THE EFFECT OF PREGELATINIZED STARCH ON THE SERUM
CONCENTRATION OF IMMUNOGLOBULIN G IN NEONATAL
CALVES FED COLOSTRUM

by

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Newborn Holstein calves were fed 0.5, 1.0 or 2.0 liters of pooled fresh colostrum supplemented with zero or 30 grams of pregelatinized starch. Each calf was bled just prior to the initial colostrum feeding and at 1, 2, 4, 8, 12, 16, 20 and 24 hours. Serum from each bleeding was analyzed for immunoglobulin G (IgG) concentration by single radial immunodiffusion. There was no significant difference in serum IgG concentration between the 0.5 and 1.0 liter colostrum fed groups at any time period. Feeding 2.0 liters of colostrum significantly (P < .01) increased serum IgG levels beginning 8 hours postprandial compared to either the 0.5 or 1.0 liter groups.

Feeding pregelatinized starch depressed (P < .01) serum IgG concentration at all levels of colostrum fed. Depressed IgG levels appeared at 4 hours and 8 hours for the 0.5 and 2.0 liter groups, respectively, but was not apparent in the 1.0 liter group until 24 hours. Multiway analysis of variance showed no interaction between pregelatinized starch supplementation and levels of colostrum. The maximum observed serum IgG level was measured between 16 and 24 hours for all treatment groups.
Immunity has been described as the condition of being resistant to disease. Acquired immunity is generally characterized as either active or passive. Natural active immunity is conferred upon an animal by exposure to (and subsequent recovery from) a disease, whereas artificial active immunity is acquired by the use of a vaccine. An animal builds specific antibodies in response to this antigenic stimulation (disease or vaccine challenge) for a long-term immunity. Passive immunity, on the other hand, is generally a rapidly acquired, but short-term resistance to disease. Acquisition of natural passive immunity primarily occurs through one of two routes: (1) transfer of maternal antibodies in utero (rabbit, guinea pig and human); or (2) absorption of ingested colostral antibodies by the newborn (ruminant, horse and pig).

The immune status of the neonatal calf continues to be an area of great concern to the bovine industry. It is thought that as a result of the type of placentation, bovine maternal immunoglobulins do not cross the placental barrier into the fetal circulation. Accordingly, the newborn calf must acquire passive immunity by intestinal absorption of antibodies present in the dam's colostrum. It is recognized that the calf is born virtually agammaglobulinemic, resulting in immunological deficiency at birth.
The absorption of colostral immunoglobulins by the calf may be affected by many factors such as maternal antibody quality, antibody concentration, intestinal epithelial maturity and environmental microbial challenge. The on-farm practice of feeding various prophylactic products against neonatal diarrhea (scours) at birth may also exert either positive or negative influence on immunoglobulin absorption.

Pregelatinized starch is a component of a recently tested anti-diarrheal compound. The starch is soluble in cold water and forms a mucoid-like gel upon standing. The purpose of the following work was to determine what effect pregelatinized starch might have on the absorption of colostral antibodies as measured by serum immunoglobulin G concentration.

**Review of Literature**

The transfer of maternal antibodies to the newborn animal through the colostrum was first noted by Ehrlich in 1892. He demonstrated the presence of antitoxins in the blood serum of the offspring of immune mice. Famulener in 1912 noted that the transmission of immunity to hemolytic diseases of newborn goats was due to the ingestion of colostrum. Howe in 1921 examined the phenomenon in detail in his study of the changes in serum proteins which follow the ingestion of colostrum in the calf. In his experiments he showed the colostrum globulins were absorbed without change in amounts large enough to substantially alter the composition of the blood plasma and that this type of absorption could only occur within a relatively short period after birth. In 1922, Orcutt and Howe found that newborn
calves from cows previously infected with *Bacillus abortus* had agglutinins in their serum after the ingestion of colostrum. Jameson, Alvarez-Tostado and Sorter in 1942 found by electrophoretic analysis that the serum of the newborn calf does not contain gammaglobulin, and that the appearance of slow-moving globulin follows the feeding of colostrum. McDiarmind in 1946 discovered that agglutinins to *Brucella abortus* were transmitted from the cow to her calf only by the ingestion of colostrum. Smith and Holm in 1948 concluded that the serum of the newborn calf does not possess any slow-moving globulins, and that after the ingestion of colostrum, an electrophoretic component appears in calf serum identical in mobility with the lactoglobulin which had previously been demonstrated to carry immunity in bovine colostrum. Brambell in 1958 substantiated the lack of immunoglobulins in newborn calf sera and concluded that gammaglobulins were derived from the first feed, being secreted in the colostrum and rapidly absorbed from the gut of the young animal. Polson, Graves and Rice and Carriere make similar reports confirming virtual agammaglobulinemia in neonatal calves.

Passive transfer of colostral immunoglobulins from the dam is the most important immediate immunologic protection available to the neonatal calf. To fully appreciate the health problems and ultimately the economic implications, studies have been conducted to elucidate the consequences of colostrum deprivation. The importance of colostral ingestion in the prevention of certain forms of neonatal disease in calves was first demonstrated experimentally over 50 years ago. In a series of papers published in the 1920's Smith and his
co-workers observed that calves deprived of colostrum almost invariably died, death being due to invasion by Escherichia coli and resultant septicemia. They concluded that the serum of the colostrum-deprived calf lacked something which prevented the invasion of these intestinal bacteria. It was subsequently shown that calf serum was devoid of globulins and agglutinins until after the ingestion of colostrum, and it was believed that the acquisition of these substances was a protective factor.

These observations of Smith pertaining to the significance of colostrum were confirmed shortly thereafter by a series of papers by Aschaffenburg and co-workers. They fed unsuckled calves various fractions of colostrum or a colostrum-like substance rich in vitamins. Only those calves receiving the globulin fraction of colostrum, or fractions containing it, survived and grew well. The majority of the colostrum-deprived calves, including those fed high-vitamin feed, died.

These two sets of experiments established the value of colostrum to the newborn calf, especially its protective value against colisepticemia, the main protective factor being associated with the immune lactoglobulins. Contemporary studies support these earlier findings and show that failure to obtain or absorb adequate amounts of colostrum often result in neonatal septicemia, diarrhea and death.

Although the value of feeding colostrum to newborn calves is widely appreciated, it is also generally accepted that ingestion of colostrum and immunoglobulin (Ig) titers alone are not a complete
guarantee against illness or death from colibacillosis. When maternal colostrum is deficient in antibodies to certain pathogenic organisms, it may provide little or no protection for calves against these disease-producing organisms. Barber examined total Ig levels in suckled calves. Out of 13 calves which died with diarrhea, nine had high serum immunoglobulin levels. It is worth noting that this study measured levels in 10-14 day-old calves as compared to day-old calves used in earlier studies. Barber also reported no relationship between performance parameters of the calves and either the immune globulin content of their serum or their weight at purchase.

Although this literature failed to show a correlation between serum globulin status and calf viability and performance, it is generally believed that the quantity of transferred colostral antibodies as influenced by several factors (colostral immunoglobulin concentration amount and time of colostrum ingestion and absorptive efficiency of the intestine) contribute to the calf's survival during the neonatal period.

Ability of the neonatal ruminant, horse and pig to absorb large protein molecules through the intestine without prior digestion or alteration is influenced by age and/or dietary regimen. In the cow and horse, this special capacity for absorption is apparently related to age and ceases when the neonate is anywhere from 24-36 hours old. On the other hand, in the pig this period of Ig absorption is primarily influenced by the dietary regimen.

The majority of work concerning cessation of absorption of large molecules (closure) has been done using the porcine model.
Young and Underdahl\textsuperscript{71} in 1949 concluded that after 48 hours some physiological change occurred in the intestinal epithelium that retarded further absorption of antibodies. Nelson\textsuperscript{43}, Barrick, Matrone and Osborne\textsuperscript{10}, Hoerlein\textsuperscript{25}, Speer et al.\textsuperscript{66} and Lecce and Matrone\textsuperscript{34} concluded that no measurable intestinal absorption occurs in the baby pig after 48 hours of age.

Lecce, Matrone and Morgan\textsuperscript{35} investigated the selectivity of the absorption phenomenon using polyvinylpyrrolidone (PVP) as a non-protein, high molecular weight, test molecule. It was observed that piglets nursing appear to stop absorbing PVP sooner than piglets fed cow's milk. Further experimentation led investigators to conclude that the time interval for the absorption of large molecules (closure) was a function of feeding regimen\textsuperscript{36,37,47,48}.

Lecce and Morgan\textsuperscript{36} compared nursing piglets with those that were fed water or starved and showed extreme differences in gamma-globulin absorption. They also found that starved piglets could still absorb colostral antibodies up to 96 hours of age. Lecce et al.\textsuperscript{37} determined that the factor responsible for closure appears to be a heat-stable, low molecular weight (less than 10-20,000) compound that is part of the dialyzate of colostrum or milk. In addition to his earlier works, Lecce\textsuperscript{31} found that piglets fed glucose were unable to absorb large molecules within an 18-24 hour period. He concluded that the capacity of a diet to diminish absorption appears to be more dependent on numbers of molecules rather than the kinds of molecules.

The absorption of macromolecules is delineated into two phases: (a) intake or internalization of pinocytotic action within the
intestinal epithelium; and (b) transport or subsequent expulsion of macromolecules into the blood. Pinocytosis is regarded as the mechanism for the absorption of large amounts of protein by some neonates.26,70 Charged nutrients are absorbed to the cell surface, thereby stimulating indentation of the surface membrane resulting in a pinching-off of the membrane and vesiculation. In this way the nutrients surrounded by the membrane are passed into the cell. In the neonatal pig, calf, kitten, lamb and goat, colostrum strongly stimulates this vesiculation of the intestinal epithelium.15,16,24,58 Proteins are considered potent stimulators of pinocytosis and are intimately involved in absorption per se. It is thought, therefore, protein must be somehow associated with the cell for closure to occur, perhaps by exhausting pinocytotic sites on the cell membrane.36,48 "Closure" related to the first phase of absorption is now defined as cessation of the uptake of macromolecules by intestinal epithelial pinocytosis. Using this definition, mammals can be placed into three groups with respect to closure times: (1) short duration, 36 hours or less, e.g., guinea pig, ruminants, pig and horse; (2) medium duration, around 6 days of age, e.g., hamster; and (3) long duration, 17-40 days, e.g., pigs, mice and rats.14,31,32

Observations have been made which first suggested that the absorption of bovine gammaglobulin from the small intestine of the newborn calf was to a large extent dependent upon factors in the colostrum.6,23 Accordingly, experimenters have made attempts to describe the action of factors which inhibit or enhance the rate of absorption of gammaglobulin in the neonate. Gammaglobulin was absorbed extremely slowly when dissolved in a chloride solution.6,22,23 Deutsch
and Smith\textsuperscript{17} found that the administration of diethy stilbestrol and progesterone, either singly or in combination with each other, did not alter intestinal permeability to immune proteins. Patt et al.\textsuperscript{46} found that supplemental histamine did not increase absorption of gammaglobulin by the intestine of newborn calves. Wegner and Schuh\textsuperscript{69} concluded that renin or sodium citrate added to colostrum had no significant effect on the absorptive titers of Ig in neonatal dairy calves.

The present study provides a quantitative analysis of the effect of pregelatinized starch on the absorption of Ig in the neonatal calf. On the other hand, the addition of lactate and pyronate,\textsuperscript{23} potassium isobutyrate,\textsuperscript{11,23} or poly-l-arginine\textsuperscript{57} to colostrum slightly enhanced the uptake of gammaglobulin.
CHAPTER 2

EXPERIMENTAL PROCEDURE

Equal numbers of colostrum-deprived Holstein bull and heifer calves were obtained from December 1977 to March 1978 at a local dairy (Shamrock Dairy, Tucson, Arizona). Colostrum deprivation was ensured by separating the calf and dam immediately following parturition and removing the calf to an individual straw-bedded pen for the duration of the trial.

A split-plot design was utilized because of repeated measures taken in each calf. Each trial block was made up of 12 animals randomly assigned to six treatment groups. Three groups of calves were fed either 0.5, 1.0 or 2.0 liters of pooled fresh colostrum and three groups received the same levels of colostrum with the addition of 30 grams of pregelatinized corn starch. This block was repeated for a total of 24 experimental animals.

Pooled colostrum for each block was obtained from the first lactation of Holstein cows at Shamrock Dairy. It was stored in a plastic-lined container and refrigerated for approximately 12 hours before use. Sample aliquots were taken for immunoglobulin (Ig) concentration analysis. Prior to being used, the colostrum was stirred to maintain a uniform mixture.

Each calf was fed the colostrum or colostrum plus starch mixture via nipple bottle at zero and twelve hours post-partum. If an
animal was unwilling to consume the fluid, an esophageal probe with bottle apparatus (Fluidfeeder, the Magrath Co.) was used to ensure complete consumption of the test material.

Blood samples were taken at 0, 1, 2, 4, 8, 12, 16, 20 and 24 hours post-partum via jugular puncture. The blood tubes were held at room temperature for one hour and then refrigerated. Serum was separated from the cell components by centrifugation and stored at -50°C for subsequent Ig quantitation.

Single radial immunodiffusion was used to measure the amount of immunoglobulin G (IgG) in the serum samples. An immunochemical kit (Miles Laboratories) was employed which provided the necessary reagents and agar plates for rapid analysis. Frozen serum samples were allowed to stand at room temperature for one hour prior to use. 2.5 µl of sample were accurately pipetted into the wells of the immunodiffusion plate. A standard curve was prepared in the same manner, by pipetting 2.5 µl of each reference standard (1.25, 2.5, 5, 10, 20 and 40 mg/ml) into wells on the same plate. To obtain standard concentrations of 1.25 and 2.5 mg/ml, dilutions were made using physiological saline solution and excess 5 mg standard from each kit. A few drops of distilled water were pipetted into the moisture trough of each plate and plates were covered and incubated at room temperature for 18 hours. Measurements of preceptin ring diameters were made directly from the immunodiffusion plates using Miles Model #42-100 Viewer/Magnifier assembly with Dia-Meter™ Measurement Template.

The data were subjected to multiway analysis of variance and differences between means were tested using least significant differences.
CHAPTER 3

RESULTS AND DISCUSSION

Serum immunoglobulin G (IgG) concentration was determined for 24 Holstein calves at several time intervals following ingestion of fresh pooled colostrum. IgG concentration of the colostrum was 32 mg/ml.

Initial serum samples taken from newborn calves prior to the ingestion of colostrum had a mean value of 0.79 mg/ml. This state of hypogammaglobulinemia was observed by Brambell who theorized that the blood level of antibodies at the time of birth was directly correlated with the development, persistence, and time of withdrawal of the yolk sac into the umbilical cord. In the calf, this event occurs early in gestation and there is little prenatal absorption. The low value for serum IgG in these newborn calves also agrees with the observation of Osburn that small amounts of immunoglobulin are synthesized endogenously by the bovine fetus as a result of antigenic stimulation. Other workers have examined the ontogeny of the bovine fetus and discovered cells containing IgG as early as 145 days of gestation.

The effect of feeding various levels of colostrum on serum IgG concentration is presented in Figure 1. Throughout the first 4-hour period, calves receiving the three colostrum levels failed to show any significant difference in their serum IgG values. At the 8 hour sampling, the 2.0 liter group exhibited higher (P < .01) serum values.
Figure 1. The effect of feeding various levels of colostrum on the concentration of serum immunoglobulin G in neonatal calves.
when compared with calves in either the 0.5 or 1.0 liter groups. Subsequent determinations proved the difference to continue throughout the test period. Maximum serum IgG absorbed was higher (P <.01) in the 2.0 liter calves than in the 0.5 or 1.0 liter groups. There was no significant difference between the two lower levels of colostrum fed. Stott found that serum IgG concentration was significantly higher in calves fed 2.0 liters of colostrum compared with 0.5 and 1.0 liter groups. In contrast to the data reported in this paper, they also found that calves fed 1.0 liters had serum IgG levels significantly higher than those of the 0.5 liter group.

Figure 2 summarizes the effect of dietary pregelatinized starch (PGS) on serum IgG concentration. Each point on the graph represents the mean value for all colostral levels in either the control or PGS groups. Serum IgG concentrations in all calves increased rapidly following colostrum ingestion and was independent of treatment. This observation is supported by several workers. For an undetermined reason, calves consuming 2.0 liters of colostrum showed no increase in serum IgG concentration during the first hour post feeding, but this value increased rapidly thereafter.

There was no difference in serum IgG levels between control and PGS treated calves through the first 4 hours post prandial. However, samples from 8 to 24 hours were divergent with the largest difference between groups occurring at 20 hours.

The maximum observed serum IgG concentration was higher (P <.01) in the control group than in the PGS treated group (Table 1). This was true of all levels of colostrum fed. Multiway analysis of
Figure 2. The effect of dietary pregelatinized starch on the concentration of serum immunoglobulin G in neonatal calves.
Table 1. The effect of various colostrum levels and pregelatinized starch on serum immunoglobulin G concentration (mg/ml) in neonatal calves.*

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*Each number in the table represents 4 replicates.
variance showed no interaction between the amount of colostrum fed and PGS treatment (Appendix A, Table A-1).

Comparisons of serum IgG concentration at each colostral level may be seen in Figures 3, 4, and 5. In Figure 3, the maximum mean serum IgG level attained by control calves was 10.30 mg/ml at 20 hours compared with 7.58 mg/ml at 24 hours in PGS-treated group. These results are in agreement with Baumwart et al. who found the maximum concentration of serum IgG in neonatal calves occurred at 20 hours post partum. It is interesting to note that the serum IgG level in the PGS-treated group continued to rise from 20-24 hours, whereas the control group showed a decline during the time interval.

Serum IgG levels for calves fed 1.0 liter of colostrum are presented in Figure 4. Maximum serum IgG concentration in the control group was 11.60 mg/ml at 24 hours. The PGS supplemented calves reached a peak concentration of 9.05 mg/ml at 20 hours. There were some notable differences between the 0.5 and 1.0 liter groups. Calves in the 1.0 liter group continued to show further IgG absorption from 20-24 hours which was not evident in 0.5 liter calves. Serum IgG levels of the PGS-treated calves fed 1.0 liter of colostrum declined during this period whereas the 0.5 liter group showed an increase in absorption during the same time interval.

Serum IgG levels for calves that reached 2.0 liters of colostrum are shown in Figure 5. The maximum serum IgG concentration in the control group was 17.80 mg/ml occurring at 20 hours. The PGS-treated group had a peak serum IgG concentration of 13.0 mg/ml at 16 to 24 hours.
Figure 3. The effect of dietary pregelatinized starch on serum immunoglobulin G concentration in neonatal calves fed 0.5 liter colostrum.
Figure 4. The effect of dietary pregelatinized starch on serum immunoglobulin G concentration in neonatal calves fed 1.0 liter colostrum.
Figure 5. The effect of dietary pregelatinized starch on serum immunoglobulin G concentration in neonatal calves fed 2.0 liters colostrum.
It is apparent from these data that colostral intake may affect serum IgG concentration in neonatal calves and that PGS exerts a depressing effect on this parameter. To evaluate the possible cause of this depressed level, it is helpful to review the mechanism by which immunoproteins are absorbed.

Pincocytosis (cell drinking) is regarded as the mechanism for the absorption of large molecules, including the specialized intestinal absorption of immunoglobulins by some neonates. During the restricted period of intestinal permeability, which varies among species, charged proteins are absorbed to the cell surface, thereby stimulating indentation and folding-in of the surface membrane and ultimate vesiculation. Thus the protein molecules are surrounded by surface membrane and pass into the cell.

Studies conducted by Payne and Marsh utilized fluorescein labeled gammaglobulin to show the relationship of time to the absorption of gammaglobulin. They found that immature intestinal epithelial cells begin to absorb gammaglobulin almost immediately. As time progresses the cell becomes packed with many small droplets of gammaglobulin. These cells apparently follow the all-or-none law of physiological activity. They seem to absorb all the gammaglobulin possible before allowing any to pass into the circulation.

The terminal ileum of the calf intestine was initially considered to be the site of protein absorption. Balfour and Comline suggested that the mucopolysaccharide portion of the ileal cell combines in some manner with the engulfed protein and may be a necessary prerequisite for absorption.
Staley et al. found that ferritin-IgG was taken up by the jejunal cell as well as by the ileal cell. However, in neither area of the intestine was ferritin observed to exit from the cell. Ferritin did not appear to come into contact with the polysaccharide containing vacuoles, which illustrates the importance of the vacuole for release of cell contents into the bloodstream and may explain the reason for failure of ferritin to be released from the cell.

From the foregoing discussions, PGS may exert its depressing effect upon serum IgG concentration by a physical interference with the pinocytotic uptake by the intestinal cell membrane.

Since pinocytosis entails enteriorization of the intestinal cell membrane, it seems probable that the capacity of the cell to engulf molecules would be limited by molecular concentration, the restriction of available luminal surface of the epithelial cell, or by mechanical impediment of contact between macromolecule and luminal cell surface. Thus a large polymer such as PGS could weakly occupy or interfere with receptor sites on the membrane surface and therefore reduce the available surface area for immunoprotein absorption. Another possible explanation is concerned with the physical nature of the compound. PGS is a polymer of α-D-glucose with the empirical formula \( (C_6H_{10}O_5)_x \). The compound is hydrophilic, forms a stable colloidal suspension in cold water, and forms a soft gel upon standing. When mixed with colostrum, it forms a viscous material similar to the consistency of thick gravy. When consumed by the newborn calf it is possible that the coating effect of the starch surrounds and masks a portion of the proteins present in the colostrum. Therefore, these
proteins never have the opportunity to come in contact with the available binding sites on the luminal surface of the intestinal cell.

It is widely recognized that immunoglobulin absorption is not consistently a sequel to colostrum feeding, and wide variations have been recorded in the serum immunoglobulin concentrations of newborn calves known or assumed to have ingested colostrum. The clinical significance of these wide variations is evidenced by the high rate of neonatal calf mortality that continues to exist throughout the world.

It is well established that the neonatal calf must ingest and ultimately absorb an adequate quantity of colostral immunoglobulin during the initial 24-36 hours after birth. Penhale et al. state that with normal IgG serum values of 7.5 mg/ml, colibacillosis is unlikely to occur. In this report, 3 of 24 calves (12.5%) failed to attain this proposed competence level (Appendix A, Table A-3). This might be expected since all 3 calves received the lowest level of colostrum supplemented with PGS.
CHAPTER 4

SUMMARY

Twenty-four newborn Holstein calves were separated from their dams immediately following parturition. Each calf was fed either 0.5, 1.0 or 2.0 liters of pooled fresh colostrum supplemented with 0 or 30 grams of pregelatinized starch (PGS). Blood samples were taken immediately following birth and at 1, 2, 4, 8, 12, 16, 20, and 24 hours. Serum samples were analyzed specifically for bovine immunoglobulin G (IgG) concentration by single radial immunodiffusion. There was no significant difference in serum IgG concentration between the 0.5 and 1.0 liter colostrum fed calves at any time period. Feeding 2.0 liters of colostrum resulted in significantly (P < .01) higher serum IgG levels 8 hours postprandial compared to either the 0.5 or 1.0 liter groups.

Feeding PGS depressed (P < .01) serum IgG concentration at all levels of colostrum fed. The difference appeared at 4 hours and 8 hours in the 0.5 and 2.0 liter groups, respectively, but was not apparent in the 1.0 liter group until 24 hours. Multiway analysis of variance showed no interaction between PGS supplementation and levels of colostrum. The maximum observed serum IgG level was measured between 16 and 24 hours for all treatment groups.
# APPENDIX A

## STATISTICAL TABLES AND INDIVIDUAL ANIMAL MEASUREMENTS

### Table A-1. Analysis of variance: effect of various colostrum levels and pregelatinized starch on maximum mean serum immunoglobulin G concentration in neonatal calves.

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<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starch (S)</td>
<td>1</td>
<td>68.01</td>
<td>68.01</td>
<td>9.02*</td>
</tr>
<tr>
<td>Liters (L)</td>
<td>2</td>
<td>254.68</td>
<td>127.34</td>
<td>16.89*</td>
</tr>
<tr>
<td>S X L</td>
<td>2</td>
<td>3.82</td>
<td>1.91</td>
<td>.25</td>
</tr>
<tr>
<td>Error</td>
<td>18</td>
<td>135.74</td>
<td>7.54</td>
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</tr>
</tbody>
</table>

*P < .01

### Table A-2. Analysis of variance: effect of various levels of colostrum and pregelatinized starch on serum immunoglobulin G concentration in neonatal calves.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blocks (B)</td>
<td>1</td>
<td>11.80</td>
<td>11.80</td>
<td>.71</td>
</tr>
<tr>
<td>Liters (L)</td>
<td>2</td>
<td>433.05</td>
<td>216.52</td>
<td>12.99*</td>
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<tr>
<td>Starch (S)</td>
<td>1</td>
<td>193.23</td>
<td>193.23</td>
<td>11.60*</td>
</tr>
<tr>
<td>L X T</td>
<td>2</td>
<td>38.97</td>
<td>19.48</td>
<td>1.17</td>
</tr>
<tr>
<td>error a</td>
<td>17</td>
<td>283.23</td>
<td>16.66</td>
<td></td>
</tr>
<tr>
<td>Time (T)</td>
<td>8</td>
<td>3,425.98</td>
<td>428.24</td>
<td>133.44*</td>
</tr>
<tr>
<td>L X T</td>
<td>16</td>
<td>558.91</td>
<td>34.93</td>
<td>10.88*</td>
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<tr>
<td>S X T</td>
<td>8</td>
<td>87.82</td>
<td>10.97</td>
<td>3.42*</td>
</tr>
<tr>
<td>L X S X T</td>
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<td>104.41</td>
<td>6.52</td>
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<tr>
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<td>3.21</td>
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*P < .01
Table A-3. Serum immunoglobulin G concentration (mg/m) in neonatal calves fed various levels of colostrum and pregelatinized starch (PGS); individual calf values (0.5 liters).

<table>
<thead>
<tr>
<th>Bleeding Time Hours</th>
<th>Calf Number</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>PGS</td>
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<tr>
<td></td>
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</tr>
<tr>
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<td>0.0</td>
</tr>
<tr>
<td>1</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>0.0</td>
</tr>
<tr>
<td>4</td>
<td>2.6</td>
</tr>
<tr>
<td>8</td>
<td>5.8</td>
</tr>
<tr>
<td>12</td>
<td>4.5</td>
</tr>
<tr>
<td>16</td>
<td>5.5</td>
</tr>
<tr>
<td>20</td>
<td>6.5</td>
</tr>
<tr>
<td>24</td>
<td>6.7</td>
</tr>
</tbody>
</table>
Table A-4. Serum immunoglobulin G concentration (mg/m) in neonatal calves fed various levels of colostrum and pregelatinized starch (PGS): individual calf values (1.0 liters).

<table>
<thead>
<tr>
<th>Bleeding Time Hours</th>
<th>Calf Number</th>
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<th>PGS 2</th>
<th>PGS 3</th>
<th>PGS 4</th>
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<th>No PGS 2</th>
<th>No PGS 3</th>
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</thead>
<tbody>
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<td>3.9</td>
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<td>0.0</td>
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</tr>
<tr>
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<td>0.0</td>
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<td>3.4</td>
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<td>1.4</td>
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</tr>
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<td>2.9</td>
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</tr>
<tr>
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<td>5.6</td>
<td>4.5</td>
<td>4.2</td>
<td>2.3</td>
</tr>
<tr>
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<td>6.4</td>
<td>6.4</td>
<td>5.8</td>
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<td>5.0</td>
<td>8.2</td>
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<td>6.4</td>
<td>9.2</td>
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<td>8.4</td>
<td>6.6</td>
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<td>11.0</td>
<td>9.2</td>
<td>11.0</td>
<td>11.0</td>
</tr>
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<td>5.8</td>
<td>9.2</td>
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</tr>
</tbody>
</table>
Table A-5. Serum immunoglobulin G concentration (mg/m) in neonatal calves fed various levels of colostrum and pregelatinized starch (PGS): individual calf values (2 liter).

<table>
<thead>
<tr>
<th>Bleeding Time Hours</th>
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<th>No PGS</th>
</tr>
</thead>
<tbody>
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<td>3</td>
</tr>
<tr>
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<td>2.6</td>
<td>2.0</td>
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</tr>
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<td>7.3</td>
</tr>
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<td>10.6</td>
<td>8.4</td>
<td>8.0</td>
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<td>11.8</td>
<td>9.2</td>
<td>12.0</td>
</tr>
<tr>
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<td>13.2</td>
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<td>15.2</td>
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<td>13.8</td>
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<td>10.6</td>
<td>12.8</td>
<td>12.6</td>
</tr>
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LIST OF REFERENCES


