Effect of Colostral Immunoglobulin G₁ and Immunoglobulin M Concentrations on Immunoglobulin Absorption in Calves

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ABSTRACT

Twenty-three calves were fed colostrum at 110 ml/kg body weight divided into two feedings at 1 and 13 h of age. The concentrations of immunoglobulins were measured in the colostrum fed and in the calves’ sera following colostrum feeding. Apparent efficiency of immunoglobulin absorption was calculated for each calf. Significant negative correlations between efficiency of absorption and mass of immunoglobulin fed were observed for both immunoglobulins. A separate group of 225 calves born on a commercial dairy were fed 2.84 L of colostrum by 4 h of age. Concentrations of immunoglobulin G₁ in the colostrum fed and in the calves’ sera at 48 h were measured. Negative correlation was observed between the efficiency of absorption and the mass of immunoglobulin G₁ fed. These results suggest a physiologic limitation to the mass of immunoglobulin that can be absorbed to serum from a given volume of colostrum. No indication of a selective immunoglobulin absorption mechanism was observed.

INTRODUCTION

Absorption of adequate amounts of colostral immunoglobulin (Ig) by calves during the first 24 h of life is critical for the calf’s subsequent resistance to infectious disease (3, 6, 11, 12, 13). All major bovine Ig classes, Ig from other species, and such non-Ig macromolecules as human serum albumin and polyvinylpyrrolidone have been shown to be transferred from the calf’s gut to the bloodstream during this period. Therefore, the mechanism of absorption of colostral Ig has been considered “nonselective” (9). However, Stott reported that calves fed colostrum containing low IgM absorb the IgM efficiently (greater than 90% absorption to serum) (15). This relationship was not seen with IgG₁ or IgA, which suggested that a qualitatively separate, saturable absorption mechanism for IgM is present in the calf. Such a mechanism for efficient absorption of IgM when the calf received only little colostrum would have considerable survival value to the calf, and has implications for both the management of colostrum feeding on the farm and experimental studies of passive transfer in calves. This report examines the efficiency of absorption of IgG₁ and IgM to serum by calves in relation to the Ig concentration in the colostrum fed.

MATERIALS AND METHODS

Calves

Experiment 1. Twenty-three calves born sequentially between April 4 to 7, 1983, on a large commercial dairy in Washington were assigned alternately to one of two colostrum feeding groups. All calves were born in a corral containing 50 to 125 late pregnant Holstein cows and heifers. At birth, calves were ear tagged for identification, had their navel dipped with iodine, and were left with their dam for 15 to 30 min. No natural suckling was allowed. Calves were weighed and removed from the corral to a small pen in a calf barn. Each of the 23 calves was fed 66 ml colostrum/kg birth weight within 2 h of birth and 44 ml/kg 12 h later. Eleven calves were fed their own dams’ colostrum that was hand milked immediately after the calves were born. Twelve calves were fed colostrum from previously
prepared pools. These colostrum pools were each composed of first milking colostrum from 3 or 4 cows. Four different pools were fed to calves in this study, with 2, 4, 3, and 3 calves fed pools 1 through 4, respectively. Pools were stored at 4°C for less than 48 h and warmed to 38°C for feeding. Each colostrum was sampled before each calf was fed, and the samples were stored at −20°C until analyzed. All feedings were by nipple bottle except for 3 calves that failed to suck voluntarily the entire amount offered and were force-fed small amounts of colostrum. Blood samples were obtained from each calf by jugular venipuncture before feeding and at 12, 24, and 48 h after feeding.

**Experiment 2.** Two hundred and twenty-five calves born on a commercial dairy in Washington between February 1981 and May 1983 were used. Each calf was fed 2.82 L of fresh colostrum by 4 h of age. Colostrum had been milked from the cow that had most recently calved, and had been stored at 4°C. When needed, colostrum was warmed to body temperature and fed by esophageal feeder. Colostrum was sampled at the time of collection, and the samples were frozen at −20°C until analyzed. Each calf was placed in an individual calf pen soon after birth, and bled between 48 and 96 h of age for measurement of serum IgGa concentration.

**Immunoglobulin Analysis**

Blood samples were centrifuged at 2000 rpm for 10 min. Serum was harvested and stored at −20°C until analyzed. Serum and colostrum IgG1 and IgM concentrations were determined by radial immunodiffusion (4). To produce repeatable colostrum Ig concentrations, the radial immunodiffusion technique was modified as follows: 1) whole colostrum was used rather than colostral whey (7), 2) samples were mixed by vortexer before aliquoting for dilution and before plating diluted samples, 3) positive displacement pipettes were used and external colostrum was removed from the pipette before delivery, 4) samples were diluted with phosphate-buffered saline (1:200 for IgG1 and 1:5 for IgM), and 5) standards derived from serial dilutions of colostrum were used. Each sample was plated in duplicate. Duplicate samples that did not agree within 10% were reassayed. In-house standards were run on each plate, and failure of these standards to fall within 20% of expected led to rejection of the assay. In Experiment 2, IgG1 concentrations were adjusted to 48 h values using an assumed half-life of 384 h (8).

**Efficiency**

Apparent efficiency of absorption (AEA) was calculated by the method of Husband (10): 

$$\text{AEA} = \left( \frac{\text{Peak serum Ig concentration} \times 0.07 \times \text{BW}^3 \times 100\%}{\text{Colostrum Ig concentration} \times \text{L colostrum fed}} \right)$$

Because no allowance is made for differences in Ig class distribution ratios between intra- and extravascular spaces, this AEA can be used to compare Ig absorption only within a given Ig class. In addition, no allowance is made for variation in serum volume as a percentage of body weight. In Experiment 2, calves were not weighed, so the AEA was calculated using an estimated average weight of 35 kg for each calf. This assumption further reduces the accuracy of the AEA estimate for each individual and tends to reduce the chances of finding a significant relationship between AEA and colostrum Ig mass fed.

**Statistical Analysis**

As has been previously reported (1) there was no significant difference in Ig absorption efficiency between calves receiving dams' colostrum and calves receiving pooled colostrum in Experiment 1. Data from calves fed both colostrum sources were combined for the analysis reported here. Correlation coefficients were calculated between the base 10 logarithm of the colostral Ig mass ingested and the serum Ig concentrations of the calves. Logarithmic transformation was suggested by the distribution of data points observed in Figures 2 and 4, as reported previously (15). Significance of correlations observed was calculated (14).

**RESULTS AND DISCUSSION**

**Experiment 1**

**Immunoglobulin M.** The concentration of IgM in individual colostrum fed to these calves varied from 1.6 to 19.5 mg/ml. Peak serum IgM concentrations attained varied with the IgM concentrations in the colostrum fed (r=.595, P<.01)(Figure 1). Therefore calves fed colostrum with higher IgM content developed higher serum IgM concentrations over the range of
Colostrum IgM concentrations examined in this study. A negative correlation between AEA for IgM and the IgM mass in the colostrum fed was observed ($r = -0.629, P<0.01$) (Figure 2). Calves fed colostrum with less IgM absorbed a higher proportion of the IgM than calves fed colostra with more IgM.

**Immunoglobulin G**. Concentrations of colostrum IgG varied from 35 to 151 mg/ml. There was a positive correlation between peak serum IgG concentrations attained by calves and the IgG concentration in the colostrum fed ($r=0.751, P<0.001$) (Figure 3). There was a negative correlation between IgG AEA and colostral IgG ($r=-0.531, P<0.01$) (Figure 4). These results follow the same pattern as those for IgM. Even though a higher proportion of the IgG fed was absorbed to serum by those calves receiving colostrum with low IgG concentration, calves fed colostrum higher with Ig concentration developed higher concentrations of serum Ig.

**Experiment 2**

Colostrum IgG concentrations varied from 11 to 118 mg/ml. A correlation was found between the serum IgG concentrations following colostrum feeding and the IgG concentration in the colostrum fed ($r=0.525, P<0.001$). There was a negative correlation between the efficiency of absorption of IgG and the colostrum IgG mass ($r=-0.433, P<0.001$) (Table 1). Concentrations of IgM were not analyzed in these calves. This pattern of increasing calf serum concentrations but decreasing efficiency of absorption with increasing Ig concentration in the colostrum fed is similar to that observed for both IgM and IgG in Experiment 1.

Stott and Menefee (15) found a similar pattern of absorption for IgM, but not IgG, and proposed a selective IgM absorptive mechanism to explain this observation. We found both IgG and IgM to be absorbed with greater efficiency when low amounts are fed, which suggests that IgM and IgG share a common or similar mechanism of absorption. This conclusion is in agreement with Brandon and Lascelles (2) who found that IgG and IgM are absorbed equally efficiently when absorption is measured directly in calves' thoracic lymphs following colostrum feeding.

Possible mechanisms that may account for the decreasing AEA to serum for IgG and IgM when colostrum high in Ig are fed include 1) saturation of a shared macromolecular transport mechanism across the calf intestinal epithelium or 2) a regulation of the Ig concentrations in calf serum, for example, a loss of Ig from serum once concentrations exceed a threshold level. If the first explanation is correct, colostrum with

![Figure 1. Serum immunoglobulin M (IgM) concentrations acquired by calves fed colostrum with different IgM concentrations.](image1)

![Figure 2. Efficiency of absorption of immunoglobulin M (IgM) by calves fed colostrum with different IgM content.](image2)
Figure 3. Serum immunoglobulin G (IgG) concentrations acquired by calves fed colostrum with different IgG concentrations.

Figure 4. Efficiency of absorption of immunoglobulin G (IgG) by calves fed colostrum with different IgG content.

Table 1. Serum immunoglobulin G (IgG) concentrations and apparent efficiencies of absorption (AEA) in calves fed 2.84 L of colostrum of various IgG concentrations by 3 h of age.

<table>
<thead>
<tr>
<th>Colostrum IgG (mg/ml)</th>
<th>n</th>
<th>Serum IgG (mg/ml)</th>
<th>Calf AEA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;20</td>
<td>24</td>
<td>9.1 1.1</td>
<td>48.4 5.6</td>
</tr>
<tr>
<td>21–30</td>
<td>47</td>
<td>13.7 0.9</td>
<td>49.5 3.8</td>
</tr>
<tr>
<td>31–40</td>
<td>46</td>
<td>13.6 0.9</td>
<td>34.8 2.4</td>
</tr>
<tr>
<td>41–50</td>
<td>34</td>
<td>16.8 1.0</td>
<td>34.0 2.1</td>
</tr>
<tr>
<td>51–70</td>
<td>45</td>
<td>22.2 1.1</td>
<td>32.5 1.6</td>
</tr>
<tr>
<td>71+</td>
<td>29</td>
<td>21.2 1.2</td>
<td>22.8 1.4</td>
</tr>
</tbody>
</table>

1 Number of calves fed colostrum of each colostrum IgG concentration group.
2 Concentrations of IgG measured between 48 and 96 h after birth and adjusted to 48 h using an assumed serum half-life of 384 h (9).
3 AEA calculated by the method of Husband (12): AEA = [(Peak serum immunoglobulin concentration) (.07) (body weight) (100%)]/[(Colostrum immunoglobulin concentration)(kg colostrum fed)].

relatively high IgG and low IgM concentrations should result in a relatively low AEA for IgM. Although we did not observe such a tendency in these calves, the limited number of observations did not allow a definite conclusion. A regulatory mechanism such as that suggested in the second explanation has been demonstrated in humans and mice but not cattle (5, 16).

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REFERENCES