Intestinal macromolecular transmission in newborn pigs: Implications for management of neonatal pig survival and health

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Abstract

The effect on intestinal macromolecular absorption capacity and immunoglobulin G (IgG) transfer of feeding sow colostrum at different intervals and in different quantities to newborn pigs was studied. An amount of 15 ml/kg body weight (BW) colostrum was fed at 3 (treatment 3–15), 6 (treatment 6–15) or 12 (treatment 12–15) h intervals, respectively, starting 0–4 h after birth for 24 h; or 30 ml/kg BW was fed at 6 h intervals (treatment 6–30) or 60 ml/kg BW at 12 h intervals (treatment 12–60), respectively. All studies had a split litter design. These pigs were compared to littermates kept with the sow (treatment With sow). The absorption of IgG and the capacity for macromolecular uptake into the blood at 12 h (BSA as marker) and at 24 h (HSA as marker) were measured at 3 h after marker feeding and followed to 48 h of age. Gavage feeding unsuckled pigs a total of 120 ml colostrum/kg BW divided into 4–8 feedings over the first 24 h after birth resulted in a blood plasma IgG profile at 48 h comparable to that of their suckling littermates. Pigs fed a total 24-h amount of 30 or 60 ml colostrum/kg BW, had significantly lower plasma IgG levels at 27 and at 48 h, respectively. Feeding these low quantities was enough to initiate closure, so that these pigs still had lower levels of circulating IgG at 48 h than their littermates, and they probably maintained these lower IgG levels throughout the sucking period. It was concluded that feeding 30 ml colostrum/kg BW 4 times over the first 24 h provided the pig with plasma IgG levels comparable to that of their suckling littermates.

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Keywords: Piglet; Immunoglobulin G; Intestinal transmission; Colostrum; Closure

1. Introduction

Cross-fostering is an accepted management tool in many herds. The aim is to provide evenly sized litters during suckling and at weaning, to reduce mortality in large litters, to handle surplus pigs because of diseases of the dam, and to reduce mortality and improve efficiency with regard to the handling of low vitality pigs. One problem is that the most efficient sows in a batch are frequently the sows that come first into heat and are bred, and then they also will farrow first. In addition, sows with large litters tend to have shorter

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gestation lengths (Svendsen and Olsson, 2003). Thus at batch farrowing, the litters from efficient sows, and the larger litters, are born first. Neonatal mortality increases with litter size, and the number of underprivileged pigs in a litter increases with the age of the sow, where usually older sows have large litters.

The colostrum and milk of the dam are the main sources of nutrition and passive immunity for the suckling pig. Therefore, the piglet is very dependent upon receiving the systemic protection to environmental pathogens provided by colostral antibodies from the dam before intestinal closure, and for receiving the local protection in the intestines provided by the antibodies and other factors in the milk both before and after closure. For a review on the acquisition of passive immunity in the newborn piglet see Rooke and Bland (2002).

In the newborn pig, macromolecules are unselectively transmitted across the intestinal wall to the blood. In suckling pigs, transmission then rapidly decreases, with intestinal closure well developed in most pigs after 18 h, and in all pigs after 36 h (Weström et al., 1984). Intestinal closure is present only in fed pigs (Lecce, 1973; Weström et al., 1984), and apparently requires about 12 h to develop (Lecce, 1966). The enterocytes of the small intestine continue to internalise macromolecules for 2–3 weeks after closure (Clarke and Hardy, 1971; Martinsson and Jönsson, 1976). Small amounts of macromolecules are transmitted to the blood of the growing pig throughout the suckling period and at least for some weeks after weaning (Svendsen et al., 1990).

Newborn pigs deprived of colostrum for 19–22 h show a decreased capacity for intestinal transmission (Svendsen et al., 1984), emphasizing the importance of an early, continual and sufficient supply of colostrum to these pigs. Since even small amounts of colostrum given to newborns will induce closure by 18–24 h (Leary and Lecce, 1978), a pig that has not been adequately fed before this time will not be able to obtain its proper supply of the necessary factors present in colostrum.

The present study is part of a larger investigation to determine an optimal management and feeding regimen for handling the “surplus” pigs in large litters that are born first in a batch farrowing system. The study presents the results of the effect on macromolecular intestinal absorption capacity and immunoglobulin G (IgG) transfer by feeding sow colostrum at different intervals and in different quantities to newborn piglets. The absorption of IgG and the capacity for macromolecular uptake into the blood circulation at 12 h (Bovine serum albumin [BSA] as marker) and at 24 h (Human serum albumin [HSA] as marker) was measured.

2. Material and methods

2.1. Animals and management

All pigs in this study were born and reared at Odarslöv research farm (Department of Agricultural Biosystems and Technology, Swedish University of Agricultural Sciences) in a closed herd. The pigs were cross-bred ((Yorkshire × Swedish Landrace) × Hampshire). Complete management, health and production data for the sows and their offspring were maintained. Farrowing was in an all in–all out unit with a thorough cleaning between batches. The pigs were weaned at 32 days.

A total of 75 piglets from 6 litters (sow age range: 2–10 litters) were studied in a split litter design. Thirty-seven pigs from 3 litters were used in Trial 1, and 38 pigs from 3 litters were used in Trial 2. In each trial, pigs from each litter were blocked by body weight and sex and then randomly assigned within block to the treatments outlined in Trials 1 and 2 (see below). In each trial, all 4 treatments were applied within each litter. Immediately after birth and before sucking, the pigs were removed from the sow and placed in the clean and straw bedded creep area at an environmental temperature of 28 °C. When farrowing was finished, after about 3–4 h, all pigs were weighed and all normal pigs of more than 1 kg were randomly distributed to the different treatment groups (Table 1); thus the unsuckled pigs were 0–4 h old at start of experiment.

2.2. Experimental trials

2.2.1. Trial 1

Study of the effect on macromolecular absorption capacity and IgG transfer to newborn piglets by feeding the same amount of colostrum at different intervals during the first 24 h, resulting in different total 24-h amounts.
Unsuckled littermates were randomly allocated to one of the 4 treatments as shown in Table 1.

2.2.2. Trial 2

Study of the effect on macromolecular absorption capacity and IgG transfer to newborn piglets by feeding different amounts of sow colostrum at different feeding intervals so that the total 24-h amounts given to the pigs in the different treatment groups were the same.

Unsuckled littermates were randomly allocated to 1 of 4 treatments as shown in Table 1.

2.3. Experimental procedures

2.3.1. Colostrum collection and gavage feeding

Pooled aliquots of 700–1000 ml colostrum per sow were obtained by manual milking during parturition and stored at 8 °C until use. At the start of the study (time 0), and during the study period, the pigs to be gavage fed were placed in a well bedded box under a heating lamp at 33 °C, where after they were returned to the sow for normal suckling. The pigs in the With sow group were given to the sow immediately (time 0) and had free access to the creep area. Using a stomach tube, the gavage fed pigs received colostrum from their respective dams that had been warmed to 38 °C in the amounts and intervals as specified in Table 1, for Trials 1 and 2, respectively. The intestinal transmission and uptake of these piglets were compared to that of littermates kept with the sow and suckling at will.

2.3.2. Intestinal transmission studies

The intestinal transmission of sow colostral IgG was determined as plasma levels at 3, 15, 27 and 48 h, respectively, after the start of the experiment. The capacity for macromolecular uptake at 12 h was determined as plasma levels 3 h after gavage feeding (at 12 h) 10 ml/kg BW of a BSA marker solution of 50 mg BSA (66 kDa, A-4503, Sigma-Aldrich Co., St. Louis, MI, USA) dissolved in 1 ml 0.9% NaCl (500 mg BSA/kg BW), as previously described (Weström et al., 1984). The capacity for macromolecular uptake at 24 h was determined as plasma levels 3 h after gavage feeding (at 24 h) 10 ml/kg BW of a marker solution of 50 mg HSA (67 kDa, Immuno AG, Vienna, Austria) dissolved in 1 ml 0.9% NaCl (500 mg HSA/kg BW).

2.4. Analyses

Blood samples were obtained in 2 ml tubes containing EDTA by puncture of the anterior vena cava at 3, 15, 27 and 48 h, respectively. Plasma was harvested after centrifugation at 3000×g and stored at −20 °C until analyses. Ten milliliter colostrum samples from each of the six sows were centrifuged at 20,000×g for 60 min at 4 °C, the lipid layer at the top and the bottom pellet were removed, and the remaining individual colostrum samples were stored at −20 °C until analyses.

The presence of IgG (mg/ml) in plasma and the centrifuged colostrum was analysed by single radial immunodiffusion (Fahey and McKelvey, 1965), using

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**Table 1**

Experimental design of feeding newborn piglets different amounts of sow colostrum during the first 24 h

<table>
<thead>
<tr>
<th>Treatment group, Trial 1</th>
<th>3–15, n=8</th>
<th>6–15, n=10</th>
<th>12–15, n=10</th>
<th>With sow, n=9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Received colostrum via</td>
<td>Gavage feeding</td>
<td>Gavage feeding</td>
<td>Gavage feeding</td>
<td>Natural nursing</td>
</tr>
<tr>
<td>Amount per feed</td>
<td>15 ml/kg BW</td>
<td>15 ml/kg BW</td>
<td>15 ml/kg BW</td>
<td>Ad libitum</td>
</tr>
<tr>
<td>Feeding interval, h</td>
<td>3</td>
<td>6</td>
<td>12</td>
<td>ca. 1</td>
</tr>
<tr>
<td>Age (h) at first feed after birth</td>
<td>0–4</td>
<td>0–4</td>
<td>0–4</td>
<td>0–4</td>
</tr>
<tr>
<td>Time of feeding, h</td>
<td>0, 3, 6, 9, 12, 15, 18, 21</td>
<td>0, 6, 12, 18</td>
<td>0, 12</td>
<td>Ad libitum</td>
</tr>
<tr>
<td>Total amount (ml/kg BW) of colostrum received</td>
<td>120</td>
<td>60</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatment group, Trial 2</th>
<th>3–15, n=8</th>
<th>6–30, n=10</th>
<th>12–60, n=10</th>
<th>With sow, n=10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Received colostrum via</td>
<td>Gavage feeding</td>
<td>Gavage feeding</td>
<td>Gavage feeding</td>
<td>Natural nursing</td>
</tr>
<tr>
<td>Amount per feed</td>
<td>15 ml/kg BW</td>
<td>30 ml/kg BW</td>
<td>60 ml/kg BW</td>
<td>Ad libitum</td>
</tr>
<tr>
<td>Feeding interval, h</td>
<td>3</td>
<td>6</td>
<td>12</td>
<td>ca. 1</td>
</tr>
<tr>
<td>Age (h) at first feed after birth</td>
<td>0–4</td>
<td>0–4</td>
<td>0–4</td>
<td>0–4</td>
</tr>
<tr>
<td>Time of feeding, h</td>
<td>0, 3, 6, 9, 12, 15, 18, 21</td>
<td>0, 6, 12, 18</td>
<td>0, 12</td>
<td>Ad libitum</td>
</tr>
<tr>
<td>Total amount (ml/kg BW) of colostrum received</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td></td>
</tr>
</tbody>
</table>
specific antibodies to porcine IgG prepared in rabbits (Carlsson et al., 1980). Quantitation of BSA (µg/ml) and HSA (µg/ml) in plasma was performed by electro-immunoassay (Laurell, 1966) using purified BSA and HSA, respectively (A-7638 and A-8763, Sigma-Aldrich Co.) as standards. Specific antisera to BSA and HSA were obtained from Dako A/S (Glostrup, Denmark). Total protein (TP) in the centrifuged colostrum was determined (mg/ml) according to Lowry et al. (1951) using BSA (fraction V, Sigma) as the standard.

2.5. Statistics

Blood plasma data were analysed following the GLM procedures of SAS (1982). The pig was the experimental unit. The following model was used to analyse data from the blood plasma studies:

\[ y_{ijkl} = \mu + p_i + t_j + s_k + e_{ijkl} \]

where \( y_{ijkl} \) is the \( ijk/l \) observation, \( \mu \) is the overall mean, \( p_i \) = effects of trial period (1, 2), \( t_j \) = effects of treatments (3–15, 6–15, 12–15, With sow, 6–30, 12–60), \( s_k \) = effects of sow No. (145:3, 169:10, 258:3, 247:3, 288:2, 212:8), \( e_{ijkl} \) = error.

A multiple \( t \)-test was used to examine pairwise differences.

The procedure for analysing pig growth followed the same basic model. All pigs had the same age at weaning so age was not included in the model.

3. Results

The number of pigs in each treatment group and production results from birth to weaning are shown in Table 2. There were no significant differences in weight gain from birth to weaning between treatment groups. Mortality was due to non-infectious causes (traumatic injuries, low birth weight, bleedings, other). One pig in treatment group 3–15 and one pig in treatment group 6–30 were treated with antibiotics because of joint infections.

The TP (mg/ml) content and the IgG content (mg/ml) in individual colostrum pools from the 6 sows are presented in Table 3. As observed, there were great differences in the content of TP and IgG between colostrum pools.

The piglet studies (Table 4, Fig. 1) in general showed that there were large individual differences within treatment groups with respect to the amount of IgG in the pig plasma. This was probably primarily due to the differences in colostral IgG levels between sows (Table 3). Gavage feeding, so that a total amount of 120 ml colostrum/kg BW was given during the first 24 h (Trial 2), resulted in approximately the same amounts of plasma IgG when measured at 27 h and at 48 h, respectively. These amounts were comparable to the IgG plasma levels observed in littermates with natural suckling (treatment With sow). Quantitatively, feeding 30 ml colostrum per kg BW at 6 h intervals

<table>
<thead>
<tr>
<th>Sow No.</th>
<th>Total protein (mg/ml)</th>
<th>IgG (mg/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>145:3</td>
<td>95.2</td>
<td>68.9</td>
</tr>
<tr>
<td>169:10</td>
<td>87.8</td>
<td>59.6</td>
</tr>
<tr>
<td>211:8</td>
<td>154.5</td>
<td>106.3</td>
</tr>
<tr>
<td>247:3</td>
<td>148.9</td>
<td>67.0</td>
</tr>
<tr>
<td>258:3</td>
<td>179.6</td>
<td>87.4</td>
</tr>
<tr>
<td>288:2</td>
<td>164.8</td>
<td>87.4</td>
</tr>
</tbody>
</table>

Table 2. Individual sow colostrum levels of total protein (mg/ml) and IgG (mg/ml)

<table>
<thead>
<tr>
<th>Treatment groups (Time interval [h]–amount of colostrum [ml/kg BW])</th>
<th>3–15</th>
<th>6–15</th>
<th>12–15</th>
<th>With sow</th>
<th>6–30</th>
<th>12–60</th>
<th>Significance*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total colostrum given (ml/kg BW)</td>
<td>120</td>
<td>60</td>
<td>30</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td></td>
</tr>
<tr>
<td>No. pigs</td>
<td>16</td>
<td>10</td>
<td>10</td>
<td>19</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Birth weight (kg), mean ± S.D.</td>
<td>1.2 ± 0.3</td>
<td>1.2 ± 0.3</td>
<td>1.3 ± 0.3</td>
<td>1.4 ± 0.3</td>
<td>1.3 ± 0.3</td>
<td>1.3 ± 0.3</td>
<td>n.s.</td>
</tr>
<tr>
<td>Weaning weight (kg), mean ± S.D.</td>
<td>7.9 ± 2.1</td>
<td>9.0 ± 1.8</td>
<td>9.0 ± 3.0</td>
<td>8.8 ± 1.4</td>
<td>8.2 ± 0.6</td>
<td>8.0 ± 1.4</td>
<td>n.s.</td>
</tr>
<tr>
<td>Preweaning death losses</td>
<td>3/16</td>
<td>1/10</td>
<td>1/10</td>
<td>3/19</td>
<td>2/10</td>
<td>1/10</td>
<td></td>
</tr>
</tbody>
</table>

* n.s. = means in a row are not significantly different (p > .05).

Table 3

Effect of gavage feeding different quantities of sow colostrum during the first 24 h after birth on the production and health of naturally reared pigs

* n.s. = means in a row are not significantly different (p > .05).
resulted in a similar or higher IgG uptake than did feeding 15 ml at 3 h intervals and 60 ml at 12 h intervals, respectively; however, there were only significant differences between treatments when measured at 15 h. In Trial 2, giving a total amount of 60 ml colostrum/kg BW during 24 h (treatment 6–15), and 30 ml (treatment 12–15), respectively, resulted in blood plasma levels of IgG at 15, 27 and 48 h which were significantly lower than for the other treatments (Table 4). The recorded IgG levels at 15, 27 and 48 h, respectively, were almost exactly double as high for treatment 3–15 pigs which received a total amount of 120 ml colostrum during 24 h as for the treatment 6–15 (total 60 ml per kg BW) pigs, and four times higher than for treatment 12–15 (total 30 ml per kg BW) pigs.

Studying the intestinal capacity for macromolecular transmission at 12 h by feeding BSA as a marker and analysing for the plasma levels of BSA at 15, 27 and 48 h for the different treatment groups, respectively, showed that the intestine was still open for macromolecular transmission at 12 h (Table 4, Fig. 2). Indeed, the BSA plasma levels at 15 h and at 27 h were similar indicating that the BSA marker was still being transmitted from the intestinal lumen to the blood later than 3 h after marker feeding. There were, however, great differences between pigs in the same treatment group, and between treatment groups (Fig. 2). The BSA transmission at 12 h was significantly lower in the pigs suckling the sow and in the 12–60 treatment group.

Table 4
Effect of giving different quantities of sow colostrum at different intervals during first 24 h after birth on the blood plasma levels of IgG, and on macromolecular uptake, where BSA was the marker at 12 h, and HSA was the marker at 24 h

<table>
<thead>
<tr>
<th>Treatment groups (time interval [h]–amount of colostrum [ml/kg BW])</th>
<th>3–15</th>
<th>6–15</th>
<th>12–15</th>
<th>With sow</th>
<th>6–30</th>
<th>12–60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total colostrum (ml/kg BW)</td>
<td>120</td>
<td>60</td>
<td>30</td>
<td></td>
<td>120</td>
<td>120</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time (h) of testing</th>
<th>IgG (mg/ml)</th>
<th>BSA (µg/ml)</th>
<th>HSA (µg/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
<td>15</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>27</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>15</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>15</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>27</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>12</td>
<td>60</td>
</tr>
</tbody>
</table>

Mean ± S.D. (n), where n = no. pigs examined.
* Means in a row with unlike superscripts are significantly different (p < .05).

Fig. 1. Effect of giving different quantities of sow colostrum to piglets during the first 24 h after birth on the blood plasma levels of IgG, measured at 3, 15, 27 and 48 h after birth, respectively. Treatment groups: time interval (h)–amount of colostrum (ml/kg BW).
It was noteworthy, however, that the 12–15 treatment pigs which had only received 15 ml colostrum per kg BW at the 12 h BSA marker feeding, also had reduced intestinal transmission (Table 4). These patterns of transmission remained the same at the 27 h and 48 h samplings, respectively.

The marker proteins BSA and HSA were fed in equal amounts and were expected to give similar values for intestinal transmission. Feeding HSA as a marker at 24 h in general showed (Table 4, Fig. 2) lower plasma levels, indicating that the intestinal closure process was well under way at that time for the pigs in the various treatment groups. Closure was almost completed at 24 h for the pigs with natural suckling (treatment With sow), and for the pigs that were given rather large quantities of colostrum at each feeding (treatments 6–30 and 12–60). For pigs only fed small quantities of colostrum over the 24 h (treatments 6–15 and 12–15), the closure process was not fully completed, and these pigs also showed higher transmission of the HSA marker molecule at 48 h. Due mainly to the great individual differences between pigs within treatment groups there were no significant differences between treatment groups.

4. Discussion

There is an abundance of general recommendations and knowledge about the handling and care of newborn pigs. However, neonatal mortality and morbidity is still a main factor limiting the economy of pig production. At a market price of 1.2€/kg dressing weight, each additional pig per sow per year means an increase in the economic return of that sow of 31.7€ (Udesen, 2001). The results from the present heightened research focus in breeding and nutrition on litter size, mothering abilities and milk production, can only come to practical use when matched with relevant basic and practical knowledge of how the newborn pig may best utilise the sow’s resources and be managed.

This study of the intestinal transmission of colostral immunoglobulins and other macromolecules as markers was designed to obtain information which may be useful to determine an optimal handling and feeding regime for “surplus” pigs in large litters in conventional pig production. With batch farrowing, the sows that have farrowed first often have large litters (Svendsen and Olsson, 2003), and therefore cross-fostering within the same batch of sows would not be possible. One or two days might elapse before there are sows with suitable litters available for the transfer of pigs. The results of the present study showed that gavage feeding unsuckled pigs a total amount of 120 ml of colostrum/kg BW divided into 4–8 feedings over the first 24 h after birth resulted in a blood plasma IgG profile at 48 h which was comparable to that of their freely suckling littermates. On the other hand, piglets fed a total 24-h amount of 30 and 60 ml colostrum/kg BW, respectively, had significantly lower plasma IgG levels at 27 and at 48 h, respectively. Indeed, within the limits of these studies, there appeared to be an almost direct, linear relationship between the amounts of colostrum given to the pig during the first 24 h and the plasma IgG level in blood samples at 15, 27 and 48 h, respectively. Feeding 30 and 60 ml colostrum/kg BW, respectively, during the first 24 h, therefore, was enough to initiate the closure process, with the result that the piglets, although they were permitted to nurse normally after 24 h, still had lower levels of circulating IgG at 48 h in comparison to their littermates, and probably main-
tained these lower IgG levels throughout the remainder of the suckling period.

Because the sow-reared piglets in this trial only consumed colostrum from their respective dams, the gavage fed pigs were also given colostrum from their respective dams. Since it has been observed that the IgG and IgA concentrations from different teat samples of the same sow may vary considerably (Svendsen and Brown, 1973), the pooled sow colostrum consisted of aliquots from 8 to 10 teats from each sow. The TP and IgG contents of the pooled colostrum from the different sows varied considerably, which is in accordance with previous publications (Klobasa and Butler, 1987; Klobasa et al., 1987; Weström and Svendsen, unpublished). The observed great individual differences within treatment groups with respect to the amount of IgG in the pig plasma probably primarily were due to the differences in colostral IgG levels between sows. Therefore, in the statistical model, the effects of the sows were also included.

It may be argued that if pooled colostrum from all the sows in the experiment had been used it may have equalized the amount of IgG given to each piglet, allowing a more precise comparison between treatment groups. However, this would require that all sows farrowed exactly at the same time, which in the experimental setting at hand was impossible without the use of medical intervention. Also, we wanted to compare the gavage fed pigs of a given sow with the natural suckled pigs of that sow.

In a study of the utilization of colostral energy by newborn pigs, Le Dividich et al. (1994) recommended a colostrum intake of 280 g/kg BW during the first 24 h after birth. The actual colostrum intake for normal suckling pigs has been shown to vary considerably. Bland et al. (1999) estimated the intake during the first 24 h to be 348 g/kg live weight, while 240 g/kg BW and 260 g/kg BW were reported by Le Dividich and Noblet (1981), and by Milon et al. (1983), respectively. In the present study, the maximum amount of colostrum given in the treatment groups in both trials was 120 ml/kg BW/24 h, which may then be assumed to be less than half of a “normal” consumption.

In the present study, 2–4 piglets per litter remained with the sow whilst the rest of the littermates were removed for 24 h and subjected to the different treatments. Under these circumstances, there would be sufficient colostrum available for nursing. Colostrum IgG concentrations change markedly with time during the initial suckling period (Klobasa et al., 1987); however, for the first 6–8 h, it was observed that these concentrations remained rather constant and high (Svendsen and Ewert, unpublished). Thus, the nursing pigs (treatment With sow) in this experiment would be expected to have obtained colostrum and IgG in much higher quantities than those given to the gavage fed treatment groups. It was interesting to note, therefore, that the 27 h IgG plasma levels for the 6–30 treatment group and the 48 h levels for all the treatment groups receiving 120 ml colostrum/kg BW during the first 24 h of life were approximately the same as for those in treatment With sow. As discussed previously, there were great individual differences within treatment groups, especially for the With sow treatment group, again underlining that natural suckling even during the best of circumstances provide the offspring with very different amounts of IgG.

The authors are well aware that porcine colostrum, in addition to immunoglobulins and nutritional factors (Le Dividich et al., 1997) contains many other components of importance for development and growth (Weström et al., 1985, 1987; Simmen et al., 1990; Reinhart et al., 1992; Jensen et al., 2001). In the present experiment we have limited ourselves to IgG studies as a marker for the acquisition of passive immunity, without which the newborn pig has few chances of survival under commercial conditions (Butler, 1979). A negative relationship between the development of active immunity and the acquisition of passive immunity in the pig has been reported by Klobasa et al. (1981). On the other hand, recent studies have implied (Rooke and Bland, 2002) that the amount of plasma IgG at 28 days of age, which includes newly synthesised IgG, is positively related to the maternal plasma IgG present at 7 days of age. When evaluating the effects of the acquisition of passive humoral immunity on the performance and health in pigs before weaning it is also important to bear in mind that a great many of the infections in suckling pigs are orally derived. Hence, passive and active local mucosal immunity is also very important to consider.

The studies using BSA as a marker showed that at 12 h of age, the intestine was still open for macromo-
molecular transmission. However, the closure process appeared to have been initiated in the suckling pigs, and possibly also in treatment group 12–60, which received the greatest amount of colostrum at the start of the experiment. It should be noted, however, that there were large individual differences between pigs. In addition, after feeding the BSA at 12 h, the pigs were also given different quantities of colostrum, depending on the experimental group. While it is recognized that colostrum enhances intestinal transmission (Weström et al., 1985), the different volumes of colostrum given in the various treatment groups might have also affected the distribution of the marker protein in the intestines, thus possibly also affecting transmission. As seen in Table 4 and Fig. 2, the 12–15 treatment group showed a rather lower intestinal transmission. These pigs had received 15 ml colostrum/kg BW at time 0 and again at 12 h, after receiving the BSA feeding, possibly receiving too little colostrum to fully enhance intestinal transmission. Marker feeding using HSA at 24 h was not affected by the various colostrum volumes given, since the pigs at this stage had been returned to the sow. After marker feeding at 24 h, it was obvious that the test groups receiving the most colostrum during the first 24 h had intestinal closure, whereas the groups receiving lowest amounts of colostrum (groups 6–15 and 12–15) still showed indications of macromolecular transmission. However, the closure process is still not fully understood. In the pig it has been suggested to be due to a humoral factor released in response to feeding (Leary and Lecce, 1978), apparently requiring approximately 12 h to develop (Lecce, 1966). Insulin may be one of the factors in the mechanisms regulating intestinal macromolecular transmission and closure (Svendsen et al., 1986), possibly being involved with the synthesis of membrane structural proteins in the intestinal enterocytes.

This study was designed to obtain more basic information about how different feeding routines affect IgG absorption and intestinal closure in neonatal pigs. It was concluded that feeding 30 ml colostrum/kg BW 4 times over the first 24 h provided the piglet with plasma levels of IgG comparable to that of suckling littermates. The results will be used in future studies on methods for the handling and feeding of “surplus” pigs in large litters in conventional production.

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