Early postnatal kinetics of colostral immunoglobulin G absorption in fed and fasted piglets and developmental expression of the intestinal immunoglobulin G receptor

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ABSTRACT: The transport of IgG across the epithelial barrier and into the circulation is achieved in part by the neonatal Fc receptor (FcRn), and this provides passive immunity to the neonate. The objective of this study was to determine the effect of time and feeding state on IgG absorption, intestinal morphology, and expression of IgG receptors in the first 24 h postbirth. Twenty newborn pigs were obtained immediately after birth and fitted with umbilical arterial catheters. Colostrum was manually collected from 12 lactating sows and centrifuged to produce defatted colostrum. Piglets were orally gavaged with 32 mL defatted colostrum per kilogram of BW (given in 2 doses 1 h apart) either at birth (0 h) or at 12 h postbirth under either fed (milk replacer) or fasted (saline solution) condition (n = 5 per treatment). A fifth reference group (n = 5) was euthanized at birth. Blood was collected every hour for the first 2 h immediately after the catheter was inserted and then every 4 h until 12 h (i.e., 0, 1, 2, 4, 8, and 12 h) for the treatment in which the defatted colostrum was given right after birth. For the treatment gavaged at 12 h postbirth, the sampling schedule was at 12, 13, 14, 16, 20, and 24 h. At 12 h postgavage, pigs were euthanized and jejunum tissues were collected for measurement of villi height, width, crypt depth, and gene expression of FcRn and β2-microglobulin (β2M) via reverse transcription PCR. Pig serum IgG concentration was determined by radial immunodiffusion. Data were analyzed according to a 2 × 2 factorial arrangement of treatments (0 h-fed, 0 h-fasted, 12 h-fed, and 12 h-fasted). There was no interaction between the time (age) of offering defatted colostrum (0 vs. 12 h) and nutritional state (fed vs. fasted) for any of the measurements, and there were no differences between fed and fasted pigs. Serum IgG concentrations increased progressively with time. Piglets offered defatted colostrum at 0 h had greater (P < 0.05) overall IgG absorption and greater (P < 0.05) villi height than those offered defatted colostrum at 12 h postbirth. Abundance of mRNA of FcRn and β2M were normalized to glyceraldehyde-3-phosphate dehydrogenase. Abundance of FcRn transcript was lower (P = 0.006) in pigs euthanized at birth compared with those euthanized at 12 h of age. In conclusion, the effects of delayed offering of defatted colostrum and age-dependent changes in IgG receptor were modest over the first 24 h of life.

Key words: colostral immunoglobulin G, immunoglobulin G receptor, serum immunoglobulin G

INTRODUCTION

Maternal antibodies play a prominent role in protecting neonatal piglets from infectious agents in the immediate days postbirth before they develop robust immunity of their own. Failure to passively transfer maternal antibodies can be devastating to the survival of the newborns (Ye et al., 2008). Neonatal piglets are born essentially agammaglobulinemic (Butler et al., 2002). Newborn piglets acquire IgG from colostrum by absorption through the intestine in the first 24 to 36 h after birth, at which time the transport phase ceases (Lecce et al., 1961, 1973; Hardy, 1969). The internalization of the macromolecules by enterocytes persists for an additional 2 to 3 wk (Clarke and Hardy, 1971; Lecce, 1973; Leary and Lecce, 1976).

Recent studies reported by Schnulle and Hurley
(2003) and Stirling et al. (2005) have shown that IgG is transported by the neonatal Fc receptor (FcRn), which is expressed in the mammary gland and intestine of adult pigs. In addition to its role in transporting IgG, FcRn appears to protect IgG and albumin from being degraded by the lysosomes (Brambell et al., 1964; Brambell, 1966; Ghetie and Ward, 2000; Chaudhury et al., 2003; Roope-nian et al., 2003; Simister, 2003). Similar to the major histocompatibility complex class I and its related molecules, FcRn is composed of a heavy chain that is noncovalently attached to a light chain β2-microglobulin (β2M) with a molecular weight of 12 kDa (Simister and Mostov, 1989; Burmeister et al., 1994). Apparently, the presence of the β2M is essential for FeRn to exit the endoplasmic reticulum (Burmeister et al., 1994; Zhu et al., 2002; Simister, 2003). Rodewald (1973) and Jones (1976) argued that a completely specific and separate system exists (although no specific description is offered) for internalizing and transporting IgG to the circulation.

The authors aimed to understand the physiological basis for intestinal closure. What are the external factors (state of feeding and time of ingestion of the first colostrum) that would accelerate or delay intestinal closure? Is intestinal closure receptor mediated in swine as it has been proven in neonatal rats? Colostrum itself plays a most important role in the induction of intestinal closure. The objective of this experiment was to examine the effects of feeding defatted sow colostrum to fed and fasted piglets on the time course of IgG absorption, jejunal morphology, and FcRn and β2M expression in the first 24 h after birth.

MATERIALS AND METHODS

All animal procedures were approved by the North Carolina State University Institutional Animal Care and Use Committee.

Colostrum Processing

Samples of colostrum were manually collected from 12 lactating sows at the North Carolina State University Swine Educational Unit over a period of 3 d (May 13, 14, and 15, 2009). Between 40 to 80 mL of colostrum was collected in separate 120 mL sample cups from various sows within 3 different phases of parturition: before farrowing, during farrowing, and after farrowing. The samples were individually labeled with the sow identification number and parity of the sow. Individual parities of the sows ranged from 1 to 7. Three colostrum samples were collected from Parity 1 sows, 11 samples from Parity 3 sows, 8 samples from Parity 4 sows, 4 samples from Parity 5 sows, and 1 sample from a Parity 7 sow. After collection, the colostrum samples were refrigerated or chilled in a cooler containing ice until laboratory processing could be performed. In the laboratory, 50 mL centrifuge tubes were filled with approximately 45 mL of the chilled colostrum samples in groups of 10. Tubes were centrifuged at 1,300 × g (IEC Centra GPR; DJB Labcare Company, Buckinghamshire, UK) for 35 min at 4°C to separate the colostrum into 2 distinct layers: an upper layer composed of fat and a protein rich lower layer (defatted colostrum), which contained large amounts of IgG. The defatted colostrum was collectively extracted from the tubes using a transfer pipette, pooled into a plastic storage container, and stored frozen at −20°C. Ultimately, 840 mL of the defatted colostrum was extracted from the overall colostrum samples obtained. The IgG concentration of the defatted colostrum (6,000 mg/dL in average for all samples) was analyzed using the radial immunodiffusion (RID) method adapted from Fahey and McKelvey (1963) and Mancini et al. (1965).

Blood Collection and Processing

Twenty colostrum-deprived pigs were catheterized immediately postfarrowing. Sow parturition was not induced for any of the sows and parturition was attended for all sows. The umbilical catheters were polyurethane single-lumen catheters, measuring 3.3 mm in diameter and 41 cm in length (Utah Medical Products, Inc., Midvale, UT). To insert the catheter into the portal vein, the cranial portion of the umbilical cord was cut about 5 cm from the belly of the pig, exposing the lumen of the umbilical vein. The catheter was inserted about 10 to 20 cm so that the tip of the catheter was in the portal vein. During this procedure (Benevenga et al., 1992), the pig was sedated with isoflurane. An intermittent injection cap (Jelco; Cardinal Health, Wright Clif, KY) was attached to the end of the catheter to facilitate the bleeding process through a needle and syringe. The catheters were both sutured and taped to the skin. Heparinized saline (2,000 IU heparin/L physiological saline) was used to flush the catheters. The average time from birth until the first blood withdrawal was 15 min. Blood was collected at time points 0, 1, 2, 4, 8, and 12 h whether or not pigs were gavaged with defatted colostrum at 0 or 12 h after birth. The collected blood samples were kept in ice until centrifugation at 1,300 × g for 25 min at 4°C and the plasma was then separated and frozen at −20°C until IgG analysis.

Pig Handling and Feeding

Pigs were collected immediately after they were born without being allowed to suckle from their dams. They were dried off, weighed (Model S200 scale; Central City Scale, Central City, NE), ear tagged, and immediately catheterized. After catheter placement, pigs were
allowed to recover under a heat lamp. The amount of defatted colostrum was analyzed for its IgG concentration (6,000 mg/dL on average) and was given at a dose of 32 mL/kg of BW (Bikker et al., 2010). This amount was divided and gavaged in 2 doses (due to the size of their stomach at birth) 60 min apart using orogastric feeding tubes measuring 41 by 3.3 mm (Kendall Dover Rob-nel; Tyco Healthcare Group LP, Mansfield, MS).

Piglets were gavaged according to a 2 × 2 factorial arrangement: 1) IgG gavaged at 0 h and then fed 20 mL of milk replacer (Advanced Birthright Nutrition, Inc., Delano, MN) at 2-h intervals until 12 h and then euthanized (averaged birth weight: 1.92 kg), 2) IgG gavaged at 0 h and then given 20 mL saline solution at 2-h intervals until 12 h and then euthanized (averaged birth weight: 1.67 kg), 3) IgG gavaged at 12 h and then fed 20 mL of milk replacer at 2-h intervals until they were euthanized at 24 h (before the administration of the IgG-rich portion, they were fed milk at 2-h intervals starting at birth; averaged birth weight: 1.43 kg), and 4) IgG gavaged at 12 h and then given 20 mL saline solution at 2-h intervals until they were euthanized at 24 h (before the administration of the IgG-rich portion, they were fed saline solution at 2-h intervals starting at birth; averaged birth weight: 1.67 kg).

Immunoglobulin G Determination

A RID assay was used to determine IgG concentration in the piglet serum and sow colostrum (Fahey and McKelvey, 1965; Mancini et al., 1965). Radial immunodiffusion is based on the diffusion of antigen from a circular well radially into a homogenous gel containing specific antiserum for a particular antigen (anti-porcine IgG). A circle of precipitated antigen and antibody forms circular well radially into a homogenous gel containing 0.002 mehtylenediaminetetracetic acid. After loading of 5 mL of pig serum per well (no dilution is needed), the plates are incubated for 24 h at room temperature. After that, the diameter of the ring was measured for each sample (24 samples/plate). The diameters of the rings are a function of antigen concentration and quantification was based on comparison with an external standard curve. The final IgG concentration of the pig serum samples and defatted colostrum was expressed as milligrams per deciliter.

Efficiency of Absorption

The efficiency of absorption of IgG was calculated by dividing the total calculated concentration of IgG in the serum of the pig by the amount supplied to each piglet × 100% as described by Bikker et al. (2010). The IgG concentration was measured in pig serum 12 h after offering the defatted colostrum to both treatments using the RID method.

Hematoxylin and Eosin Staining

Jejunum samples were collected (25 cm from the stomach) and preserved in a formalin solution and stored at room temperature for histology analysis (Corl et al., 2007). Tissues were trimmed into 5-mm thick sections and placed in processing cassettes. The tissues were processed in a Tissue-Tek VIP5 tissue processor (Sakura Finetek, Torrance, CA) using a standard overnight processing schedule. Tissues were embedded in paraffin and 5-μm sections were mounted on glass slides. The slides were stained on a DRS-601 slide stainer (Sakura Finetek, Torrance, CA) with hematoxylin and eosin, cleared, and mounted with a permanent media. The staining method involves application of hemalum, which is a complex formed from aluminum ions and oxidized hematoxylin. This colors nuclei of cells (and a few other objects, such as keratohyalin granules) blue. The nuclear staining is followed by counterstaining with an aqueous or alcoholic solution of eosin Y, which colors eosinophilic structures in various shades of red, pink, and orange. The stained tissues in glass slides were examined using a microscope (Olympus AH-2 Vanox-S Microscope; Ultrasonic Power Corporation, Freeport, IL) and measured using software (SPOT Imaging Solutions, Sterling Heights, MI).

RNA Extraction

We scraped the mucosa of the jejunum of 25 neonatal piglets (5 pigs at birth, 10 pigs at 12 h postbirth, and 10 pigs at 24 h postbirth) and then froze it in liquid nitrogen and stored it at –80°C until RNA extraction was performed. Total RNA from the jejunum mucosa of the pigs was extracted using an RNeasy kit (Qiagen, Germantown, MD). The total RNA was quantified using a spectrophotometer (NanoDrop Spectrophotometer2000C; Thermo Scientific, Wilmington, DE) and the quality was evaluated by 1.2% agarose gel electrophoresis. Intact 28S and 18S RNA were observed on the gel indicating minimal or no degradation of the RNA.

cDNA Synthesis

One microgram of total RNA was used to synthesize cDNA using the kit (High Capacity cDNA Reverse Transcription Kit; Applied Biosystems Inc., Foster City, CA) according to manufacturing recommendations.
Before use, cDNA was diluted 1:20 with filtered water (Milli-Q; Millipore Corp., Billerica, MA).

**Real-Time PCR**

Primers for the genes FcRn, \( \beta_2M \), and glyceraldehyde-3-phosphate dehydrogenase (GAPDH) were designed using a software program (Beacon Designer; Premier Biosoft International, Palo Alto, Ca; Table 1). The GAPDH was selected as the housekeeping gene because of its expression stability in different pig tissues (Foss et al., 1998; Garcia-Crespo et al., 2005). The optimum annealing temperatures were 57°C for FcRn, 58°C for \( \beta_2M \), and 58°C for GAPDH. Single reactions were prepared for each cDNA along with each serial of dilution using the mix (ABI SYBR Green Master Mix; Applied Biosystems Inc.). A negative control (no reverse transcriptase) was included to confirm the absence of genomic DNA. Each reaction was conducted in triplicate and consisted of 20 \( \mu L \) containing 1 \( \mu L \) of 1:20 diluted cDNA, 0.4 \( \mu L \) of forward primer, 0.4 \( \mu L \) of reverse primer, 0.2 \( \mu L \) of Fluorocein, 10 \( \mu L \) of the mix (ABI SYBR Green Master Mix; Applied Biosystems Inc.), and 8 \( \mu L \) of diethylpyrocarbonate water (Fisher Scientific, Pittsburgh, PA). The real time quantitative PCR (qPCR) was run (Bio-Rad iCycler iQ; Bio-Rad Laboratories), and the cycling program was reported by Hansen et al. (2009).

**Comparative Cycle Threshold Method**

Real-time PCR is a powerful tool to quantify gene expression. The quantitative endpoint for real-time PCR is the threshold cycle (\( C_T \)). The \( C_T \) is defined as the PCR cycle at which the fluorescent signal of the reporter dye crosses an arbitrarily placed threshold (Schmittgen and Livak, 2008). The numerical value of the \( C_T \) is inversely related to the amount of amplicon in the reaction (i.e., the lower the \( C_T \) the greater the amount of amplicon). We compared the change in \( C_T \) values (\( \Delta C_T \)) of 2 treatments (0 and 12 h) vs. control (birth) to determine the relative changes in expression for the FcRn and \( \beta_2M \) genes. Again they were both normalized to GAPDH.

The comparative \( C_T \) method makes several assumptions, including that the efficiency of the PCR is close to 1 and the PCR efficiency of the target gene is similar to the internal control gene (Livak and Schmittgen, 2001).

**Statistical Analysis**

The experimental design was a 2 × 2 factorial arrangement of treatments (offered defatted colostrum at 0 or 12 h under fed or fasted condition). Total IgG absorption and tissue histology were analyzed using the PROC GLM (SAS Inst. Inc., Cary, NC). Pig was the experimental unit. Birth weight was used as covariate. Least squares means were calculated and \( P < 0.05 \) was chosen to determine their significance. For analysis of gene expression, we used software (Relative Expression Software Tool; Pfaffl et al., 2002). Subsequently, the expression ratio results of the 4 investigated transcripts were tested for significance by a randomization test.

**RESULTS**

There was no interaction between the time of offering defatted colostrum and the status of feeding (fed or fasted). Pigs offered defatted colostrum at 0 h after birth had a greater serum IgG concentration (Fig. 1) compared with pigs offered defatted colostrum 12 h after birth (1,290 vs. 1,026 mg/d; \( P < 0.05 \)). Serum IgG concentration was measured in both treatments 12 h after the defatted colostrum was offered. There was a delay of 2 h in detecting any serum IgG concentration for those pigs offered defatted colostrum and the status of feeding (fed or fasted). Pigs offered defatted colostrum at 0 h after birth had greater serum IgG concentration (Fig. 1) compared with pigs offered defatted colostrum 12 h after birth (1,290 vs. 1,026 mg/d; \( P < 0.05 \)). Serum IgG concentration was measured in both treatments 12 h after the defatted colostrum was offered. There was a delay of 2 h in detecting any serum IgG concentration for those pigs offered defatted colostrum at 0 h after birth. This delay was longer (4 h) for those pigs offered defatted colostrum 12 h after birth. The efficiency of serum IgG transported to the blood stream (Fig. 2) was calculated 12 h after defatted colostrum was offered to both treatments. Pigs offered defatted colostrum at 0 h after birth had greater serum IgG concentration in their serum compared with those offered defatted colostrum 12 h after birth (21.5 vs. 17.1%, respectively). Pigs offered defatted colostrum at 0 h after birth had greater serum IgG concentration in their serum compared with those offered defatted colostrum 12 h after birth (21.5 vs. 17.1%, respectively).

**Table 1. Real-time PCR primers**

<table>
<thead>
<tr>
<th>Genes</th>
<th>Primer sequence</th>
<th>Accession no.</th>
<th>Product length, bp</th>
</tr>
</thead>
<tbody>
<tr>
<td>FcRn</td>
<td>F: 5′-CCTCCTGATATACATGGC-3′ R: 5′-TGAAACAATGAGAACACAAA-3′</td>
<td>AM40682.1</td>
<td>82</td>
</tr>
<tr>
<td>( \beta_2M )</td>
<td>F: 5′-GGCTGCTCTCAGTGCTG-3′ R: 5′-AGTTACAAGATTTGTCTC3′</td>
<td>NM213978.1</td>
<td>102</td>
</tr>
<tr>
<td>GAPDH</td>
<td>F: 5′-ACACTACTCTTCTACTCTTG-3′ R: 5′-CAAATTCATTGTCGTACCAG-3′</td>
<td>DQ845173.1</td>
<td>90</td>
</tr>
</tbody>
</table>

1Sigma Genosys, Woodlands, TX.
2FCRn = neonatal Fe receptor; \( \beta_2M = \beta_2 \)-microglobulin; GAPDH = glyceraldehyde-3-phosphate dehydrogenase.
3F = forward; R = reverse.
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There were no differences between the 2 treatments in jejunal villi width and crypt depth measurements.

The gene expression of FcRn of 12-h-old pigs was upregulated by 1.8-fold \((P = 0.006)\) over pigs at birth (Fig. 4). In contrast, FcRn expression in 24-h-old pigs was not different \((P = 0.928)\) from pigs at birth. There was no difference among treatments in the expression of \(\beta_2\)M (data not shown).

**DISCUSSION**

Colostrum itself plays a most important role in the induction of intestinal closure. The formation of colostrum in the sow starts about 1 mo prepartum with an intensive transfer of immunoglobulins from the serum to the udder (Jonsson, 1973). This process virtually ceases after parturition, resulting in a sharp decrease of the IgG concentration in the colostrum (Frenyo et al., 1980; Klobasa, 1986). These authors also confirmed that IgG absorption by the piglet starts declining 24 h postpartum. Blecha (1998) indicated that the IgG concentration of colostrum is greatest during the birth process and decreases during the first day of lactation.

Butler et al. (2002) reported that low amounts of maternal IgG may be passed to the fetus through the placenta. Le Dividich et al. (2005) found that immunoglobulin transfer via the placenta is negligible. We were unable to detect any IgG that may have passed from the placenta to the fetus immediately after birth (Fig. 1). These findings confirm that neonatal piglets at birth possess almost no serum immunoglobulin and undetectable concentrations of specific antibodies. There was a delay of 2 h on detecting any serum IgG concentration for those pigs offered defatted colostrum at 0 h after birth. This delay was longer (4 h) for those pigs offered defatted colostrum 12 h after birth. Werhahn et al. (1981) reported that labeled porcine IgG was found in the blood of artificially reared piglets as early as 4 h after administration.

The efficiency of porcine IgG transported to the blood in our study did not differ between fed and fasted animals. This is consistent with data reported by Werhahn et al. (1981). They reported that piglets starved for 24 h had absorbed no less IgG than those given IgG the first 2 to 4 h after birth. They also reported that absorption ability was preserved in piglets starved for 106 h after birth and merely given water 3 times a day.

The offering of the defatted colostrum at birth (0 h treatment) vs. waiting 12 h (12 h treatment) yielded 4.4% more IgG transported to the blood (21.5 vs. 17.1%), perhaps because of the greater jejunal villi of 0 h treatment pigs. We assume that the larger the jejunal villi, the greater the absorption of nutrients (e.g., IgG) present in the defatted colostrum. These results are consistent with
those reported by Leary and Lecce (1979). They gavaged piglets with 500 mg of porcine IgG plus 500 mg of bovine albumin and they observed a 21.7% increase in the IgG transported to the blood. They also gavaged piglets with 500 mg of porcine IgG plus 500 mg of porcine albumin and observed a 17.6% increase in the IgG transported to the blood. By some unknown mechanism, bovine colostrum, when compared with mature milk, is able to augment the absorption of porcine IgG (Werhahn et al., 1981). Bikker et al. (2010) removed piglets from dam before suckling and allocated them to 5 treatments. Piglets received either 28 g of standardized sow colostrum per kilogram of BW (control) or 1 out of 4 products containing porcine IgG and fats, porcine IgG and glycine, porcine IgG and dextrose and fat, and porcine IgG and dextrose and dried fat. After 12 h of fasting, during which only water was given to all groups, they recorded the efficiency of IgG absorption to be 19.5, 22.8, 14.5, 27.7, and 4.8%, respectively, for all groups. They concluded that the absorption of IgG from a single dosed oral supplement of a porcine plasma-derived product can be as great as or greater than IgG absorption from a single dose of sow colostrum.

Newborn piglets acquire IgG from colostrum by absorbing it through the intestine over a period of nearly 36 h postpartum. We argue that this time may be shorter than we anticipated. Our data indicate that there is a downregulation of the FcRn receptor 24 h postpartum. Epithelial cells of neonatal rodents possess specific IgG receptors, which disappear in parallel to the waning of neonatal absorption (Guyer et al., 1976; Borthistle et al., 1977). Whether the gut could indefinitely retain the capacity to absorb IgG in the absence of ingested food remains questionable and unknown from our findings.

Various researchers (Kraehenbuhl and Campiche, 1969; Staley et al., 1969; Rodewald, 1973) have indicated that the lost absorptive capacity of the gut of the piglet must not depend solely on a change in the gut epithelial cells. Kraehenbuhl and Campiche (1969) argued that closure may involve a change not in the uptake by gut cells of IgG but rather a change in the intracellular enzymatic activity of the gut cells. The other issue in question is to recognize whether there are differences in absorption among the different IgG subpopulations. We did not consider such differences in the design or the interpretation of our results.

Many researchers (Moon, 1971; Smith and Jarvis, 1978; Carlile and Beck, 1983; Smith, 1985) have conducted trials to determine whether gut closure is a function of immature cells being replaced by mature cells in the small intestine. This effect seemed to be answered by Rundell and Lecce (1971), who concluded that intestinal epithelial cell turnover and closure are not related to one another in species other than the rat. They performed combined autoradiographic and fluorescent absorption marker studies on neonatal mice, hamsters, rabbits, guinea pigs, and pigs. Their findings yielded 2 specific outcomes: 1) the turnover time of porcine intestinal epithelium is about 5 d and 2) closure (uptake and transport) occurred before the initial cell population was replaced.

On the other hand, Clarke and Hardy (1971) argued that the process of incorporation of IgG into the circulation of neonatal pigs stops when the enterocytes are unable to discard the absorbed IgG through the lateral or basal membranes. The work of Moon (1971) supported findings by Lecce and Rundell (1972). Moon (1971) conducted an autoradiographic study injecting tritiated thymidine into intestinal epithelium. He found that the jejunal-ileal epithelial cells were not extruded at 2 or 3 d age according to research in rats, but the cells remained on the villi for 7 to 10 d, an age that is beyond the normal onset of closure. This conclusion is in agreement with the work of other researchers (Clarke and Hardy, 1971; Lecce, 1973) who reported that the neonatal piglet could still take up but not absorb macromolecules for several days after closure.

Smith and Jarvis (1978) conducted a similar study supporting the findings by Moon (1971). In a similar study using tritiated thymidine, they found that labeled cells originated in the crypts and migrated onto the villi at a rate of 0.4 cells/h. This rate remained unchanged and independent of the area of the small intestine throughout the first 4 d postpartum. They concluded that the cessation of uptake and the acquired resistance of piglets to viral insult were dependent on the final disappearance of cells that were present at birth in the neonatal pig intestinal epithelium.

The ages at which macromolecular uptake stops and the intestinal epithelium of the neonatal is replaced seem to be the same. However, closure seems to occur independently of both mechanisms. We could then hypothesize that similar to the intestinal epithelial cells of the rats, the intestinal epithelial cells of the neonatal pig retain their capacity to take up macromolecules throughout their lifespan but, unlike the rat, they lose their ability to transport macromolecules to the circulation some time before they are shed from the villi.

In summary, the greatest IgG absorption was attained when piglets were given colostrum immediately after birth. Pigs supplemented at birth had higher villi height than those supplemented at 12 h after birth. They also had a greater percentage of IgG transported in the blood when compared with those supplemented at 12 h after birth. The relative FcRn expression increased transiently in 12-h-old pigs when compared with the other treatments. The results indicate that if there is an interest in supplementing a sow/bovine colostrum supplement to piglets to improve their immune status, the recom-
mended time to gavage is immediately at birth. We are not aware of any other studies reporting similar findings on the FcRn expression in jejunal tissues under fed and fasted conditions in neonatal pigs. Further studies are needed to examine the other mechanisms proposed that a specific and separate system exists for internalizing and transporting IgG to the circulation. Whether absorption of IgG by the neonatal piglet is receptor mediated or mediated by a specific or separate system, the whole mechanism is reasonably complicated and highly regulated.

**LITERATURE CITED**


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