fed groups on the first 2 d of life possibly reflected the relatively high protein intake.

It is well established that newborn calves are characterized by relatively low concentrations of plasma glucose and that glucose concentrations rapidly increase after intake of the first meal (Hadorn et al., 1997; Egli and Blum, 1998). A significant increase after the first meal was seen only in MR-fed calves, and the postprandial rise was greater in calves fed MR at a high level. Marked postprandial hyperglycemia in group HFMR may have been due to a particularly high lactose intake (Grüttter and Blum, 1991; Hammon and Blum, 1998b). Interestingly, postprandial glucose responses at the end of the 1st wk were smaller in MR- than in CO-fed calves,
in accordance with Hadorn et al. (1997) and Hammon and Blum (1998b). This indicated rapid adaptation to differences in feeding and an improved glucose status in CO- compared with MR-fed calves. However, differences in feeding density within CO- as well as within MR-fed calves did not significantly influence basal and postprandial glucose concentrations during the 1st wk of life.

High NEFA concentrations after birth, followed by a rapid decline after the first meal, were in accordance with previous studies (Ronge and Blum, 1988; Vermorel et al., 1989; Baumrucker and Blum, 1994; Hadorn et al., 1997; Hammon and Blum, 1998b). Plasma NEFA concentrations did not differ in response to high or low feeding density in CO-fed calves but were higher on d 2 in calves fed MR on a low compared to a high level, suggesting a greater fat mobilization in group LFMR than in HFMR.

In CO-fed calves, an increase of plasma triglyceride and cholesterol concentrations was seen in this study, as also shown previously (Leat, 1967; Kurz and Willett, 1991; Blum et al., 1997). We found an improved triglyceride and cholesterol status in calves fed CO on a high level, mainly due to greater fat intake in group HFc than in group LFC. However, greater fat intake in group HFMR did not improve triglyceride and cholesterol status in MR-fed groups. Triglyceride and cholesterol concentrations remained low in both MR-fed groups. Therefore, causes other than feeding density were obviously responsible for an improved triglyceride and cholesterol status in CO-fed calves. A reduced rise of triglyceride and cholesterol concentrations in newborn calves was observed if CO was fed with a delay of 24 h after birth and was interpreted to be the consequence of reduced fat digestion and decreased fatty acid absorption (Blum et al., 1997). Because plasma cholesterol concentrations are increased in calves by feeding cholesterol-free milk (Jacobsen et al., 1974), postabsorptive factors seem to regulate plasma cholesterol concentrations as well and may have contributed to differences between CO- and MR-fed calves.

A greater postprandial insulin response following the first meal in calves fed MR at high compared with low densities was likely the consequence of greater postprandial hyperglycaemia. Various other factors, such as feeding density and energy intake, protein intake, and GI hormones (Guilloteau et al., 1997; Hadorn et al., 1997) possibly contributed to modified insulin secretion. The postprandial insulin response was not influenced by feeding density on d 7 in MR-fed calves and was reduced in both MR-fed groups compared to d 1. However, different CO feeding densities influenced basal plasma insulin concentrations and tended to affect the postprandial response on d 7. Elevated plasma insulin concentrations several days after birth possibly also expressed accelerated pancreatic development in calves fed CO intensively.

The study failed to show differences of plasma glucagon concentrations dependent on feeding density within CO- or MR-fed groups. However, glucagon concentrations increased after intake of the first meal in all groups, and the rise was more important in CO- than in MR-fed groups. This was in accordance with Hammon and Blum (1998b) but in contrast to Mao et al. (1994), who found a gradual decrease of glucagon concentrations in CO-fed calves during the 1st wk of life. Furthermore, our study shows that glucagon behaved differently up to d 7 dependent on whether calves were initially fed CO or MR. The failure of effects of feeding density within CO- and MR-fed groups on plasma glucagon concentrations and the marked effects of initial CO vs MR feeding suggest that non-nutrient components may have additionally contributed to the regulation of the glucagon status.

Generally, feeding density within CO- or MR-fed groups had no effects on plasma GH concentrations. Because of restricted blood sampling, the study did not allow a detailed description of the GH status. However, during the 1st wk plasma GH concentrations seemed to be higher in MR- than in CO-fed calves. Thus, GH concentrations seemed to be dependent on whether calves were initially fed CO or MR. The study also failed to show effects of feeding density within CO- or within MR-fed groups on plasma IGF-I concentrations. This was somewhat surprising because prolonged CO feeding (six times instead of only once) caused higher IGF-I concentrations in neonatal calves (Hammon and Blum, 1997b). Concentrations of IGF-I decreased in calves initially fed MR but remained relatively high in those initially fed CO. Such differences in IGF-I concentrations between CO- and MR-fed calves were also described by Hammon and Blum (1997b), and increased IGF-I concentrations were seen in suckling calves that ingested CO ad libitum (Egli and Blum, 1998). Interestingly, IGF-I concentrations behaved inversely to GH concentrations. Lower GH and higher IGF-I concentrations in CO- than in MR-fed calves are partly the result of higher energy intake (Kinsbergen et al., 1994; Breier and Sauerwein, 1995), higher fat intake (Coxam et al., 1989), and higher protein intake (Miura et al., 1992). As seen for GH, plasma IGF-I concentrations from d 4 on were not dependent on feeding density within MR- and CO-fed groups but remained high in CO-fed calves and low in MR-fed calves. Calves of group HFMR had lower plasma IGF-I concentrations on d 7 than calves of group HFc, although both groups received the same amounts of milk from d 4 on. Obviously, CO feeding is important to maintain high plasma IGF-I concentrations during the 1st wk of life, although absorption of colostral IGF-I does not seem to be of significance (Vacher et al., 1995; Hadorn et al., 1997; Hammon and Blum, 1997b).

Concentrations of cortisol at birth decreased during the 1st wk in all groups, in accordance with previous studies (Ronge and Blum, 1988; Mao et al., 1994; Hadorn et al., 1997; Hammon and Blum, 1998b). Feeding density within CO- or MR-fed groups had no effects on basal cortisol concentrations. Cortisol concentrations
tended to be higher in MR- than in CO-fed calves on the first 3 d. This might have been the result of different nutrient intake in CO- and MR-fed calves, as described (Hammon and Blum, 1998b).

The decline of thyroid hormone concentrations within the 1st wk of life was similar in all groups and has repeatedly been described (Kahl et al., 1977; Davicco et al., 1982; Ronge and Blum, 1988; Baumrucker and Blum, 1994; Hadorn et al., 1997; Hammon and Blum, 1998b). The T3 and T4 concentrations are markedly influenced by energy intake in older cattle (Blum et al., 1985) and in calves of at least 1 wk of age (Grongnet et al., 1985; Kinsbergen et al., 1994). However, different feeding densities within CO- or MR-fed groups failed to show any effects on T3 and T4 concentrations in neonatal calves.

Implications

Colostrum fed early postnataally affects the metabolic profile, endocrine status, and intestinal absorptive capacity of calves, and these effects, compared with those of milk replacer, are associated with better growth performance immediately after birth. Thus, colostrum seems to be important for sufficient passive immunity and for enhancing developmental changes and improving postnatal metabolism in calves. An approximately 30% difference in the amount of milk replacer fed did not affect the metabolic and endocrine status in calves fed only milk replacer, whereas a similar difference in colostrum feeding improved protein and fat metabolism.

Literature Cited


