COLOSTRAL IMMUNOGLOBULIN TRANSFER IN DAIRY CALVES REMAINING WITH THEIR DAMS FOR TWELVE TO TWENTY-SIX HOURS POSTPARTUM AS A MANAGEMENT PRACTICE

by

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STATEMENT BY AUTHOR

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ABSTRACT

The purpose of this experiment was to determine the concentrations of serum immunoglobulins in heifer calves left with their dams to suckle for 12 to 26 hours following parturition. All calves were bottle-fed one liter pooled colostrum approximately six hours after separation from their dams. The effect of this feeding on serum Ig concentrations was also measured.

Serum IgG and IgM concentrations were quantitated by radial immunodiffusion. Nearly one-third of 983 calves left to suckle their dams had virtually no serum immunoglobulins. After bottle-feeding, one-tenth remained agammaglobulinemic. Less than 4% of all calves and less than 14% of agammaglobulinemic calves died before two months of age. After bottle-feeding, average serum Ig concentrations of the calves that died were significantly lower than for calves that survived two months.

The unexpected low death loss among agammaglobulinemic calves suggests that bottle-feeding colostrum may be beneficial to the calf even if no additional colostral Ig's are absorbed. This agrees with previous findings of local immune activity of colostral Ig within the gut.

CHAPTER 1

INTRODUCTION

The transfer of passive immunity from mother to young via the colostrum has been the subject of numerous studies in the last two decades. Its importance to the health of the bovine neonate is well documented. Therefore, it is of concern to anyone raising calves that as many as possible acquire passive humoral immunity which can be quantitated by measuring the serum immunoglobulin concentration.

The purpose of this experiment was to determine the occurrence of hypo- and agammglobulinemia in calves allowed to remain with their dams to suckle for approximately one day postpartum. Since it is common practice to feed each calf pooled colostrum after separating it from its dam when approximately 24 hours old, the effect of this feeding on serum Ig concentrations was also evaluated. By associating these results with death losses in calves younger than two months, the practice was evaluated and improvements in management were suggested based on predictions stemming from the findings.

CHAPTER 2

REVIEW OF LITERATURE

During the last two decades, studies have shown increased incidence of colibacillosis, salmonellosis, septicemia, and diarrhea in newborn calves is associated with low serum immunoglobulin concentrations (6, 7, 9, 20, 21, 22, 28). Penhale et al. (22) considered calves with serum concentrations below 5.0 mg/ml IgG and 1.1 mg/ml IgM to be hypogammaglobulinemic. In contrast, other researchers have reported that calves with a combined serum IgG and IgM concentration less than 19 mg/ml were susceptible to extensive morbidity and mortality (7, 9).

Since the bovine neonate is virtually agammaglobulinemic at birth, acquisition of adequate amounts of colostral Ig is important to its health and well being. The immature intestinal epithelial cells absorb the colostral macromolecules from the gut lumen by pinocytosis and discharge them into the calf's circulatory system (13). These cells are continuously replaced by mature epithelial cells incapable of transferring intact colostral immunoglobulins (3). At approximately one day of age, this replacement is complete and ceasation of Ig transfer (closure) occurs (22). In a controlled experiment, Stott et al. (27) determined the time of closure averages 25 to 26 hours postpartum with a standard deviation of approximately four hours. They found that closure time follows a normal distribution and ranges from 12 to 36 hours. The rate of absorption of intact macromolecules declines with time until closure, and feeding large amounts of colostrum tends to advance the time of closure slightly. The serum Ig concentration reaches a maximum at closure, after which it declines until active synthesis within the calf begins (8, 15, 18). Thus, the age at which a calf is first fed influences the amount of maternal immunoglobulin in the circulation (28). The colostral Ig concentration and the amount of colostrum ingested have also been cited as factors affecting the serum Ig concentrations in post-colostral calves (4, 11). Kruse (11) determined that 69 to 78% of the variability in post-colostral serum Ig concentrations is due to the mass of Ig given to the calf, the age of the calf, and the weight of the calf. Selman, McEwan, and Fisher (24) found that calves which obtain colostrum by suckling usually attain higher serum Ig concentrations than those that are bottle-fed. Three reasons were presented to explain this phenomenon: calves usually suckle within six hours postpartum, they usually ingest more colostrum than when bottle-fed, and the absorption process may be more efficient when calves are left with their dams.

The incidence of hypogammaglobulinemia in herds in which calves are allowed to suckle their dams free-choice ranges from 20% to over 40%, according to several studies (2, 10, 14, 15, 22, 23). Some reports attributed this high occurrence of hypogammaglobulinemia to a premature loss of the ability of the intestinal epithelium to absorb macromolecules (6, 7, 10, 20, 25). But, these reports did not account for the variability in serum Ig concentrations due to known influencing factors:

age of calf at feeding, amount of colostrum fed, colostral Ig concentration, and the fact that some calves may not have suckled.

To determine whether a calf will always nurse when given the opportunity, Selman, McEwan, and Fisher (23) observed that nine out of 30 dairy and beef calves did not suckle their dams, or suckled very little, within eight hours postpartum. Thus, there is no guarantee that each and every calf with access to its dam will actually ingest colostrum. Further it was determined that incidence of hypo- and agammaglobulinemia is high even among suckled calves (14, 15).

From the above discussion, it would seem that there are factors which effectively influence the serum Ig concentrations in newborn calves receiving colostrum. Age of the calf at the time of feeding and the amount of colostrum ingested are most important. If each calf suckles or otherwise obtains a sufficient amount of colostrum as soon as possible after birth, it can be expected that each calf will attain a high level of passive immunity.

CHAPTER 3

EXPERIMENTAL PROCEDURE

For this experiment, 909 newborn Holstein and 74 newborn Guernsey heifer calves were treated according to the traditional management procedure of a large commercial dairy. They remained with their dams until 0900 of the morning following parturition in order to allow them time to suckle colostrum before being separated. Calves that were born only a few hours prior to the 0900 separation time were left with their dams an additional 24 hours to give them a better opportunity to obtain colostrum. It was calculated that most calves were with their mother for 12 to 26 hours, providing ample time to suckle before separation, while a few fell on either side of this range.

The separated calves were placed in individual pens and bottle-fed one liter of fresh pooled colostrum at 1500 hours. Before feeding, a blood sample was taken from the jugular vein by venipuncture, and again 24 hours later. The blood was allowed to clot; the serum withdrawn and stored frozen. The assay for IgG and IgM concentrations was by radial immunodiffusion as described by Fahey and McKelvey (5) and modified by Stott et al. (29). The serum Ig concentrations were quantitated to the nearest 0.1 mg/ml.

The pre-feeding and post-feeding serum samples allowed an evaluation of colostral Ig absorption due to calves remaining with their dams, as well as the benefit resulting from feeding colostrum afterward. To describe these effects, the calves were grouped according to their serum IgG and IgM concentrations at the times of their first and second bleedings. Serum IgG concentrations were: 0.0 to 1.9, 2.0 to 3.9, 4.0 to 5.9, 6.0 to 11.9, 12.0 to 17.9, 18.0 to 23.9, 24.0 to 29.9, and greater than 30.0 mg/ml. For IgM, they were 0.0 to 0.9, 1.0 to 1.9, 2.0 to 3.9, 4.0 to 5.9, 6.0 to 7.9, 8.0 to 9.9, 10.0 to 11.9, and greater than 12.0 mg/ml. For each Ig class and each bleeding, the number of calves, and the percent of the total, with serum Ig concentrations falling within each group was tallied. Calves with serum IgG and/or IgM concentrations falling into the lowest groups (IgG less than 2.0 mg/ml or IgM less than 1.0 mg/ml) of either Ig class at the time of the first bleeding were assumed not to have suckled before closure. Concentrations within this range have been reported to be regularly found in the sera of pre-colostral calves (12, 15, 22, 28).

By subtracting the pre-fed serum Ig concentration from the post-fed value, the change in each calf's serum Ig concentration due to feeding colostrum was measured. With calves that showed an increase, it was tested for significance by analysis of variance. Calves showing no serum IgG nor IgM increase were assumed to have undergone closure before being bottle-fed colostrum. For each pre-fed serum Ig concentration group, the percentage of calves failing to absorb additional colostral Ig upon feeding was determined.

The birthdate of each calf was recorded, along with any death dates that occurred before two months of age. Using analysis of variance, the average serum Ig concentration of calves that died was compared to that of the surviving calves. A chi-square analysis was used to test for a significant difference between the percentage of calves that died with low serum Ig concentrations versus those with high serum Ig concentrations.

CHAPTER 4

RESULTS

Some 35.2% of the calves had less than 2.0 mg/ml serum IgG (lowest group) at the time of the first blood sampling (Table 1). A similar proportion (35.7%) fell in the lowest group of serum IgM concentrations (less than 1.0 mg/ml, Table 2). There were 133 calves that had an extremely low serum concentration of one Ig class, but fell into a higher group in the other Ig class. Thus, 415 calves (42.2%) were virtually devoid of gammaglobulins of one or both classes, and showed no evidence of suckling any appreciable amount of colostrum during the time allowed to do so. The remaining 57.8% had serum IgG and IgM concentrations higher than the lowest cetegory of each Ig class.

Fewer calves had low serum IgG and IgM concentrations at the time of the second (post-fed) blood sampling than at the time of the first (pre-fed) sampling (Tables 1 and 2). The mean pre- and post-fed serum IgG and IgM concentrations are given in Table 3. One calf's pre- and post-fed serum samples had 63.0 mg/ml IgG, and a few calves had between 50.0 and 60.0 mg/ml IgG in their sera. The maximum IgM concentrations were 14.0 mg/ml (pre-fed) and 15.0 mg/ml (post-fed).

Some 285 calves (29.0%) did not absorb measurable additional colostral Ig following pooled colostrum feeding. In calves which absorbed some colostral Ig by bottle-feeding, the average increases in

Table 1. Distribution of calves according to pre- and post-feeding serum IgG concentrations

Serum IgG (mg/ml)	Pre-feed		Post-feed	
0.0 - 1.9	346	35.2%	117	11.9%
2.0 - 3.9	56	5.7	96	9.8
4.0 - 5.9	33	3.4	97	9.9
6.0 - 11.9	125	12.7	180	18.3
12.0 - 17.9	148	15.1	151	15.4
18.0 - 23.9	127	12.3	157	15.9
24.0 - 29.9	82	8.3	93	9.5
30.0 +	72	7.3	92	9.3
Totals	983	100.0%	983	100.0%

Table 2. Distribution of calves according to pre- and post-feeding serum IgM concentrations

Serum IgM (mg/ml)	Pre-feed		Post-feed	
0.0 - 0.9	351	35.7%	204	20.8%
1.0 - 1.9	99	10.1	162	16.5
2.0 - 3.9	228	23.2	265	27.0
4.0 - 5.9	154	15.7	174	17.7
6.0 - 7.9	72	7.3	95	9.6
8.0 - 9.9	43	4.4	50	5.1
10.0 - 11.9	28	2.8	24	2.4
12.0 +	8	0.8	9	0.9
Totals	983	100.0%	983	100.0%

Table 3. Statistical data of the pre- and post-feed serum IgG and IgM concentrations

		Mean	s.d.	c.v
Serum IgG (mg/ml)	pre-feed	11.3	11.9	105.3%
	post-feed	14.0	11.3	80.7%
Serum IgM	pre-feed	2.9	2.9	100.0%
	post-feed	3.4	2.8	82.4%

serum IgG and IgM concentrations were 5.0 ± 4.5 mg/ml and 1.3 ± 1.3 mg/ml, respectively. These increases were significant for both Ig classes ($p < 0.005$).

No correlations were found among the pre-fed serum IgG or IgM concentrations and their respective increases after colostrum feeding ($p > 0.1$). However, the proportion of calves that failed to absorb additional colostral Ig after bottle-feeding was significantly greater among calves which attained high serum Ig concentrations by suckling ($p < 0.005$, Table 4). This proportion increased almost linearly with increased pre-fed IgG or IgM serum concentration.

There was no significant difference between the proportions of Holsteins and Guernseys which showed a lack of suckling (41.5% versus 51.4%, $p > 0.1$). Likewise, there was no significance between the percentages of Holstein calves and Guernsey calves showing no increase in serum Ig concentrations after bottle-feeding (28.5% versus 35.1%, $p > 0.1$). While neither the pre-fed nor the post-fed serum IgG concentrations

Table 4. Proportion of calves showing cessation of Ig absorption before bottle-feeding colostrum according to pre-feeding serum IgG and IgM concentrations

Serum IgG (mg/ml)	%	Serum IgM (mg/ml)	%
0.0 - 1.9	12.1	0.0 - 0.9	16.2
2.0 - 3.9	21.4	1.0 - 1.9	26.3
4.0 - 5.9	27.3	2.0 - 3.9	33.3
6.0 - 11.9	30.4	4.0 - 5.9	35.1
12.0 - 17.9	36.5	6.0 - 7.9	41.7
18.0 - 23.9	39.7	8.0 - 9.9	37.2
24.0 - 29.9	56.1	10.0 - 11.9	71.4
30.0 +	50.0	12.0 +	75.0
All calves	29.0	All calves	29.0

showed any significant breed differences, both serum IgM concentrations were higher in Holsteins than in Guernseys (Table 5). Since no conclusive differences between breeds could be demonstrated in this study, all calves were treated as one breed.

During this study, 38 of 983 calves (3.9%) died before two months of age. The mean Ig concentrations at the time of the second sampling were significantly lower for calves that died than for those which survived (Table 6). The agammaglobulinemic calves had a greater percentage of deaths than calves with higher concentrations of circulating immunoclobulins ($p < 0.001$, Table 7). However, 72 of 83 agammaglobulinemic calves (86.7%) survived longer than two months. A significantly higher proportion of Guernsey calves died compared to Holsteins (12.2% versus 3.2%, $p < 0.05$).

Table 5. Comparison of mean serum Ig concentrations of Holstein and Guernsey calves

		Holstein (909)	Guernsey (74)	Sig. Diff.
Serum IgG (mg/ml)	pre-fed	11.3 ± 11.7	11.2 ± 13.8	NS
	post-fed	14.0 ± 11.1	13.8 ± 13.1	NS
Serum IgM (mg/ml)	pre-fed	3.0 ± 3.0	2.0 ± 2.3	$p < 0.008$
	post-fed	3.5 ± 2.8	2.9 ± 2.4	$p < 0.08$

Table 6. Comparison of mean serum Ig concentrations of calves dying before two months of age and calves surviving at least two months

	Dying before two mos. old	Surviving at least two mos.	Sig. Diff.
N (%)	38 (3.9)	945 (96.1)	
Mean serum IgG (mg/ml)	8.5 ± 11.3	14.2 ± 11.2	$p < 0.002$
Mean serum IgM (mg/ml)	2.6 ± 2.9	3.5 ± 2.8	$p < 0.05$

Table 7. Comparison of death rates of agammaglobulinemic calves and other calves*

	Agamm.		Other	
Died before two months old	11	13.3%	27	3.0%
Survived at least two months	72	86.7%	873	97.0%
Totals	83	100.0%	900	100.0%

* Death rate of agammaglobulinemic calves significantly greater than among other calves ($p < 0.001$)

CHAPTER 5

DISCUSSION

Although the design of the experiment did not permit an exact determination of the proportion of calves which did not suckle, it is evident that 30 to 40 percent of calves left with their dams did not obtain sufficient colostrum to provide any degree of passive immunity above that normally found in calves at birth (Tables 1 and 2). With a large number of calves involved, this compares favorably with previous reports in which 20 to 40 percent of calves given the opportunity to suckle were observed not to do so (2, 10, 15, 22, 23). The results of the present study may be partially explained by the fact that some calves were born closer to the time of separation from their dams than others. Although these calves would not have had as much chance to suckle, they would more likely retain some capacity to absorb colostral Ig when bottle-fed later. Table 4 shows that this was, in fact, the case. It appears that feeding colostrum to calves allowed to remain with their dams benefitted proportionally more hypogammaglobulinemic calves than normal ones through an increase in serum Ig concentrations.

There were 83 calves which were agammaglobulinemic at the time of the second bleeding. Evidently, these did not suckle even when given ample time to do so, nor were they able to absorb colostral Ig on bottle-feeding. Among calves showing increased serum Ig concentrations resulting from colostrum feeding, not all could be considered to have acquired adequate levels of passive immunity. The mean serum Ig increase due to feeding colostrum (5.0 mg/ml IgG and 1.3 mg/ml IgM) was no greater in agammaglobulinemic calves than in those which had high serum Ig concentrations after remaining with their dams. Thus, calves which were agammaglobulinemic before bottle-feeding tended to have low serum Ig concentrations after feeding. This is expected, since feeding probably occurred near or after the time of closure, which can occur as early as 12 hours postpartum in some calves (27). Therefore, many hypogammaglobulinemic calves benefit little or not at all from delayed colostrum feeding with regard to systemic immunity.

One would expect a high death loss associated with this type of management, based on earlier reports (7, 9, 25). But, of the 83 calves which were virtually agammaglobulinemic at the time of the second bleeding, only 13.7% actually died within two months of birth (Table 7). Previous reports have stated that over 60% of agammaglobulinemic calves raised in intensive housing, as in the present experiment, either die of neonatal diarrhea or require treatment for it (9, 25). Calves in these studies were deprived colostrum from the moment of birth, while in the present experiment all calves were bottle-fed colostrum. The colostrum given all calves after removal from their dams may have acted at the site of bacterial and viral invasion in the lumen of the gut to prevent epithelial destruction, as suggested by Logan and Penhale (17) and Logan et al. (19). Since this type of local immune action is independent of intestinal Ig absorption, calves that did not suckle benefitted from feeding colostrum, even after cessation of Ig absorption.

Furthermore, Barber (1) points out that good management practices may overcome the effects of low serum Ig concentrations.

It is interesting to note that the Guernsey calves suffered a proportionately higher death loss than Holsteins. While it cannot be concluded that this was related to the significantly lower serum IgM concentrations found in Guernseys (Table 5), Logan and Penhale (16) have noted a relationship between low serum IgM and increased susceptibility to E. coli infection.

The results presented in Table 6 indicate that a high concentration of circulating immunoglobulins may reduce death losses by increasing resistance to, or recovery from, neonatal diseases. Although a calf given colostrum soon after parturition will absorb some Ig, not all calves obtain colostrum soon enough when left to suckle. This may be due to inaccessability of the dam's udder or lack of vigor in the calf, as observed by Selman et al. (23). As a result, hypogammaglobulinemia occurs in calves left to suckle, and remains in some calves even when bottle-fed colostrum afterward.

An alternative is to bottle-feed colostrum as soon after birth as possible in order to provide circulating immunoglobulins and to prevent bacterial or viral damage to the gut epithelium through local immune action in the intestinal lumen. After this feeding, the calves may be left to suckle their dams to increase serum Ig concentrations above those normally attained by bottle-feeding. This practice should provide a high degree of both enteric immune protection and systemic immunity to almost all calves in a dairy herd. It would therefore be superior to the procedure followed in this study.

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