Effects of Passive Immunity on Growth and Survival in the Dairy Heifer[1,2]

J. D. ROBISON,[3] G. H. STOTT,[4] and S. K. DeNISE
Department of Animal Sciences
University of Arizona
Tucson 85721

ABSTRACT

Effects of 24 to 48 h serum Ig concentration on growth and survival of 1000 Holstein heifer calves were evaluated. Average serum Ig for all calves was 25.71 (SD = 19.06) mg/ml with a range of .05 to 108.27. Serum Ig concentrations were below 12 mg/ml in 28% of the heifers. Both season and age of dam contributed significantly to the variation in 24 to 48 h concentrations of serum Ig. Concentration of serum Ig at 24 to 48 h was a significant source of variation affecting average daily gain through the first 180 d of life. Seasonal factors also were significant in influencing rate of gain from birth to 180 d. Age of dam was a significant source of variation in calf weight gains but only for the first 35 d. Mortality was 6.78% for heifers with less than 12 mg/ml serum Ig at 24 to 48 h as compared with 3.33% mortality for calves with greater than 12 mg/ml concentration.

INTRODUCTION

Passive immunization through the absorption of colostral antibodies is an important and essential process for the well-being of the bovine neonate. The establishment of a pool of circulating, passively acquired Ig provides the immune protection necessary to assist the calf through its early stages of growth and development. Failure to absorb adequate amounts of Ig often results in a high rate of morbidity and mortality (1, 2, 10, 12, 13, 14).

Antigen specificity of absorbed Ig is important in determining the protective ability of colostrum. Deficiency of a specific antibody could explain why some calves, appearing to have sufficient total antibody concentration, die as a result of pathogenic challenge. However, McGuire et al. (13) determined that most calves dying from infections failed to absorb sufficient amounts of colostral Ig. Thomas and Swann (20) suggested that passively acquired Ig, although not specific for the pathogen investigated, reduced the animal's susceptibility to other invasive pathogens and, thereby, the effects of secondary infection.

Although the half-life of colostrum-derived Ig is short, approximately 21 d, directly influences the course of disease in the calf for the first 4 to 6 mo. Williams et al. (22) postulated that good initial immunity might allow animals to control establishment of successive pathogens; thus, the immune system can produce adequate amounts of a specific antibody rather than be overwhelmed by the sudden influx of invasive pathogens. The diseased animal cannot utilize its ingested nutrients solely for growth and development because a portion of the nutrient pool must be devoted to inactivating and eliminating invasive pathogens as well as repairing any damaging effects resulting from their presence.

Previous studies (8, 15) have investigated the influence of passive immunity on postnatal growth; however, the growth periods studied were confined to preweaning growth, so no information regarding the long-term effects was obtained. The present experiment was to determine the influence of passive immunity on weight gain and performance of Holstein dairy heifers from birth to 180 d of age over the wide

Received August 20, 1987.
Accepted December 7, 1987.
[1] Published with the approval of the Director of the Experiment Station as Journal Article Number 4423.
[2] The authors gratefully acknowledge the cooperation of Shamrock Farms Co.
[3] PO Box 217, Five Points, CA 93624.
[4] 2001 Little Rock Rd., Emmett, ID 83617.

range of Ig concentrations found within a dairy herd.

MATERIALS AND METHODS

With the cooperation of a large, commercial dairy, 1000 Holstein heifer calves were studied. No attempt was made to alter the existing protocol for handling calves. All heifer calves, except freemartins, were identified at birth with an ear tag, and dam and sire information was recorded. Calves were allowed to suckle their dams for up to 24 h postpartum. No attempt was made to ensure that calves suckled and no supplemental colostrum was fed. After removal from their dams, heifers were placed in individual calf pens. Calves were fed twice daily 2 L of whole milk obtained from cows through their first six milkings postpartum. A 16% CP calf starter was offered for ad libitum intake from d 3 postpartum. All calves were weaned at approximately 70 d of age. At weaning, calves were grouped into pens of 16. At approximately 3-wk intervals, these smaller groups were combined into groups of 48. After approximately 3 wk, calves were sorted by size, and groups of 96 were maintained through 180 d of age. Alfalfa hay was offered ad libitum from weaning through 180 d, and calf starter was fed at a rate of 2 kg/d per calf. Individual BW was recorded between 28 and 48 h after birth and at 35, 70, 105, and 180 d. Average daily gains were calculated for each animal between weigh periods.

Blood samples (10 ml) were obtained via jugular venipuncture between 24 and 48 h and at 35 d. Samples were cooled to 4°C immediately following collection. Serum was obtained via centrifugation from each sample within 24 h of collection. Serum was stored at 20°C until analyzed.

Serum samples were assayed for total Ig using the radial immunodiffusion (RID) gel procedure (5). All plates were incubated 20 h at 4°C in humidifier chambers. Antiserum was rabbit antibovine gamma globulin. Standards utilized for RID plates were from preparations of adult bovine serum quantitated by Lowry protein determination (11) and verified.

A four-parameter logistic transformation (6) for competitive ligand assays was modified for RID and used to fit all standard curves. Control samples were assayed in duplicate on each agar plate. If the control sample was not within 2 SD of the mean ($\bar{x}$ = 2.677, s^2 = .129), the assay was rejected and repeated. The CV for all assays was 4.8%.

Immunoglobulin concentrations at 24 to 48 h were analyzed from a model that included season of birth, age of dam, and a covariate of birth weight. Season was defined by month of birth, January through September. Dams were grouped by age: 2 yr, 3 to 6 yr, and 7 yr and older. The effects of 24 to 48 h Ig concentrations on the concentration of Ig at 35 d were evaluated using simple linear regression.

Growth traits of weights and gains from birth to 180 d were analyzed with a model containing month of birth, age of dam, and a covariate of serum Ig at 24 to 48 h as independent variables. In order to evaluate the effects of a serum Ig concentration on survival, five categories of serum Ig concentration at 24 to 48 h were developed, and percentage mortality calculated. The groups were <12, 12.1 to 18, 18.1 to 25, 25.1 to 40, and >40 mg/ml.

RESULTS AND DISCUSSION

The average 24 to 48 h total serum Ig content was 25.71 (SD = 19.06) mg/ml with a range of .05 to 108.27. Table 1 presents the mean squares from the analysis of 24 to 48 h serum Ig concentrations. Month of birth was a significant source of variation for 24 to 48 h serum Ig concentrations. Stott et al. (19) reported that high ambient temperatures act as a depressant to colostral antibody absorption in the neonatal calf. However, in the current study, mean Ig concentration in serum (29.54 mg/ml) was higher for calves born during the hotter months of the year, June through

TABLE 1. Mean squares from the analysis of 24 to 48 h serum Ig concentrations.

Variable	df	MS
Month of birth	8	2086.9**
Age of dam	2	2258.4**
Birth weight	1	433.6
Residual	768	347.2

**$P<.01$.

September, than for calves born from January through May (23.37 mg/ml). The differences between studies could be due to colostral intake, which was limited for the first 12 h for calves in the study conducted by Stott et al. (19), but calves in this study were allowed to suckle freely. During hotter months, calves may have ingested larger quantities of colostrum to satisfy their thirst than did calves in the study by Stott et al. (19).

Birth weight did not influence serum Ig concentrations in dairy heifers at 24 to 48 h. These findings are in agreement with Norman et al. (16) for beef calves. Age of dam was a significant source of variation for 24 to 48 h serum Ig concentration. Edwards and Broom (4) reported that the proportion of dairy calves that had suckled within 6 h of birth decreased as age of dam increased. The data presented support this observation for dairy calves, because the mean 24 to 48 h serum Ig concentration for calves from 2-yr-old cows was higher than that observed for 3 to 6, and 7-yr-old cows (29.36 vs. 24.79 and 26.48, respectively). The decrease in serum Ig concentrations associated with increasing age of dam can be attributed to various concepts of increasing cow age. As demonstrated by Edwards and Broom (4), the first 6 h of life are critical in determining the ultimate amount of colostral Ig absorption. The sooner the calf ingests colostrum, the greater its chances are of attaining adequate serum Ig concentrations. Delays in ingestion of colostrum have been associated with poor udder conformation (3, 10, 17) and often are associated with increasing age of calves. A dilution of concentrated colostral antibodies within the udder just prior to parturition or prepartum milk leakage in high producing cows also may contribute to decreased Ig concentrations in calves at 24 to 48 h.

Mean 35 d serum Ig concentrations were 19.41 (SD = 8.25) mg/ml, ranging from 2.04 to 55.55. Forty-nine percent of the variation found in 35 d serum Ig concentrations was due to the variation in Ig concentration found at 24 to 48 h ($P<.001$). The regression coefficient of 35 d serum Ig concentration on 24 to 48 h concentration was .30 mg/ml. The precise physiological importance of this relationship is beyond the scope of this study. However, data presented demonstrate that the concentration of serum Ig at 35 d partially was dependent upon the antibody absorbed by 24 to 48 h.

Mean weights, SD, and ranges of recorded weights are presented in Table 2. Average birth weight of heifers in this study (39 kg) was in accord with the average for the Holstein breed. Calves at all other ages weighed less than Heinrichs and Hargrove (7) reported as standards for Holstein heifers.

Regression coefficients of growth rate on Ig at 24 to 48 h are in Table 3. Serum Ig concentrations at 24 to 48 h were a significant factor influencing the growth rate from birth to 180 d. The effect of the passively acquired immunity appears strongest during the 70 to 105-d growth period. This period coincides with the age at weaning, initial grouping of the calves, and thus, increased external stress factors. Month of birth also was a significant source of variation in ADG at all ages. Age of dam was significant for weight gains from birth to 35 d.

Results of this study are in accord with those of Nocek et al. (15) and Kim (8). Higher concentrations for serum Ig in calves are associated with an increased daily liveweight gain

TABLE 2. Mean body weight (kg) and range for each sampled age.

Age	n	Mean BW	SD	Minimum	Maximum
Birth	999	39	5	23	56
35 d	969	49	5	32	68
70 d	984	70	8	44	98
105 d	971	92	13	51	139
180 d	884	152	19	83	209

TABLE 3. Regression coefficients (B_1) of average daily gain on 24 to 48 h serum Ig concentrations for each growth period.

Growth period	B_1	SE
	(kg/d)	
Birth to 35 d	.008**	.002
35 to 70 d	.016**	.003
70 to 105 d	.026**	.005
105 to 180 d	.009**	.004

**$P<.01$.

though weaning. In addition, data presented provide evidence that the influence of 24 to 48 h serum Ig concentrations on gain extends beyond weaning to at least 180 d of life. Proper growth and development during this first 180 d is critical to subsequent growth, development, reproduction, and production of the dairy heifer.

A summary of the effects of 24 to 48 h serum Ig concentration on survival is in Table 4. Of the 43 calves that died in the first 180 d, 19 (44.2%) had concentrations of ≤12 mg/ml of colostral Ig by 24 to 48 h. Mortality during the first 35 d was very low but markedly increased during each subsequent growth period. Low serum Ig concentrations were presumed to predispose beef calves to a higher risk of death during the first 50 d of life (22). Others have found an inverse relationship between 24 to 48 h serum Ig concentrations and mortality (9, 18, 21) but reported no apparent age limitation. Data in Table 4 indicate that hypogammaglobulinemic calves at 24 to 48 h suffer a greater mortality rate through the first 180 d. Calves with low serum Ig at 24 to 48 h also suffered increasing losses with each growth period. Apparently, calves with higher serum Ig concentrations (>8 mg/ml) at 24 to 48 h have a greater ability to withstand the harmful effects of the environment. The concentrations reported in this experiment do not reflect the quality of the colostrum or the time at which Ig was absorbed.

Maternally derived antibody has a significant role in providing protection to the calf. Insufficient serum Ig concentrations at 24 to 48 h could necessitate an immune response by the calf before it is immunologically capable of handling an invasion of pathogenic organisms. Illnesses often associated with such invasions detract from the normal growth and development of the calf. Calves with adequate serum Ig often are able to inactivate pathogenic invasions earlier than calves with lower serum Ig which must mount an immune response for defense. Therefore, calves having adequate serum Ig will continue to grow normally and not be deterred as would calves with insufficient Ig. Through the process of a successful transfer of colostral antibody, although not necessarily pathogen-specific, the calf is better able to grow at a normal rate through the first 6 mo. Proper management of factors influencing absorption of colostral immunoglobulins by the neonatal dairy heifer would enhance the replacement rearing program.

TABLE 4. Summary of calf mortality by growth period and categories of serum Ig concentrations at 24 to 48 h.

Growth period	Ig Group, mg/ml					Total died
	≤12	12.1 to 18	18.1 to 25	25.1 to 40	>40	
0 to 35 d	1	1	1	...	1	4
35 to 70 d	4	4	...	3	...	11
70 to 105 d	6	1	2	2	2	13
105 to 180 d	8	2	1	1	3	15
No. died	19	8	4	6	6	43
No. started	280	157	135	197	231	1000
Mortality, %	6.78	6.09	2.98	3.04	2.59	4.30

REFERENCES

1 Boyd, J. W. 1972. The relationship between serum immune globulin deficiency and disease in calves: a farm survey. Vet. Rec. 90:645.

2 Boyd, J. W., J. R. Baker, and A. Leyland. 1974. Neonatal diarrhea in calves. Vet. Rec. 95:310.

3 Bringnole, T. J., and G. H. Stott. 1980. Effect of suckling followed by bottle feeding colostrum on immunoglobulin absorption and calf survival. J. Dairy Sci. 63:451.

4 Edwards, S. A., and D. M. Broom. 1979. The period between birth and first suckling in dairy calves. Res. Vet. Sci. 26:255.

5 Fahey, J. L., and E. M. McKelvey. 1965. Quantitative determination of serum immunoglobulins in antibody-agar plates. J. Immunol. 94:84.

6 Finney, D. J. 1976. Radiology and assay. Biometrics 32:721.

7 Heinrichs, A. J., and G. L. Hargrove. 1987. Standards of weight and height for Holstein heifers. J. Dairy Sci. 70:653.

8 Kim, J. W. 1981. The development of immunoglobulin status of blood serum in calves and its impact on rearing performance in a suckler cow herd. Ph.D. Diss., Georg-August-Universitat Gottingen.

9 Lecce, J. G., and D. O. Morgan. 1962. Effect of dietary regimen on cessation of intestinal absorption of large molecules (closure) in the neonatal pig and lamb. J. Nutr. 78:263.

10 Logan, E. F., and T. Gibson. 1975. Serum immunoglobulin levels in suckled beef calves. Vet. Rec. 97:229.

11 Matte, J. J., C. L. Girard, J. R. Seoane, and G. J. Brisson. 1982. Absorption of colostral immunoglobulin G in the newborn dairy calf. J. Dairy Sci. 65:1765.

12 McEwan, A. D., E. W. Fisher, and I. E. Selman. 1970. Observations on the immune globulin levels of neonatal calves and their relationship to disease. J. Comp. Pathol. 80:259.

13 McGuire, T. C., N. E. Pfeiffer, J. M. Weikel, and R. C. Bartsch. 1976. Failure of colostral immunoglobulin transfer in calves dying from infectious disease. J. Am. Vet. Med. Assoc. 1697:713.

14 Muggli, N. E., W. D. Hohenboken, L. V. Cundiff, and K. W. Kelly. 1983. Inheritance of maternal immunoglobulin G1 concentration by the bovine neonate. Proc. West. Sec. Am. Soc. Anim. Sci. 34:260.

15 Nocek, J. E., D. G. Braund, and R. G. Warner. 1984. Influence of neonatal colostrum administration, immunoglobulin, and continued feeding of colostrum of calf gain, health, and serum protein. J. Dairy Sci. 67:319.

16 Norman, L. M., W. D. Hohenboken, and K. W. Kelley. 1981. Genetic differences in concentration of immunoglobulins G1 and M in serum and colostrum of cows and in serum of neonatal calves. J. Anim. Sci. 53:1465.

17 Selman, I. E., A. D. McEwan, and E. W. Fisher. 1970. Studies on natural suckling in cattle during the first eight hours postpartum. II. Behavioural studies (calves). Anim. Behav. 18:284.

18 Selman, I. E., G. H. de la Fuente, E. W. Fisher, and A. D. McEwan. 1971. The serum immune globulin concentrations of newborn dairy heifer calves: a farm survey. Vet. Rec. 88:460.

19 Stott, G. H., F. Wiersma, B. E. Menefee, and F. R. Radwanski. 1976. Influence of environment on passive immunity in calves. J. Dairy Sci. 59:1306.

20 Thomas, L. H., and R. G. Swann. 1973. Influence of colostrum on the incidence of calf pneumonia. Vet. Rec. 92:454.

21 Thorton, J. R., R. A. Willoughby, and B. J. McSherry. 1972. Studies on diarrhea in neonatal calves: the plasma proteins of normal and diarrheic calves during the first ten days of age. Can. J. Comp. Med. 36:17.

22 Williams, M. R., R. L. Spooner, and L. H. Thomas. 1975. Quantitative studies on bovine immunoglobulins. Vet. Rec. 96:81.