INFLUENCE OF ENVIRONMENTAL TEMPERATURE DURING LATE GESTATION AND SOON AFTER BIRTH ON IgG ABSORPTION BY NEWBORN PIGLETS

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The possibility that environmental temperature, in late gestation or soon after birth, can modify the ability of the newborn piglet to absorb immunoglobulin G (IgG) was studied. Fifteen pregnant Yorkshire sows were exposed to either 5 or 18°C from day 104 postbreeding until 6 h postpartum, at which time they were moved to a normal 18°C farrowing room. All sows were bled to determine serum concentration of cortisol. At birth, the piglets were assigned to either a 14 or 35°C environment for 6 h. The piglets were force-fed bovine colostrum four times during the first 6 h of life and bled nine times between birth and day 21 to determine the concentrations of serum porcine and bovine IgG. The concentration of serum cortisol, in the sows subjected to the 5°C environment, increased in response to treatment. Cortisol concentrations remained elevated until the sows returned to the 18°C environment. Piglets from sows maintained at 5°C had marginally higher concentrations of serum bovine IgG than piglets from control sows. Exposure of piglets to 14°C at birth reduced absorption of IgG; however, they continued to absorb IgG after they were moved to a thermoneutral environment. By 21 days, only those piglets from sows exposed to 5°C showed a significant productionof IgG. Piglets from sows exposed to 5°C and maintained at 35°C after birth had the highest serum concentration of IgG. These results indicate that environmental temperature during late pregnancy can modify IgG absorption by newborn piglets.

Key words: Immunoglobulins, colostrum, absorption, cortisol, piglet

[Influence de la température ambiante à la fin de la gestation et peu après la naissance sur l'absorption de l'IgG chez les porcelets.]

Titre abrégé: Influence de la température sur l'absorption de l'IgG chez les porcelets.

Nous avons voulu vérifier s'il était possible que la température ambiante, à la fin de la gestation on peu après la naissance, puisse influer sur l'aptitude des porcelets à absorber l'ummunoglobuline G (IgG). Quinze truies Yorkshire gravides ont été réparties en deux groupes, l'un gardé à 5 et l'autre à 18°C, du 104e jour de la gestation jusqu'à six heures après la mise bas. Elles ont ensuite été transférées dans une chambre de mise bas normale à 18°C. Toutes les truies ont été saignées pour la détermination de la teneur de leur sérum en cortisol. Dès leur naissance, les porcelets ont été gardés pendant six heures à une température ambiante de 14 ou de 35°C. Ils ont été gavés de colostrum bovin quatre fois durant les six premières heures de leur vie et saignés neuf fois entre la naissance et l'âge de 21 jours pour la détermination des teneurs du sérum en IgG porcine et bovine. La teneur en cortisol du sérum était plus élevée chez les truies gardées à une température ambiante de 5°C. Elle est demeurée élevé jusqu'au transfert des truies à 18°C. Les porcelets des truies gardées à 5°C présentaient des teneurs en IgG bovine du sérum très légèrement

supérieures à celles des porcelets des témoins. Les porcelets placés à une température de 14°C à leur naissance ont montré une baisse de l'absorption d'IgG. Ils ont toutefois continué à absorber l'IgG aprés leur transfert à une température normale. À 21 jours, seuls les porcelets des truies gardées à 5°C présentaient une production significative d'IgG. Les teneurs les plus élevées du sérum en IgG ont été observées chez les porcelets des truies gardées à 5°C et qui avaient été placés à 35°C après leur naissance. Nos résultats démontrent que la température ambiante à la fin de la gestation peut influer sur l'absorption de l'IgG chez les porcelets.

Mots clés: Immunoglobulines, colostrum, absorption, cortisol, porcelet

The quality of the environment in which an animal lives influences many physiological functions and has a profound effect on the animal's performance (Curtis 1981). The immunological status of the newborn is no exception. Young piglets depend upon maternal colostrum to passively acquire immunoglobulins (Butler et al. 1981) before their own reticuloendothelial system becomes fully operational.

The absorption of immunoglobulins from colostrum is determined by the capacity of the small intestine to take up and transport macromolecules from the intestinal contents to the circulatory system (Moog 1979). The exact mechanism which prevents the transfer of macromolecules through the intestinal epithelium is not clear. However, it has been demonstrated that the uptake of macromolecules in the pig depends on the presence of fetal enterocytes in the small intestine, and this process will cease only when these fetal enterocytes are extruded from the villi and replaced by mature ones (Patt 1977). At the time of replacement a significant reduction in the risk of pathogenic infection will occur (Smith and Peacock 1980).

Cold stress following birth can affect acquisition (Blecha and Kelley 1981) but not absorption of immunoglobulins (Kelley et al. 1982) by piglets. Since there is a lack of information on the effects of environmental stress prior to birth on the capacity of the newborn pig to absorb IgG, the present study was conducted to determine if cold stress applied to the pregnant sow or to the newborn piglet could affect the capacity of the piglet to absorb IgG from ingested colostrum.

MATERIALS AND METHODS

Fifteen pregnant Yorkshire sows from the Arkell Swine Research Centre of the Ontario Ministry of Agriculture and Food were randomly allocated to either a cold or a thermoneutral environment. All sows were cannulated through the ear vein on day 102 of gestation and allowed to rest for 2 days. During this period the sows were kept in farrowing crates within a farrowing room maintained at 18°C and 37% RH. This room also served as the control environment for the experiment. The cold chamber was equipped with cooking and humidity control units which allowed it to be maintained at 5°C with 63% RH. Within the cold room, eight 0.65 × 2.1-m gestation stalls were used to house the sows. Before moving the respective sows to the cold chamber on day 104 of gestation 10 mL of blood were taken from each sow. Control sows were also bled at this time but not moved. Thereafter, all sows were bled through the cannulae twice daily until day 5 postpartum, between 0730 and 0830 h and 1930 and 2030 h.

At birth, the piglets were taken from the sows, identified, weighed and bled from the suborbital sinus with a 2.5-cm × 20-gauge needle. Alternate piglets were allocated, irrespective of sex, to either a 14°C (cold) or a thermoneutral 35°C environment for 6 h. Cold-exposed sows were moved to farrowing crates in the control room after farrowing. Each piglet was returned to its respective sow at 6 h of age.

During the 6 h of separation from the sow, the piglets were force-fed from a pool of cow colostrum at a rate of 25 mL/kg of body weight. Feeding took place at 0.5, 2, 4 and 6 h of age. The colostrum was maintained frozen in 150-mL aliquots in sterilized plastic bags until farrowing commenced. After each pig was born, enough colostrum was thawed and warmed to 37°C before use. Piglets were bled and weighed again at 6 h, 1, 2, 4, 8, 12, 16, and 21 days of age.

Three piglets were taken from each of the three cold-exposed and four control sows' litters and

sacrificed at birth or at 6 h of age. The small intestines of these piglets were excised and preserved for future microscopic analysis. To select these pigs, the seventh pig born alive was sacrificed at birth and two random pigs were sacrificed at 6 h (one from each treatment). These data are not included in this report. Therefore, only 55 of the 64 piglets born in the cold and 59 of the 71 born in the control room are included in the present study.

Blood samples from the sows and piglets were cooled to 4°C within 1 h of collection, allowed to clot for 24 h, centrifuged for 10 min and the serum separated into plastic vials, frozen and stored at −17°C until analyzed. Sow serum was analyzed for cortisol using a solid phase RIA developed by Micromedics System Ind. (Horsham Pa.). The piglet serum was analyzed for bovine and porcine IgG using a modification (Bate and Hacker 1985) of the radial immunodiffusion procedure developed by Mancini et al. (1965).

The experiment was designed as a split plot, where sow housing temperatures constituted the main plots and the temperatures to which the piglets were exposed constituted the subplots. Data were analyzed statistically using a general linear models SAS computer program (Goodnight 1979).

RESULTS

The concentrations of serum cortisol were the same for both groups of sows before applying the cold stress (Fig. 1). Within 12 h of exposure to cold stress, the serum cortisol concentration almost doubled in the cold stressed group in comparison to that of the controls ($P<0.05$). This difference was maintained throughout the time the sows were kept at 5°C. Thirty-six hours prior to parturition, the serum levels of cortisol increased in both groups ($P<0.01$) and subsequently returned to basal levels within 12 h after farrowing. The cortisol levels were similar for both experimental groups following the sows' transfer to the 18°C environment.

The concentration of bovine IgG was higher in serum of piglets from sows housed at 5°C than in piglets from control sows (Fig. 2A). This difference was only signif-

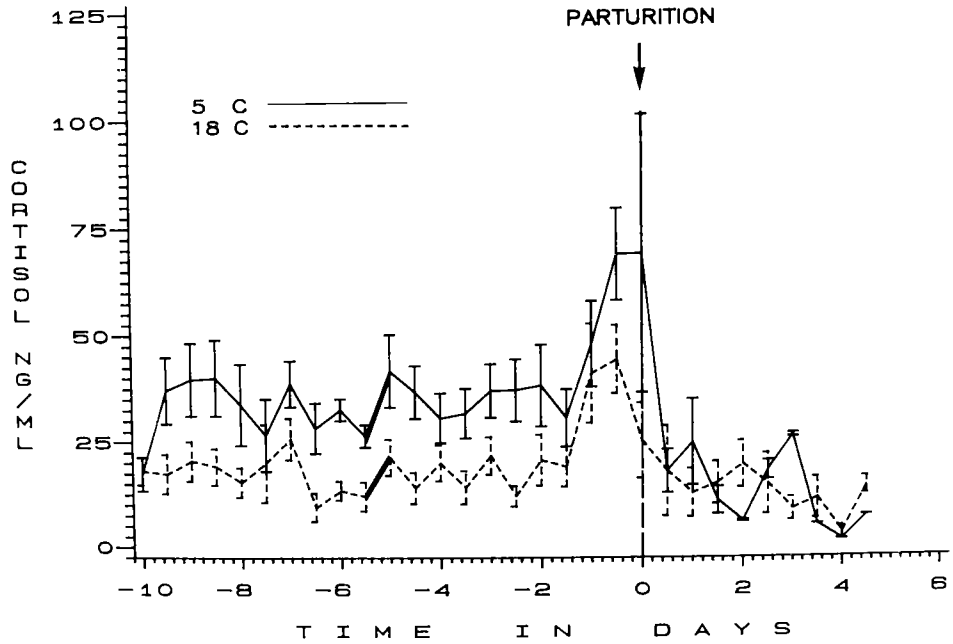

Fig. 1. Pre- and postpartum serum concentration of cortisol in sows exposed to 5°C (———) or 18°C (- - - - -) during the last 10 days of pregnancy. The thick line joins the 10th sample after beginning of infusion and the 10th sample prior to parturition.

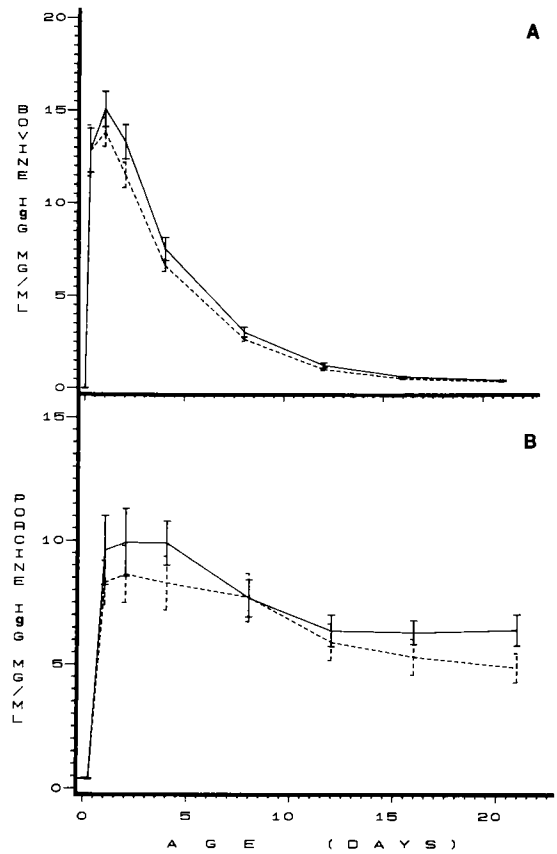

Fig. 2. Serum concentration of bovine IgG (A) and porcine IgG (b) in piglets from sows exposed to 5°C (———) or 18°C (- - - - -) during the last 10 days of pregnancy.

icant on the second day ($P<0.05$). A similar trend was found for porcine IgG (Fig. 2B). By the third week postpartum only the piglets from cold-exposed sows produced their own IgG in quantities sufficient to overcome the normal catabolism of IgG. On day 21 postpartum these piglets had higher ($P<0.05$) serum porcine IgG than those piglet born to control sows.

Cold-stressed piglets absorbed less bovine IgG within the first 6 h of life than piglets maintained at thermoneutrality ($P<0.05$) (Fig. 3A). Moreover, the piglets maintained at thermoneutrality, but from mothers who were cold-stressed, reached by day 1 and sustained until day 4, higher concentrations ($P<0.01$) of serum bovine IgG than those piglets maintained at thermoneutrality but born from control sows.

After cold-stressed piglets were removed from the cold, their serum concentrations of bovine IgG increased, reaching maximum levels at 1 day of age. No differences in IgG concentration existed at any time between cold-stressed pigs whose mothers were either cold-stressed or controls.

In all experimental groups, the concentration of porcine IgG followed a similar pattern to that observed for bovine IgG (Fig. 3B). No differences in birth weight existed as a consequence of sow treatment or thereafter, as a consequence of piglet treatment.

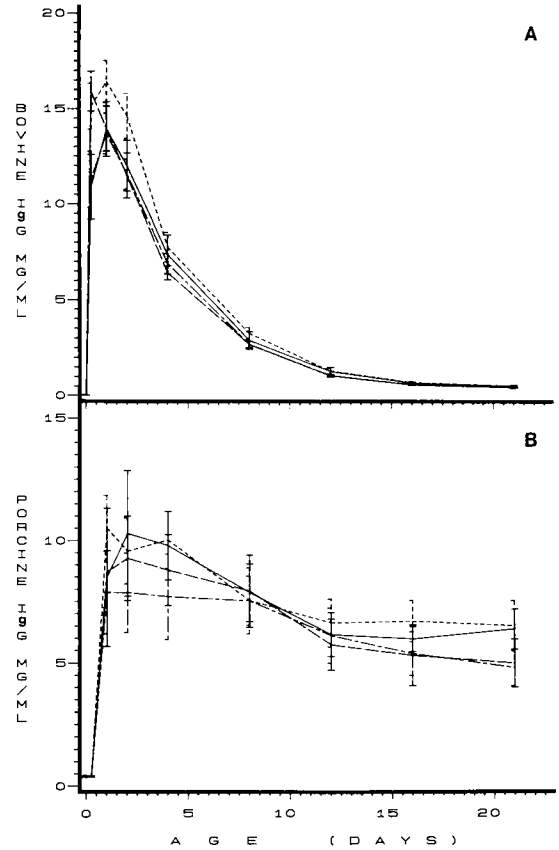

Fig. 3. Serum concentration of bovine IgG (A) and porcine IgG (B) in piglets maintained for 6 h at 14°C and delivered by sows kept at 5°C (————) or 18°C (— . —. —) and in piglets maintained for 6 h at 35°C and delivered by sows at 5°C (- - - - -) or 18°C (— — — —).

The stillbrith rate was 9.8 and 9.58% for litters from cold-exposed and control sows, respectively. The mortality until 3 wk, excluding the sacrified piglets, was 7.04 and 9.85% for the respective groups ($P>0.05$). Piglets which died during the experiment did not gain weight after birth (Table 1). During the first day of life, the concentration of serum bovine IgG was similar among piglets which died and those which survived, whereas the serum concentration of porcine IgG was lower ($P<0.05$) in the piglets which did not survive (Table 1).

No correlation was found between the serum level of cortisol in the pregnant sows and the serum concentration of either bovine or porcine IgG in their piglets. Neither sex, nor the order of birth influenced the serum IgG concentration in the newborn piglets.

DISCUSSION

A preparturient rise in serum cortisol has been reported previously in cold-stressed sows (Rafai and Fodor 1980) and in sows maintained at ambient temperature (Baldwin and Stabenfeldt 1975). Exposure of sows to cold stress during late gestation may be responsible for the improved absorptive capacity suggested by the in-

Table 1. Average weights (kg) concentration of BIgG† and PIgG‡ (mg/mL) in piglets which survived or died during the experimental period

	Treatments											
	5°C						18°C					
	Survived			Died			Survived			Died		
Time	*n*§	Wt	SE	*n*	Wt	SE	*n*	Wt	SE	*n*	Wt	SE
0 h	50	1.26	0.04	5	1.20	0.15	52	1.33	0.04	7	1.13	0.14
6 h	50	1.28	0.04	4	1.14	0.15	52	1.32	0.03	7	1.16	0.13
1 day	50	1.37	0.04	2	1.12	0.31	52	1.41	0.04	3	1.01	0.22
2 days	50	1.47	0.05	1	0.83		52	1.51	0.04	2	1.33	0.18
4 days	50	1.76	0.05				52	1.78	0.05	1	1.60	
Time	*n*	BIgG	SE	*n*	BIgG	SE	*n*	BIgG	SE	*n*	BIgG	SE
0 h	50	0.00	0.00	5	0.00	0.00	52	0.00	0.00	7	0.00	0.00
6 h	50	14.88	0.94	4	9.88	2.36	52	15.11	0.76	7	12.54	3.59
1 day	50	16.16	0.77	2	17.96	1.56	52	14.22	0.56	4	9.90	2.84
2 days	50	13.41	0.66				52	11.72	0.53	2	9.70	1.29
4 days	50	7.51	0.43				52	6.60	0.29	1	4.99	
Time	*n*	PIgG	SE	*n*	PIgG	SE	*n*	PIgG	SE	*n*	PIgG	SE
0 h	50	0.37	0.01	5	0.32	0.03	52	0.38	0.01	7	0.39	0.01
6 h	50	0.37	0.01	4	0.34	0.04	52	0.33	0.01	7	0.40	0.01
1 day	50	13.38	0.80	2	1.33	1.06	52	13.02	0.86	4	6.26	2.03
2 days	50	13.01	0.75				52	12.44	0.84	2	8.08	1.74
4 days	50	10.47	0.57				52	10.68	0.80	1	7.02	

†Immunoglobulin G of bovine origin.
‡Immunoglobulin G of porcine origin.
§Number of piglets.

creased IgG serum concentration in pigs born to these sows. Whether this phenomenon was mediated through glucocorticoids cannot be confirmed due to the lack of correlation between the concentration of cortisol in sows and the average concentration of IgG in the piglets. However, a similar increase in piglet serum IgG resulted from direct activation with ACTH of the pregnant sow adrenal (Bate and Hacker 1985).

The lower serum bovine IgG concentration measured in piglets exposed to 14°C could be attributed to a reduction in blood flow to the small intestine, rather than a decreased absorptive capacity. A shift in circulation, caused by cold stress, has been demonstrated in dogs (Griffin et al. 1960) and sheep (Schaefer and Young 1980). In contrast, a prolonged but moderated cold stress (21°C) did not affect the absorptive capacity of IgG in newborn pigs (Kelley et al. 1982). The fact that the serum concentration of bovine IgG increased rapidly upon transfer of piglets from a cold to a normal room suggests that the reduction in absorption is not mediated by changes in the epithelium of the small intestine. Apparently 14°C was cold enough to force a shift in blood circulation within the piglets.

The fact that piglets from cold-stressed sows, who were maintained at thermoneutrality after birth, have the highest IgG profile of the four groups reinforces the suggestion that prepartum exposure of the sow to cold may prove beneficial for the piglets as long as they are provided with a favorable environment at birth.

The loss of weight after birth, and the low concentrations of porcine IgG in the piglets which died, indicate that those piglets suckled little or none from the sow before death. Therefore, their death could not be attributed to a reduced absorption of IgG but rather to a lack of ingestion of colos-

trum or to some other predisposing factor.

Early production of IgG in piglets born to cold-stressed sows, in quantities sufficient to overcome the rate of catabolism, is another beneficial effect of the cold treatment of sows and may prove important at weaning. This finding is of special importance considering that it contradicts the reported fact that the onset of IgG production is directly related to the magnitude of the peak concentration attained by passive acquisition of serum IgG (Klobasa et al. 1981). This finding brings forth the possibility of having piglets which are better protected soon after birth and also at weaning.

The delayed immunoglobulin production by newborn piglets has been attributed to inefficient differentiation of B lymphocytes (Namioka et al. 1983). It is possible that glucocorticoids, or other undetermined substances produced by animals under cold stress, could stimulate early B lymphocyte differentiation in utero, with the consequent premature production of porcine IgG.

It can be concluded from this study that exposure of pregnant sows to adverse environmental conditions, such as cold during the last 10 days of gestation, can improve the absorption rate of IgG by the newborn piglet. However, although this may help, it does not necessarily guarantee an increase in the overall rate of survival.

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Baldwin, D. M. and Stabenfeldt, G. H. 1975. Endocrine changes in the pig during late pregnancy, parturition and lactation. Biol. Rep. **12**: 508–515.

Bate, L. A. and Hacker, R. R. 1985. The influence of the sow's adrenal activity on the ability of the piglet to absorb IgG from colostrum. Can. J. Anim. Sci.**65**: 77–85.

Blecha, F. and Kelley, K. W. 1981. Cold stress reduces the acquisition of colostral immunoglobulin in piglets. J. Anim. Sci. **52**: 594–600.

Butler, J. E., Klobasa, F. and Werhahn, E. 1981. The differential location of IgA, IgM and IgG in the gut of suckled neonatal piglets. Vet. Immunol. Immunopath. **2**: 53–65.

Curtis, S. E. 1981. Environmental management in animal agriculture. Anim. Environ. Ser. Publ. Mahomet, Ill.

Goodnight, J. H. 1978. Statistical analysis system user's guide. SAS Institute Inc.

Griffin, W. O., Casteneda, A., Nicoloff, D. M., Stone, N. W. and Wangsteen, O. H. 1960. Influence of local hypothermia on absorption from isolated intestinal segments. Proc. Soc. Exp. Biol. Med. **103**: 757–761.

Kelley, K. W., Blecha, F. and Regnier, J. A. 1982. Cold exposure and absorption of colostral immunoglobulins by neonatal pigs. J. Anim. Sci. **55**: 363–368.

Klobasa, F., Werhahn, E. and Butler, J. E. 1981. Regulation of hormonal immunity in the piglet by immunoglobulins of maternal origin Res. Vet. Sci. **31**: 195–206.

Mancini, G., Carbonara, A. O. and Heremans, J. F. 1965. Immunochemical quantitation of antigens by single radial immunodiffusion. Immunochemestry **2**: 235–256.

Moog, F. 1979. The differentiation and redifferentiation of the intestinal epithelium and its brush border membrane. Devel. Mam. Abstr. Proc. Ciba Found. Series **70**: 31–51.

Namioka, S., Ohsugi, T., Fujimoto, T. and Maede, Y. 1983. Lymphocyte transformation of perispheral blood lymphocytes and plaque forming cells of the spleen and the mesenteric lymph node in suckling piglets with and without immunopotentiators. Jap. J. Vet. Res. **31**: 53–64.

Patt, J. A. 1977. Factors affecting the duration of intestinal permeability to macromolecules in newborn animals. Biol. Rev. **52**: 411–429.

Rafai, P. and Fodor, E. 1980. Studies on porcine adrenocortical function II. Effect of the ambient temperature and restricted feeding on the peripheral cortisol level. Acta Vet. Acad. Sci. Hungaricae. **28**: 443–454.

Schaefer, A. L. and Young, B. A. 1980. Gastrointestinal blood flow distribution in cold-exposed sheep. Can. J. Anim. Sci. **60**: 677–681.

Smith, M. W. and Peacock, M. A. 1980. Anomalous replacement of foetal enterocytes in the neonatal pig. Proc. R. Soc. Lond. B. **206**: 411–420.