Effect of Fat Content of Colostrum on Voluntary Colostrum Intake and Fat Utilization in Newborn Pigs

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ABSTRACT: The effects of colostral fat level on voluntary colostrum and ME intake were determined in 25 newborn pigs during the first postnatal day. Within a litter, five pigs were obtained before nursing and allotted on the basis of initial body weight (BW) at 2 h of age to one of the five treatments: killed or ad libitum bottle-fed sow colostrum containing 2.5, 5.0, 7.5, or 10.0% of total fat. A total of 24 feedings was provided at 60-min intervals, and pigs were killed 1 h after the final feeding. Total colostrum intake averaged 584.8 ± 42 g (i.e., 436 g/kg of average BW) with the first two feedings accounting for 19.8% of the total consumption. Colostrum intake decreased linearly (P < .08) by 5.9 g/kg of average BW per 1% increase in the level of fat. However, GE and ME intake increased linearly (P < .01) by 7.65 and 4.09 kcal/kg average BW per 1.0 g/kg of average BW increase in fat intake, respectively. Adipose tissue lipoprotein lipase increased (P < .01) during the first postnatal day. Carcass fat deposition and fat oxidation increased linearly (P < .01) by .36 and .20 g/kg of average BW per 1.0 g/kg of average BW increase in fat intake, respectively. We suggest that increasing the fat content in colostrum has little effect on voluntary colostrum intake, and the practice may be an efficient method for improving the energy supply to newborn pigs.

Key Words: Newborn Animals, Colostrum, Fat, Energy, Pigs

Introduction

Insufficient supply of energy during d 1 of life is a leading cause of neonatal mortality and poor growth in pigs (Pettigrew, 1981; English and Morisson, 1984; Chiang et al., 1990; Hoy et al., 1994). One strategy to improve the energy status of newborns is to increase the fat content of colostrum. Indeed, the overall capacity of pigs to oxidize long-chain fatty acids in colostrum, although being low at birth, increases dramatically during d 1 of life (Herpin and Le Dividich, 1995). However, evidence indicates that the content and fatty acid pattern of colostrum can be manipulated by the dietary fat source consumed by the sow during late gestation (Seerley, 1984; Jackson et al., 1995). Furthermore, the addition of fat to sow diets can cause up to a 31% increase in the total volume of milk produced (Coffey et al., 1982). However, in growing pigs, the increase in the energy concentration of the diet results in a decrease in voluntary feed intake, and metabolizable energy intake remains nearly constant (NRC, 1987; Forbes, 1995). Little is known about the effects of fat content in colostrum and hence its energy concentration on voluntary colostrum intake by newborn pigs. However, the beneficial effect of an enhanced fat intake can be limited by a slower gastric emptying rate (Siegel et al., 1985) and/or by impaired digestion due to the low activity of pancreatic lipase at birth (Cranwell, 1995). This study was designed to examine the effects of fat content in colostrum and energy intake and fat utilization in pigs during d 1 of life.

Materials and Methods

Animals. Twenty-five newborn Piétrain × Large White pigs from five litters were used. Five pigs were removed from each sow immediately after birth, before nursing, then dried, weighed, and placed in a plastic-coated wire cage in a temperature-controlled room maintained at 34°C. After a period of 120 ± 20 min, pigs were reweighed (initial body weight, IBW) and placed in individual wire cages (.37 × .27 × .29 m), equipped with a tray for excreta collection, in the temperature-controlled room. On the basis of IBW, one pig (initial slaughter group, ISG) was killed to determine initial body composition. The remaining four pigs were allotted to treatments consisting of sow
colostrum that was formulated to contain 2.5, 5.0, 7.5, or 10.0% colostral fat. A litter was considered as a replicate, and there were five replicates.

**Colostrum.** Two pools of colostrum were obtained from several sows by manual expression during (C0) and approximately 24 h after (C24) parturition. Intravenous injection of 20 IU of oxytocin was used to initiate milk let down at 24 h. Fat was removed from each pool using a dairy separator. Thus, from each defatted C0 and C24, four experimental colostra were formulated to contain 2.5, 5.0, 7.5, and 10.0% fat by reinduding part of their corresponding removed fat (Table 1). Moreover, to mimic changes occurring in the composition of colostrum shortly after parturition, equal volumes of each experimental C0 and its corresponding C24 were mixed to produce intermediate colostrum C12. All colostra were then subdivided into 40- to 50-g portions and kept at -20°C until used.

**Feeding.** Bottle-feeding was chosen to provide pigs with an unlimited availability of colostrum while enabling a precise measurement of colostrum consumption. Soon after allotment to treatment group, pigs were taught to drink colostrum from an infant’s nursing bottle. Pigs were lightly restrained under one arm, the forelimbs were held in the operator’s hand, and the teat was repeatedly placed in the mouth to train the pig. The sucking response was learned quickly, usually in less than 2 min, and less than 10 g of a control colostrum (5% fat) was used to train each pig to nurse from a bottle.

After pigs learned to suck from the artificial teat, they vigorously consumed colostrum with only a few pauses. Attempts to reject the teat and to escape the operator’s restraint were taken to signal the end of the sucking and that ad libitum intake was reached. The first experimental meal was given 1 h after the pigs were able to suck from the teat. Colostrum was warmed to 38°C, and the amount ingested was measured by weighing (± 0.1 g) the bottle before and after feeding. A total of 24 meals (eight meals of each C0, followed by eight meals of each C12, and finally by eight meals of each C24) were given at 60-min intervals.

**Urine and Feces Collection.** Urine and feces were collected separately at 8-h intervals. Urine was collected on ice, and drops of .1 N H2SO4 were added to ensure pH being less than 6. At each collection, the tray was rinsed with .01 N H2SO4. At the end of the trial, washings and feces were mixed, weighed, and stored at -20°C. Urine was also weighed and stored at -20°C.

**Slaughter Procedure.** One hour after the final meal, corresponding to a mean age of 27 h, pigs were anaesthetized using halothane inhalation, weighed, and killed by exsanguination. The gastrointestinal tract (GIT) and pancreas were removed and weighed. The pancreas and samples of subcutaneous adipose tissue from the interscapular area were removed, frozen in liquid N2, and stored at -70°C. The GIT was divided into stomach and small and large intestine. The stomach was opened, emptied, and rinsed with distilled water. Intestinal contents were gently expressed, and the lumen flushed with distilled water. The contents of the small and large intestines were combined and stored at -20°C. The carcass, including the emptied GIT, was also stored at -20°C for subsequent mincing and homogenization.

**Analysis.** Samples of colostrum and carcass and the total volume of digesta and fecal material were freeze-dried and analyzed for dry matter nitrogen with the Kjeldahl procedure and gross energy (GE) using an adiabatic bomb calorimeter (Gallekamp & Co. Ltd, London, U.K.). Urinary GE was determined on freeze-dried material. Total fat in colostrum was determined using the Rose-Gottlieb method (AOAC, 1975). Total fat of the carcass, GIT contents, and feces was extracted with diethyl ether after hydrochloric acid hydrolysis. The pancreas was analyzed for lipase according to the method of Rathelot et al. (1975). Activity of adipose tissue lipoprotein lipase (LPL) was determined using the procedure described by Herpin et al. (1992).

**Calculations.** Fat absorption was calculated as follows: Fat absorbed = Fat intake – (Fat in GIT contents + Fecal fat). Metabolized energy (ME) intake was calculated as ME intake = GE intake – (GE in GIT contents + Fecal and urinary GE). Gross energy absorbed and fat absorbed were calculated.

**Statistical Analysis.** Data were analyzed as a complete, balanced block design (block = litter). Orthogonal contrasts were used to test the effect of age (15G killed at the start of the experiment vs

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**Table 1. Average gross composition of colostra**

<table>
<thead>
<tr>
<th>Time of collection, h:</th>
<th>0</th>
<th>24</th>
<th>0</th>
<th>24</th>
<th>0</th>
<th>24</th>
<th>0</th>
<th>24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter, %</td>
<td>19.50</td>
<td>18.18</td>
<td>21.09</td>
<td>20.21</td>
<td>23.46</td>
<td>22.76</td>
<td>25.16</td>
<td>24.81</td>
</tr>
<tr>
<td>Crude protein, %b</td>
<td>12.52</td>
<td>10.40</td>
<td>12.30</td>
<td>10.28</td>
<td>12.00</td>
<td>10.01</td>
<td>11.68</td>
<td>10.00</td>
</tr>
<tr>
<td>Lactose, %</td>
<td>3.21</td>
<td>3.88</td>
<td>3.32</td>
<td>3.96</td>
<td>3.29</td>
<td>3.69</td>
<td>3.29</td>
<td>3.76</td>
</tr>
<tr>
<td>Fat, %</td>
<td>1.91</td>
<td>2.15</td>
<td>3.98</td>
<td>4.80</td>
<td>6.80</td>
<td>7.41</td>
<td>9.01</td>
<td>9.94</td>
</tr>
<tr>
<td>Gross energy, kcal/g</td>
<td>1.04</td>
<td>0.96</td>
<td>1.20</td>
<td>1.18</td>
<td>1.43</td>
<td>1.40</td>
<td>1.62</td>
<td>1.58</td>
</tr>
</tbody>
</table>

*aExpressed on an as-fed basis.

*bCrude protein was calculated as N % × 6.38 (Oftedal, 1981).
Results

Composition of Colostra and Colostrum Consumption. Table 1 shows the composition of colostra collected during and 24 h after parturition. As expected, the increase in colostrum fat level (CFL) was associated with an increase in GE content and a decrease in moisture and CP contents. Level of lactose was similar across the treatments, averaging 3.52%, but the level was 16% higher in colostrum collected 24 h after parturition.

The initial BW of pigs in all five groups was 1,210 ± 68 g (Table 2). Body weight of the pigs increased over the 24 h of investigation, but there was no significant difference in BW gain. The amount of colostrum used to train the pigs to drink from the bottle was not taken into account, because it was minimal and there were losses when the pigs were trained to use the artificial nipple. Total colostrum intake was positively related to IBW (r = .79, P < .01), increasing by .50 ± .09 g/g increase in IBW. There was no significant effect of CFL on total colostrum intake; the overall mean was 584.8 ± 42.5 g in 24 h. However, when expressed as grams per kilogram of average BW, total colostrum intake decreased linearly (P < .08) with the increase in CFL according to the following equation:

\[ Y_{CI} = -5.9 (± 2.9) x + 469 (± 18) \]
\[ (n = 20, r = -.43) \]

where \( Y_{CI} \) = colostrum intake (g/kg average BW) and \( x \) = CFL (%). Colostrum intake increased linearly with CFL when expressed as grams of DM (P < .09) or as grams DM per kilogram of average BW (P < .01).

No effect of CFL on the temporal pattern of colostrum intake during d 1 of life was evident; thus, data from the four treatments were pooled (Fig. 1). The intake was the highest during the first two feedings (cumulative intake was 86.2 ± 5.9 g/kg of average BW), which accounted for 19.8% of the total colostrum ingested during the first day after birth. Thereafter, consumption declined rapidly to a constant rate of 13.3 g/kg of average BW per feeding during the last eight feedings.

Fat and Energy Balance. There was a quadratic effect of CFL on fat intake (P < .01), fat remaining in stomach (P < .07), and total GIT fat (P < .10) and a linear increase (P < .01) in excreted fat (Table 3). However, as a percentage of fat intake, stomach, total GIT fat contents, and excreted fat averaged 36.3 ± 2.6, 39.9 ± 2.1, and 3.8 ± .7%, respectively, and were not affected by CFL. As a percentage of fat intake, fat absorbed averaged 56.0 ± 3.1% and was similar among the treatment groups.

The increase in CFL resulted in a linear increase (P < .01) in GE and ME intake (Table 3). Stomach and total GIT GE contents also increased linearly (P < .01) with CFL. However, as a percentage of GE intake, stomach and total GIT GE contents represented 22.1 ± 1.7 and 25.6 ± 1.8%, respectively, in all groups. Gross energy and ME intake were related to fat intake by the following equations:

\[ Y_{GE} = 7.65 (± .9) x + 388 (± 23) \]
\[ (n = 20, r = .89) \]

\[ Y_{ME} = 4.09 (± .9) x + 290 (± 23) \]
\[ (n = 20, r = .73) \]

where \( Y_{GE} \) and \( Y_{ME} \) = GE and ME intake (kcal/kg average BW), respectively, and \( x \) = fat intake (g/kg average BW). Therefore, a 1.0 g increase in fat intake corresponded to 7.65 and 4.09 kcal/kg of average BW increases in GE and ME intake, respectively, during d 1 of life. As a percentage of GE absorbed, ME intake was similar across the treatment groups and averaged 95.7 ± .5%.

Body Composition. Body composition of the pigs is given in Table 4. Compared with the control pigs killed at 2 h, the pigs killed at 27 h had less (P < .01) body moisture and more (P < .01) body protein, total fat, and energy content. For the pigs killed at 27 h,
Table 2. Initial body weight and effects of fat percentage in colostrum on colostrum intake in newborn pigs

<table>
<thead>
<tr>
<th></th>
<th>ISG&lt;sup&gt;a&lt;/sup&gt;</th>
<th>2.5</th>
<th>5.0</th>
<th>7.5</th>
<th>10.0</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of pigs</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Initial BW, g</td>
<td>1205</td>
<td>1217</td>
<td>1196</td>
<td>1219</td>
<td>1225</td>
<td>31</td>
</tr>
<tr>
<td>BW gain, g</td>
<td>221</td>
<td>268</td>
<td>256</td>
<td>275</td>
<td>275</td>
<td>26</td>
</tr>
<tr>
<td>Total colostrum intake</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>607.7</td>
<td>585.6</td>
<td>583.6</td>
<td>562.2</td>
<td>42.5</td>
<td></td>
</tr>
<tr>
<td>g/kg avg BW&lt;sup&gt;bc&lt;/sup&gt;</td>
<td></td>
<td>459.6</td>
<td>439.6</td>
<td>433.0</td>
<td>412.0</td>
<td>16.9</td>
</tr>
<tr>
<td>g DM&lt;sup&gt;d&lt;/sup&gt;</td>
<td>116.8</td>
<td>122.4</td>
<td>135.0</td>
<td>140.5</td>
<td>9.7</td>
<td></td>
</tr>
<tr>
<td>g DM/kg avg BW</td>
<td>88.3</td>
<td>91.9</td>
<td>100.4</td>
<td>102.9</td>
<td>3.8</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Initial slaughter group.
<sup>b</sup>Average body weight was defined as (BW at start + BW at killing)/2.
<sup>c</sup>Linear effect of colostral fat level (P < .08).
<sup>d</sup>Linear effect of colostral fat level (P < .09).

Table 3. Effects of fat level in colostrum on fat and energy balance<sup>a</sup>

<table>
<thead>
<tr>
<th></th>
<th>ISG&lt;sup&gt;a&lt;/sup&gt;</th>
<th>2.5</th>
<th>5.0</th>
<th>7.5</th>
<th>10.0</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat balance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fat intake&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10.44</td>
<td>19.38</td>
<td>30.15</td>
<td>36.00</td>
<td>36.00</td>
<td>.80</td>
</tr>
<tr>
<td>Fat remaining in gastrointestinal tract (GIT)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stomach&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.76</td>
<td>7.38</td>
<td>11.35</td>
<td>12.09</td>
<td>.72</td>
<td></td>
</tr>
<tr>
<td>Total&lt;sup&gt;d&lt;/sup&gt;</td>
<td>4.19</td>
<td>8.12</td>
<td>12.30</td>
<td>13.66</td>
<td>.74</td>
<td></td>
</tr>
<tr>
<td>Fat in feces&lt;sup&gt;e&lt;/sup&gt;</td>
<td>.39</td>
<td>.64</td>
<td>1.10</td>
<td>1.64</td>
<td>.20</td>
<td></td>
</tr>
<tr>
<td>Fat absorbed&lt;sup&gt;e&lt;/sup&gt;</td>
<td>5.85</td>
<td>10.61</td>
<td>16.70</td>
<td>20.70</td>
<td>.55</td>
<td></td>
</tr>
<tr>
<td>Energy balance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GE intake&lt;sup&gt;e&lt;/sup&gt;</td>
<td>473.1</td>
<td>537.2</td>
<td>619.7</td>
<td>656.9</td>
<td>23.7</td>
<td></td>
</tr>
<tr>
<td>GE remaining in GIT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stomach&lt;sup&gt;e&lt;/sup&gt;</td>
<td>91.2</td>
<td>113.8</td>
<td>151.3</td>
<td>150.4</td>
<td>10.0</td>
<td></td>
</tr>
<tr>
<td>Total&lt;sup&gt;e&lt;/sup&gt;</td>
<td>108.3</td>
<td>132.7</td>
<td>170.2</td>
<td>177.4</td>
<td>10.0</td>
<td></td>
</tr>
<tr>
<td>GE in feces</td>
<td>11.6</td>
<td>14.5</td>
<td>18.1</td>
<td>22.6</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>GE absorbed&lt;sup&gt;e&lt;/sup&gt;</td>
<td>353.2</td>
<td>390.0</td>
<td>431.0</td>
<td>456.8</td>
<td>20.3</td>
<td></td>
</tr>
<tr>
<td>GE in urine</td>
<td>18.9</td>
<td>17.9</td>
<td>17.4</td>
<td>16.3</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Metabolized energy intake&lt;sup&gt;e&lt;/sup&gt;</td>
<td>335.3</td>
<td>372.1</td>
<td>414.0</td>
<td>440.6</td>
<td>19.8</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Data are expressed as g (fat) or kcal/kg avg BW.
<sup>b</sup>Quadratic effect of fat level (P < .08).
<sup>c</sup>Quadratic effect of fat level (P < .07).
<sup>d</sup>Quadratic effect of fat level (P < .10).
<sup>e</sup>Linear effect of fat level (P < .01).

Table 4. Effect of colostral fat level on carcass composition of pigs

<table>
<thead>
<tr>
<th></th>
<th>ISG&lt;sup&gt;a&lt;/sup&gt;</th>
<th>2.5</th>
<th>5.0</th>
<th>7.5</th>
<th>10.0</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture, %</td>
<td>80.52</td>
<td>80.34</td>
<td>79.22</td>
<td>79.79</td>
<td>79.12</td>
<td>.26</td>
</tr>
<tr>
<td>CP (N × 6.25), %</td>
<td>10.73</td>
<td>11.86</td>
<td>12.38</td>
<td>11.71</td>
<td>11.93</td>
<td>.23</td>
</tr>
<tr>
<td>Total lipid, %&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.70</td>
<td>1.79</td>
<td>2.28</td>
<td>2.65</td>
<td>2.88</td>
<td>.07</td>
</tr>
<tr>
<td>Accreted lipid, g/kg avg BW&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.99</td>
<td>7.02</td>
<td>10.06</td>
<td>13.01</td>
<td>.86</td>
<td></td>
</tr>
<tr>
<td>Gross energy, kcal/g&lt;sup&gt;d&lt;/sup&gt;</td>
<td>.84</td>
<td>.88</td>
<td>.93</td>
<td>.94</td>
<td>.96</td>
<td>.016</td>
</tr>
</tbody>
</table>

<sup>a</sup>Initial slaughter group.
<sup>b</sup>Pigs were fed the indicated level of colostral fat and then killed at 27 h of age.
<sup>c</sup>ISG vs 27 h group (P < .01).
<sup>d</sup>Linear effect of colostral fat level within the 27-h group of pigs (P < .01).
Table 5. Effects of fat level in colostrum on the weight of pancreas, activity of pancreatic lipase, and adipose tissue lipoprotein lipase activity

<table>
<thead>
<tr>
<th>Item</th>
<th>ISG (^a)</th>
<th>2.5</th>
<th>5.0</th>
<th>7.5</th>
<th>10.0</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pancreas</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight, g/kg BW(^e)</td>
<td>1.07</td>
<td>1.30</td>
<td>1.32</td>
<td>1.44</td>
<td>1.30</td>
<td>0.08</td>
</tr>
<tr>
<td>Lipase activity(^c)</td>
<td>392</td>
<td>129</td>
<td>151</td>
<td>136</td>
<td>142</td>
<td>34</td>
</tr>
<tr>
<td>Adipose tissue lipoprotein lipase activity(^d)</td>
<td>8.7</td>
<td>35.4</td>
<td>32.8</td>
<td>34.6</td>
<td>41.1</td>
<td>3.7</td>
</tr>
</tbody>
</table>

\(^a\)Initial slaughter group.  
\(^b\)Pigs were fed the indicated level of colostral fat and then killed at 27 h of age.  
\(^c\)Expressed as micromoles of fatty acid produced per minute per gram of tissue.  
\(^d\)Expressed as micromoles of fatty acid produced per hour per gram of tissue.  
\(^e\)ISG vs 27 h group (P < .01).  

there was no effect of CFL on body moisture and protein, but total body fat and energy contents increased linearly (P < .01) with CFL. The amount of deposited body fat was calculated by subtracting the amount measured at 27 h from estimated initial body fat using data obtained from the group of pigs killed at the start of the experiment. The amount of fat deposited was related to the amount ingested by the following equation:

\[
Y_{AC} = .36 (\pm .04) x + .45 (\pm 1.16)  
\]

(n = 20, r = .89) [4]

when Y\(_{AC}\) = deposited fat (g/kg of average BW) and x = ingested fat (g/kg of average BW). The intercept was not different from zero, indicating that in the absence of ingested fat, fat deposition was negligible.

Enzyme Activities. There were no effects of CFL on pancreas weight, lipase activity, or adipose tissue LPL activity (Table 5). During the first postnatal day, weight of pancreas increased by 24% (P < .01), whereas a decrease (P < .01) in the activity of lipase was observed. Adipose tissue LPL activity increased (P < .01) during the 1st d of life.

Discussion

Results of the present study indicate that increasing the fat content of colostrum has little effect on voluntary colostrum intake in newborn pigs and improves the availability of fat as an energy source. Further, they demonstrate that newborn pigs have considerable capacity to ingest colostrum.

Colostrum Consumption. In optimal conditions with respect to provision of colostrum, suckling behavior (i.e., no competition between siblings), and environmental temperature, pigs consuming colostra containing 5.0 and 7.5% fat, which are in the range usually found in colostrum (Pettigrew, 1981; Coffey et al., 1982; Jackson et al., 1995), consume a total of 584.6 g of colostrum during the first postnatal day. This value is positively correlated with the pig’s body weight, thus confirming the response observed in natural suckling (Fraser and Rushen, 1992). Total colostrum intake amounts to 436 g/kg of average BW, which is very close to that of 456 mL/kg BW (i.e., 460 g/kg BW if we assumed that the specific gravity of average colostrum is 1.01 g/mL, our unpublished observations) obtained by Burrin et al. (1994) in similar feeding conditions. Our value is 22% greater than the maximum of 356 g/kg BW estimated for newborn lambs; this estimate is an extrapolation to 24 h and is based on data for the first 18 h after birth (Mellor and Murray, 1986). More importantly, our measured value is much greater than the 240 and 260 g/kg of average BW reported for naturally suckling pigs (Le Dividich and Noblet, 1981; Milon et al., 1983), even if the weigh-suckle-weigh method used in these studies to determine colostrum intake is recognized to underestimate consumption by 31% (Rudolph et al., 1984). An intake of 405 g was reported by Varley et al. (1987). However, no information was provided on the body weight of the pigs, making a comparison of data difficult. Expressed as grams of DM, colostrum intake averaged 96 g/kg of average BW, which is also much greater than values of 60 g estimated from the data of NRC (1987) in 8- to 15-d-old pigs, or those of 50 to 56 g reported for 15-kg pigs (Le Dividich, 1981; NRC, 1987).

The temporal pattern of colostrum intake is, on the whole, similar to that found in natural suckling (Herpin and Le Dividich, 1995), with the intake being the highest in the first postnatal hours. In the present study, the initial two feedings accounted for 19.8% of the total amount ingested on d 1 of life. As a percentage of body weight, this corresponded to 8.6%, which is somewhat higher than values of 5.0 to 7.0% reported by Fraser and Rushen (1992) in sow-reared pigs in the first hour after successful suckling had been established. After this large initial intake, pigs consumed colostrum at a more modest rate. Intake of 20 g/h (approximately 16 g/average BW\(^{-1}\cdot h\(^{-1}\)) per pig in the 3rd and 4th h was reported by Fraser and Rushen (1992). In our study, consumption decreased to an average value of 13.3 g/kg average BW\(^{-1}\cdot h\(^{-1}\) in the last eight feedings.
Overall, our data suggest that the digestive capacity of pigs is high at birth and would largely compensate for the low energy reserves. However, although the temporal pattern of colostrum intake is similar in bottle-fed and sow-reared pigs, the amount of colostrum ingested under bottle-feeding conditions (i.e., without neonatal competition) may not reflect colostrum intake under suckling conditions.

Effect of Fat Level on Colostrum and Energy Intake.
In growing pigs, it is accepted (NRC, 1987; Forbes, 1995) that changes in the dietary energy concentration result in appropriate changes in voluntary feed intake so that metabolizable energy intake remains nearly constant. In 1-d-old pigs, results of the present study indicate that a 60% increase in GE concentration of colostrum (from 1.0 to 1.6 kcal GE/g) causes only a 10% decrease in colostrum consumption, but it increases GE and ME intakes by 50 and 31%, respectively. This response suggests that colostrum consumption is less dependent on its energy concentration, and hence its fat content. This observation is in agreement with the finding that a gastric load of 12 mL of medium-chain triglycerides had no effect on subsequent milk intake in newborn pigs (Benevenga et al., 1989). Also, newborn infants are reported to ingest as much high-fat milk as low-fat milk (Nysenbaum and Smart, 1982). However, in older pigs (age 3 to 22 d), a 50% decrease in the energy concentration of a milk replacer containing 1.12 kcal GE/mL was partly compensated for by a 36% increase in milk intake (Wangsness and Soroka, 1978). Taken together, these data suggest that, as in newborn infants (Fomon et al., 1975) and rats (Houpt and Epstein, 1973), the mechanisms controlling energy intake are not fully developed in pigs during the early suckling period. As a result, increasing the fat concentration of colostrum may represent an efficient method for improving the energy supply to newborns.

Fat Utilization. The 56% efficiency of conversion for ingested fat into absorbed fat available for storage and(or) oxidation is rather low. This could reflect an inadequate digestion of fat caused by the low activity of pancreatic lipase at birth (Cranwell, 1995). In addition, the enzyme activity dramatically decreased by 64% during the first postnatal day, and this decrease was only partly compensated for by the 26% increase in the weight of the gland (Le Dividich et al., 1991). However, as a percentage of ingested fat, fecal fat averaged 3.8 ± .7% and was not affected by the amount of ingested fat, which provides some evidence that digestion of fat was not impaired by the low activity of lipase. The fact that approximately 36% of the ingested fat remained in the stomach of pigs at slaughter indicates that gastric emptying was probably the main factor limiting the availability of ingested fat for deposition and(or) oxidation during the first 1 of life. Interestingly, as a percentage of fat intake, the amount of fat remaining in the stomach was not affected by the amount of ingested fat. This suggests that gastric emptying is not delayed by colostra high in fat. Similar observations were made by Wangsness and Soroka (1978). In contrast, in tube-fed pigs, gastric emptying was delayed by high-fat colostrum (Le Dividich et al., 1991). No explanation for this discrepancy is offered.

Once absorbed, fat is deposited and(or) oxidized. In our study, the carcass fat content was increased by 69% in 24 h in pigs on the highest level of colostral fat. In terms of absolute amount, the increase attained 97%, which is somewhat higher than values of 28 to 60% found over the same period in natural suckling (Elliot and Lodge, 1977; Okai et al., 1977; Bishop et al., 1985). Adipose tissue LPL, an enzyme playing a key role in the regulation of fat storage, undoubtedly contributes to this remarkable capacity of pigs to deposit large amounts of fat soon after birth. Indeed, its activity is already high at birth, being similar to that found in 33-kg pigs (Rinaldo and Le Dividich, 1991), and the increase found at 24 h agrees with that found at 48 h by Steffen et al. (1978). Furthermore, the increase in enzyme activity was not dependent on the amount of ingested fat, suggesting that LPL activity was not limiting for fat deposition. This deposition was primarily dietary fat in origin and did not result from lipogenesis, because in the absence of ingested fat, deposition was negligible (Le Dividich et al., 1994). On this basis, fat oxidized can be estimated as follows: Fat oxidized = Fat absorbed − Fat deposited. The amount of oxidized fat was related to the amount of fat ingested by the following equation:

\[
YOX = 0.20 (\pm 0.04) x + 0.34 (\pm 1.15)
\]

\[n = 20, r = 0.73\]  \[5\]

where \(YOX\) = fat oxidized (g/kg of average BW) and \(x\) = fat ingested (g/kg of average BW). So, a 1.0 g/kg of average BW increase in fat ingested during the first day of life corresponded a 0.2 g/kg of average BW increase in the amount of fat oxidized. This is consistent with the well-known increasing contribution of colostral fat to energy metabolism during the first day of life as indicated by the progressive decline in respiratory quotient (Noblet and Le Dividich, 1981; Berthon et al., 1993). In addition, the linear increase in the amount of fat oxidized with the amount of fat ingested suggests that the availability of fat is a major factor limiting oxidation and favors feeding high-fat colostrum to newborn pigs.

Implications

Newborn bottle-fed pigs have considerable capacity for ingesting colostrum during the first day of life, and voluntary colostrum intake is less dependent on its fat content. Further, accreted and oxidized fat are positively dependent on the intake of colostral fat. We suggest that increasing the fat content in colostrum

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Literature Cited


